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Silicon carbide companies building vertically integrated supply chains

IQE partners with Porotech • GlobalFoundries unveils GF Labs • NREL raises one-sun solar cell efficiency record to 39.5%

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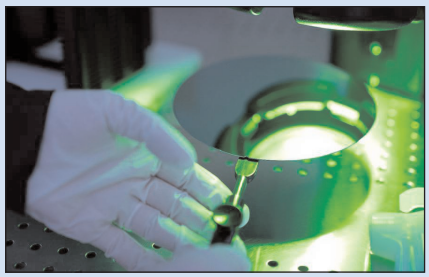
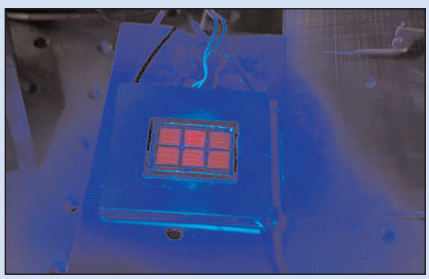


p34 IQE has partnered with Porotech to enter the market for micro-LEDs in micro-display applications.



p48 NREL has raised the efficiency record for solar cells (under standard one-sun global illumination) to 39.5%.

Cover: For its next-generation electric vehicles, China-based car maker NIO Inc has chosen onsemi's latest VE-Trac Direct SiC power module, which is an integrated single-side direct cooling (SSDC) power module in a six-pack configuration with a low turn-on resistance of 1.7mΩ. **p10**

editorial

Vertical integration for SiC and GaN

At mid-May's PCIM Europe 2022 in Nuremberg, Germany, ROHM introduced its new power semiconductor solutions focusing on e-mobility and energy conversion applications, and announced its European and global business activities, strategies and silicon carbide (SiC) investment plans (see page 8). Japan's ROHM recently increased its SiC power semiconductor production capacity by completing a new building at its Apollo plant in Chikugo, and its production subsidiary SiCrystal in Nuremberg plans to grow its capacity to several 100,000 substrates per year. "We recognize Europe as a priority market to focus on, with many companies leading technological innovation in automotive and industrial equipment," the firm says.

Meanwhile, Japan's NEDO has funded Tokyo-based epiwafer maker Showa Denko K.K. (SDK) to develop 8" (200mm)-diameter SiC epiwafers, including increasing the growth rate for SiC bulk single-crystal (see page 9). SDK launched mass production of 6" (150mm) SiC substrates only in March, aiming to create a stable second source of substrates (while continuing to buy from commercial suppliers) and to improve the quality of its epiwafers.

SDK's extension of its SiC wafer manufacturing business up the supply chain from epiwafers to substrates is an example of the wider trend in SiC for firms to vertically integrate — see Knowmade's analysis (pages 65–67) of patents along the entire power SiC supply chain, from bulk substrates and epitaxial wafers to devices, modules and circuits. As well as SDK acquiring SiCrystal in 2009, European silicon chip maker STMicroelectronics (which launched its first SiC MOSFETs in 2009, and its third generation of STPOWER SiC MOSFETs last December) fully acquired Swedish 150mm SiC wafer maker Norstel in late 2019 (and made its first 200mm SiC substrates last July).

The model for such vertical integration is US-based Wolfspeed (formerly Cree), which makes SiC substrates, chip and modules. This has been followed by US-based substrate maker II-VI Inc, which in August 2020 acquired Swedish SiC epiwafer and device maker Ascatron and this February expanded a SiC device and module technology license agreement with GE.

In addition to mergers and acquisitions, there has also been collaboration between firms in adjacent stages of the supply chain. Most recently, ST said it is supplying SiC technology for the eMPack electric vehicle (EV) power modules made by Nuremberg-based Semikron, following a four-year technical collaboration to design-in ST's SiC power semiconductors (page 13).

Partnerships are also prevalent in the gallium nitride (GaN) power sector. In May, Netherlands-based silicon chip maker Nexperia partnered with Japan-based KYOCERA's Austrian subsidiary KYOCERA AVX Components (Salzburg), which makes automotive electronics, to develop GaN power modules for EVs (page 16). This follows Nexperia entering the GaN device market in 2019, and it is currently gearing up to enter the power SiC device market.

While much of the development of power GaN and SiC supply chains comprises acquisitions or collaborations involving firms in the USA, Japan and particularly Europe, one obstacle is the geopolitical barriers to trade. In particular, Nexperia is a subsidiary of China's Wingtech Technology. Last July, it agreed to buy the UK's 200mm compound semiconductor wafer foundry Newport Wafer Fab (NWF) in South Wales. However, on 25 May, the UK Government said that the deal will now be scrutinized under the new National Security and Investment Act on the grounds that NWF has multiple contracts with the UK government, including defence-related projects. See next issue for details.

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

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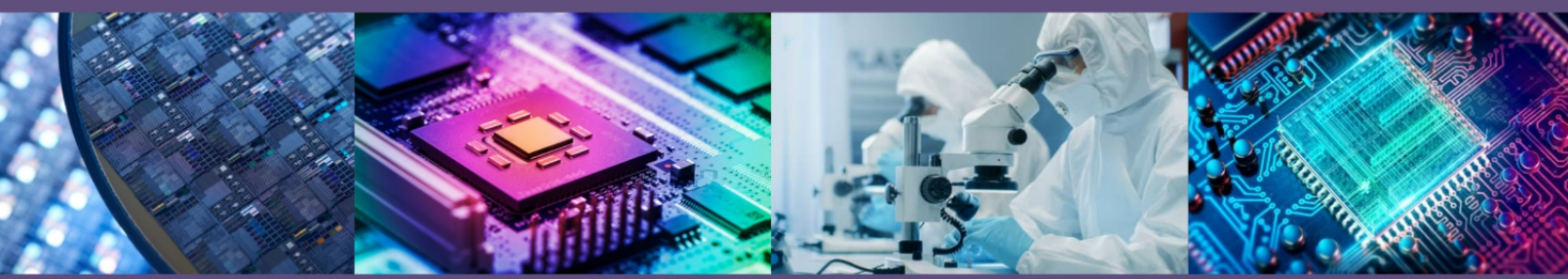

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news

DoD awards GlobalFoundries $117m to transfer 45nm SOI from East Fishkill to fab in Malta, NY

Defense Production Act Title III funding to ensure access critical to Department of Defense strategic systems

As part of the USA's effort to sustain the microelectronics manufacturing capability necessary for national and economic security, and in support of Executive Order 14017 'America's Supply Chains', the Department of Defense (DoD) has awarded $117m under Defense Production Act Title III to GlobalFoundries (GF) of Malta, NY, USA (which has operations in Singapore, Germany and the USA).

GlobalFoundries will transfer its 45nm silicon-on-insulator (SOI) semiconductor manufacturing process from its Fab 10 facility in East Fishkill, NY, to its Fab 8 facility in Malta, NY.

The effort is a follow-on from an $8m award issued last year through which GF conducted initial engineering baseline activities for the transfer. The new agreement will ensure access to 45nm SOI semiconductors critical to DoD strategic systems.

The agreement is the latest collaboration in the long-standing partnership between the DoD and GF to provide silicon-based semiconductors for defense aerospace applications.

www.globalfoundries.com

pSemi appoints veteran from parent firm Murata as CEO

Murata company pSemi Corp of San Diego, CA, USA — a fabless provider of radio-frequency integrated circuits (RFICs) based on silicon-on-insulator (SOI) — has appointed Tatsuo Bizen as CEO. He succeeds interim CEO Takaki Murata.

Bizen joins pSemi from parent company Murata, where for more than 30 years he has served in a variety of global leadership roles in the USA, Japan and Europe, acquiring an extensive background in RF and power management.

"pSemi is vital to Murata's future as our business increasingly focuses on differentiated semiconductor solutions," says interim CEO Takaki Murata. "In our search for a pSemi CEO, it was critical that we found the right match — someone who would guide and enhance the vision we have for pSemi," he adds. "I am confident that Bizen-san can fulfill and further pSemi's vision to connect the world and Murata with cutting-edge semiconductor technologies in RF, power management and sensors."

A Murata employee since 1985, Bizen is currently VP of the power module division. From 2012 to 2015, he was president & CEO of the Murata Power Solutions subsidiary headquartered in Massachusetts. Bizen spent the prior three years as head of Murata's global corporate marketing. From 2007 to 2009, he was president & CEO of SyChip Inc, a Texas-based Murata subsidiary that provided RF chip-scale modules. His earlier experience includes involvement in the development of RF modules such as electronic TV tuners and circuit modules for wireless communication, and product management for RF components and modules in Germany, the Netherlands and Sweden.

"Since the Murata acquisition in 2014, I have worked closely with pSemi employees, who have always impressed me with their hard work, can-do attitudes and inventive ideas," comments Bizen. "I look forward to working together with my pSemi colleagues to create innovative semiconductor solutions for the connected world."

www.psemi.com

GF Labs unveiled to accelerate technology innovation

Program advances long-term technology roadmap, including RFSOI, silicon germanium, gallium nitride

At its annual GF Technology Summit (GTS) in San Jose, California, GlobalFoundries of Malta, NY, USA (which has operations in Singapore and Germany as well as the USA) has announced the launch of GF Labs, a new program that aims to extend the development horizon of its semiconductor technology and broaden its portfolio of feature-rich solutions. GF Labs will focus on advancing new technology and long-term roadmap differentiation with the aim of enabling GF customers to develop innovative products and accelerate their time-to-market.

Targeted technology megatrends include the Internet of Things (IoT), 5G, 6G, cloud computing, artificial intelligence (AI), quantum computing and next-generation automotive, all of which will propel semiconductor market revenue to more than $1.3 trillion by the end of the decade, forecasts International Business Strategies.

GF has a track record of innovating materials such as FD-SOI (fully depleted silicon-on-insulator) on 22FDX (22nm fully depleted silicon-on-insulator), and novel device architectures that enabled the launch in March of GF Fotonix, the firm's next-generation silicon photonics platform.

GF Labs is intended to expand and accelerate this momentum by creating an open framework of internal and external R&D initiatives that deliver a pipeline of market-driven process technology solutions for future data-centric, connected, intelligent and secure applications.

"Fostering semiconductor innovation is critical to delivering a differentiated technology portfolio that will continue to fuel emerging markets," says Gregg Bartlett, GF's senior VP of technology, engineering and quality. "Our focus is on making sure we're always developing the latest technologies that provide meaningful differentiation for our customers, not just in the near-term but far into the next decade."

GF has a track record of building partnerships with startup innovators, industry consortia, material suppliers, universities and government entities worldwide. Leveraging GF's patent portfolio and technical expertise in digital, analog, mixed-signal, RF and embedded memory, GF Labs will harvest capabilities from a broad research platform including the Interuniversity Microelectronics Centre (IMEC) in Belgium, Fraunhofer in Germany, Defense Advanced Research Projects Agency (DARPA) in the USA, and the Institute for Microelectronics in Singapore, along with a broad network of university partnerships.

R&D within GF Labs is underway with a range of technology capabilities and solutions already in development such as radio frequency silicon-on-insulator (RFSOI) and silicon-germanium (SiGe). GF will continue to invest to expand and develop tailored solutions, with GF Labs serving as the R&D engine accelerating solutions based on wide-bandgap semiconductors that go beyond the traditional approach of shrinking transistors. Additional program details and partners will be announced in second-half 2022.

"IQE's collaboration with GF on gallium nitride (GaN) accelerates the development of differentiated technology platforms that enable smart mobile devices, wireless infrastructure, power electronics and next-generation displays," comments Americo Lemos, CEO of epiwafer & substrate maker IQE plc of Cardiff, UK.

R&D within GF Labs is underway with a range of technology capabilities and solutions already in development such as RFSOI and SiGe

"Micledi has developed a unique and innovative solution for micro-LED arrays," says Soeren Steudel, chief technology officer of Micledi Microdisplays. "Our technology is based on an innovative combination of III/V materials processing, 3D integration and 300mm silicon-based processing combined with a proprietary ASIC to provide a self-contained, compact monolithic AR [augmented reality] display with high image quality and power efficiency. Our partnership with GF is enabling future AR devices and revolutionizing how digital information is delivered to consumers," he adds.

"SOITEC and GF's close collaboration on state-of-the-art RFSOI and FD-SOI substrate development continues to set the pace for the introduction of market-leading solutions for each generation of mobile connectivity standards," reckons SOITEC's chief operating officer Bernard Asper.

"GF technologies made 5G mm-wave possible with 45RSOI and 22FDX processes first used by universities and then by most companies in 5G and SATCOM. It is now taking steps to establish a leadership position in 6G," remarks Gabriel M. Rebeiz Ph.D., Distinguished Professor and the Wireless Communications Industry Endowed Chair at the University of California, San Diego (UCSD). "We've been collaborating on a broad set of high-risk, high-payoff research projects leveraging the unparalleled benefits of FD-SOI, RF-SOI and SiGe technology with demonstrated phased-arrays and transceivers up to 180GHz and, together, we are pushing the limits," he adds. "GF has been a great partner, with an accurate design kit at greater than 100GHz. They also support innovative work and enable the successful demonstration of complex 6G systems."

www.globalfoundries.com

ROHM highlights new power semiconductor developments and SiC capacity investment

SiCrystal targets production of several 100,000 substrates per year

At Power, Control and Intelligent Motion (PCIM) Europe 2022 in Nürnberg Messe, Nuremberg, Germany (10–12 May), ROHM Semiconductor Europe introduced its new power semiconductor solutions focusing on e-mobility and energy conversion applications. The firm also announced its European and global business activities, strategies and silicon carbide (SiC) investment plans.

One of ROHM's new power innovations is its fourth generation of SiC MOSFETs, which achieves up to 50% lower switching loss and 40% reduction of on-resistance without sacrificing short-circuit ruggedness. The latest generation also offers a more flexible gate voltage range (15–18V) and supports turn-off with zero voltage — enabling simple gate drive circuits with unipolar supply to be used.

"The demand for SiC will continue to grow, and ROHM will also increase sales," foresees Dr Kazuhide Ino, managing executive officer & chief scientific officer (CSO) of ROHM Co Ltd. "We will accelerate further investment and product development based on the technology we have cultivated as a leading SiC manufacturer. In addition, our company will continue to propose solutions that combine not only SiC products but also peripheral components and customer support."

Recently, ROHM increased its production capacity for SiC power semiconductors with the completion of a new building at its Apollo plant in Chikugo, Japan. "As a vertically integrated semiconductor manufacturer we are largely independent of suppliers and can respond more flexibly to market changes," states Wolfram Harnack, president of ROHM Semiconductor Europe. "The high degree of integration of our fabs gives us an advantage over other manufacturers who outsource many production steps. In addition, we are making great efforts to further optimize our supply chains, including our production system, and to achieve stable supplies for our customers."

As the demand for silicon carbide wafers will continue to grow in the future, ROHM plans to expand its investments and production capacities. In addition, ROHM's production subsidiary SiCrystal in Nuremberg, Germany plans to strongly grow its capacities and staffing. "SiCrystal's intermediate goal is to achieve nine-figure sales by producing several 100,000 substrates a year," says SiCrystal's CEO Dr Robert Eckstein.

"We were able to achieve record sales in the last fiscal term and expect to continue strong performance in the current fiscal term," says ROHM's president & CEO Isao Matsumoto. "Accordingly, we revised the medium-term management plan upward and ahead of schedule," he adds. "Among the global markets, we recognize Europe as a priority market to focus on, with many companies leading technological innovation in automotive and industrial equipment. Also, ROHM will continue to provide customers with solutions centered on power and analog products, which are ROHM's specialties," Matsumoto concludes.

www.rohm.com/web/global/sic-mosfet

ROHM's new building at its Apollo plant in Chikugo, Japan.

NEDO funds Showa Denko's 8" SiC wafer development

Nine-year project to reduce defect density by order of magnitude

Tokyo-based wafer manufacturer Showa Denko K.K. (SDK) says that its 'Project to Develop SiC Wafers Technology for Next-generation Green Power Semiconductors' has been selected by Japan's New Energy & Industrial Technology Development Organization (NEDO) as an R&D target of 'Next-generation Digital Infrastructure Construction' as part of its Green Innovation Fund projects.

In October 2020, the Japanese Government unveiled aims to achieve carbon neutrality by 2050. To significantly accelerate efforts toward structural changes in the energy and industrial sectors and to make corresponding investments in innovation, the Ministry of Energy, Trade and Industry (METI) decided to develop a ¥2 trillion Green Innovation Fund under NEDO.

SDK's business manufacturing SiC epitaxial wafers for power semiconductors is claimed to have the top share of the global SiC epi-wafer market. In the project, SDK plans to use its intellectual property portfolio and development expertise to develop SiC epiwafers with a diameter of 8-inches, and to reduce the defect density by at least one order of magnitude, hence reducing production costs for next-generation power semiconductors.

During the project's implementation period of nine years (from fiscal 2022 to fiscal 2030), SDK aims to develop technology to accelerate the growth rate of SiC bulk single crystal in cooperation with Japan's National Institute of Advanced Industrial Science and Technology (AIST).

www.sdk.co.jp

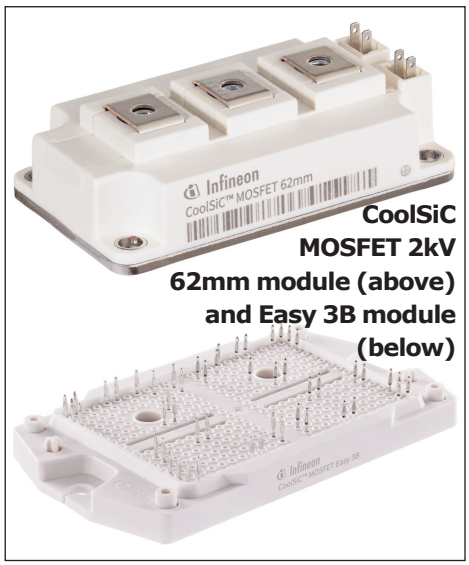
Infineon extends CoolSiC portfolio to 2kV voltage class

Extended gate voltage operating range enables simple, high-power-density solutions for 1500V_{DC} applications

The increasing demand for high power density is pushing developers to adopt 1500V_{DC} links in their applications to increase the rated power-per-inverter and reduce system costs. However, 1500V_{DC}-based systems also pose more challenges on the system design, such as fast switching at high DC voltage, which typically requires a multi-level topology. This leads to a complicated design and a relatively high number of components.

To address this challenge, Infineon Technologies AG of Munich, Germany has introduced its expanded CoolSiC portfolio with high-voltage solutions to provide the foundation for next-generation photovoltaic, electric vehicle (EV) charging and energy storage systems.

The extended CoolSiC portfolio offers 2kV silicon carbide (SiC) MOSFETs, along with a 2kV SiC diode for applications up to 1500V_{DC}. The new SiC MOSFET combines both low switching losses and high blocking voltage in one device that can optimally meet the requirements of 1500V_{DC} systems. The new 2kV CoolSiC technology offers a low drain–source on-resistance ($R_{DS(on)}$) value. In addition, the rugged body diode is suitable for hard switching. The technology enables sufficient over-voltage margin and offers ten times lower failure-in-time (FIT) rate caused by cosmic rays, compared with 1700V SiC MOSFETs. Furthermore, the extended gate voltage operating range makes the devices easy to use, says the firm.



CoolSiC MOSFET 2kV 62mm module (above) and Easy 3B module (below)

The new SiC MOSFET chip is based on Infineon's M1H SiC MOSFET technology (introduced in mid-April). The latest advances enable a significantly larger gate voltage window that improves the on-resistance for a given die size. Simultaneously, the larger gate voltage window provides a high robustness against driver- and layout-related voltage peaks at the gate, without any restrictions even at high switching frequencies. Infineon offers a range of EiceDRIVER gate drivers with functional isolation of up to 2.3kV to support the 2kV SiC MOSFETs.

Samples of the 2kV CoolSiC MOSFETs are available now in EasyPACK 3B and 62mm modules, and later in a new high-voltage discrete TO247-PLUS package. In addition, Infineon offers a design-in eco-system with a 2.3kV isolation-capable EiceDRIVER. The start of production of the Easy 3B (DF4-19MR20W3M1HF_B11) — a power module with four boost circuits that acts as the MPPT (maximum power point tracking) stage of a 1500V PV string inverter — is planned for third-quarter 2022, with the 62mm module in half-bridge configuration (3mΩ, 4mΩ, 6mΩ) to follow in fourth-quarter 2022. The discrete devices utilizing the latest .XT interconnection technology will be available by the end of 2022.

www.infineon.com/coolsic

China-based EV car maker NIO selects onsemi's silicon carbide traction power modules

SiC-based VE-Trac modules extend driving range by 4% versus silicon

Power semiconductor IC supplier onsemi of Phoenix, AZ, USA says that China-based car maker NIO Inc has chosen its latest VE-Trac Direct SiC power modules for its next-generation electric vehicles (EVs). The silicon carbide (SiC)-based power modules enable longer range, higher efficiency and faster acceleration for EVs.

The VE-Trac Direct SiC is an integrated single side direct cooling (SSDC) power module in a six-pack configuration with a low turn-on resistance of 1.7mΩ. This platform implements onsemi's second-generation SiC MOSFET technology to achieve higher performance, efficiency and quality while sharing a compatible package footprint with its insulated-gate bipolar transistor (IGBT) predecessor. An integrated pin fin baseplate enables direct liquid cooling and easy assembly, which allows maximum power output and more efficient thermal dissipation.

"From all the solutions we considered, the VE-Trac Direct SiC traction power modules offered the best efficiency during testing, allowing us to extend our New European Driving Cycle (NEDC) range by 4% compared to the current silicon solution," comments Alan S. Zeng, senior VP at NIO. "onsemi convinced us with the high performance and reliability of its products as well as the excellent support from its engineering and management team," he adds. "We look forward to collaborating with onsemi on bringing more innovative EVs to market for generations to come."

The VE-Trac Direct SiC traction power module.

The VE-Trac offerings, including the previously introduced VE-Trac Dual and VE-Trac Direct platforms, are available in silicon-based IGBT and in SiC with various voltages, and for traction inverter powers ranging from 100kW to 250kW. With its standardized mechanical footprints and expanded power ratings, the VE-Trac product family is designed to scale EV power outputs, accelerating the adoption of hybrid and battery EVs (BEV).

"This design collaboration is the culmination of substantial efforts onsemi has put into developing the right technologies for emerging applications such as smart EVs," says Simon Keeton, executive VP & general manager of Power Solutions Group at onsemi. "onsemi is the only supplier of silicon carbide solutions with vertical integration capability including SiC boule growth, substrate, epitaxy, device fabrication, best-in-class integrated modules and discrete package solutions," he claims. "We are rapidly expanding our SiC capacity and are uniquely positioned to address the growing EV market with supply assurance, performance, quality and tailored SiC end solutions."

onsemi showcased its intelligent power and sensing solutions, including VE-Trac platforms, at the Power, Control and Intelligent Motion (PCIM) Europe 2022 event in Nuremberg, Germany (10–12 May).

www.mesago.de/en/PCIM/main.htm
www.onsemi.com

Wolfspeed exhibits at PCIM 2022

Focus on silicon carbide at Power, Control and Intelligent Motion event

At Power, Control and Intelligent Motion (PCIM) Europe 2022 in Nürnberg Messe, Nuremberg, Germany (10–12 May), Wolfspeed Inc (formerly Cree) of Durham, NC, USA — which makes silicon carbide materials as well as silicon carbide (SiC) and gallium nitride (GaN) power-switching & RF semiconductor devices, for applications such as electric vehicles (EVs), fast charging, 5G, renewable energy and storage, and aerospace & defense — exhibited and offered insights into the latest developments in the industry.

Ty McNutt, director of business development, gave a presentation on 'Wolfspeed Power Modules for Today's EV Market'. Guy Moxey, senior director of power marketing, presented 'Silicon Carbide: New applications within Industrial and Energy-The next Great Frontier'.

Wolfspeed also gave demonstrations of some of its new products this year. Highlights included the Modular Silicon Carbide Evaluation System and the 600k Three-Phase Dual Inverter Reference Design Using the XM3 Power Module.

www.mesago.de/en/PCIM/main.htm
www.wolfspeed.com

Qorvo/UnitedSiC launches 1200V Gen 4 SiC FETs

Higher performance serves migration of bus designs to 800V

Qorvo Inc of Greensboro, NC, USA (which provides core technologies and RF solutions for mobile, infrastructure and defense applications) has launched the new UF4C/SC next-generation series of 1200V Gen 4 silicon carbide (SiC) field-effect transistors (FETs) with what are claimed to be industry-leading figures of merit in on-resistance: 1.35mΩ-cm^2 RDS(on)xA; 0.78Ω-μJ $R_{DS(on)}$xEoss; 4.5Ω-pF $R_{DS(on)}$x$C_{oss,tr}$; and 0.9Ω-nC $R_{DS(on)}$xQ_g.

All $R_{DS(on)}$ options (23mΩ, 30mΩ, 53mΩ and 70mΩ) are offered in the industry-standard 4-lead Kelvin source TO-247 package, providing cleaner switching at higher performance levels. The 53mΩ and 70mΩ devices are also available in the TO-247 3-lead package. The series has what is claimed to be excellent reliability, based on well-managed thermal performance (a result of an advanced silver-sinter die attach and advanced wafer-thinning process).

The new UF4C/SC series of 1200V Gen 4 SiC FETs is suited to mainstream 800V bus architectures in onboard chargers for electric vehicles (EVs), industrial battery chargers, industrial power supplies, DC/DC solar inverters, as well as welding machines, uninterruptible power supplies (UPS), and induction heating applications.

"Expanding our 1200V range with higher-performance Gen4 options allows us to better serve the engineers who are moving their bus designs to 800V," says Anup Bhalla, chief engineer — Power Devices, UnitedSiC/Qorvo. "In electric vehicles, this move to higher voltages is inevitable and these new devices, with four different $R_{DS(on)}$ classes, help designers select the best possible SiC choice for every design."

All 1200V SiC FETs are included in FET-Jet Calculator, a free online design tool that allows instant evaluation of efficiency, component losses, and junction temperature rise of devices used in a wide variety of AC/DC and isolated/non-isolated DC/DC converter topologies. Single and paralleled devices may be compared under user-specified heat-sinking conditions to enable optimum solutions.

Pricing (1000-up, FOB USA) for the new 1200V Gen 4 SiC FETs ranges from $5.71 for the UF4C120070K3S to $14.14 for the UF4SC120023K4S. All devices are available from authorized distributors.

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onsemi showcases energy-efficient solutions at PCIM

First TOLL-packaged 650V SiC MOSFET launched

At Power, Control and Intelligent Motion (PCIM) Europe 2022 in Nuremberg, Germany (10–12 May), onsemi introduced a range of new power solutions.

onsemi gave live demonstrations of its latest technologies, showing how they enable the development of solutions for applications including e-mobility, energy storage, and smart power. Included among the demos are a Student Formula car developed in conjunction with Technical University Munich, and an e-scooter. Also on show is an electric vehicle (EV) charger from Kempower that incorporates onsemi silicon carbide (SiC) diodes and a warehouse robot with ecoSpin.

onsemi launched a new power bundle for USB-C PD (power delivery) charging above 100W, featuring the NCP1623, NCP1345 and NCP4307 — all part of the critical conduction mode PFC, high-frequency quasi-resonant (QR) and synchronous rectifier controller family. The USB-C offering is further expanded by the launch of new USB-C controllers.

onsemi also introduced multiple new SiC power switching devices, all of which offer enhanced performance over previous generations. The first TOLL-packaged 650V 33mΩ SiC MOSFET, NTBL045N065SC1, is launched with less footprint, less space and lower package inductance than D2PAK 7-lead. This provides Kelvin source configuration to improve switching loss and gate noise and guarantees MSL1 (Moisture Sensitivity Level 1). SiC devices offer significant advantages over their silicon predecessors, including enhanced efficiency at high frequencies, lower EMI, higher-temperature operation and greater reliability. onsemi claims to be the only supplier of SiC solutions with vertical integration capability including SiC boule growth, substrate, epitaxy, device fabrication, integrated modules and discrete package solutions.

Lastly, onsemi also presented the seventh-generation insulated-gate bipolar transistor (IGBT) and diode for the first time. The latest 1200V FS7 IGBT has reduced forward-bias voltage by 20% from the previous generation, greatly improving the efficiency and power density in motor control application. The firm also launched fast version FS7 IGBT for medium-high switching frequency applications in solar, UPS and energy storage, in which the switching loss is 50% improved. The FS7 portfolio is further extended with 750V and 1200V VE-Trac Direct automotive-qualified solutions, with what is said to be excellent ruggedness, soft switching and high efficiency to meet EV traction needs.

Also at PCIM, onsemi staff presented a number of topics, covering SiC technology within the poster sessions, power electronics at the industry forum, the e-mobility forum, and the exhibitor forum.

www.mesago.de/en/PCIM/main.htm
www.onsemi.com

ST and MACOM RF GaN-on-Si prototypes achieve technology and performance milestones

Prototypes moving to qualification and industrialization within 2022

STMicroelectronics of Geneva, Switzerland and MACOM Technology Solutions Inc of Lowell, MA, USA (which designs and makes analog RF, microwave, millimeter-wave and photonic semiconductors, components and subassemblies for telecom, industrial and defense and data-center applications) have announced the production of radio-frequency gallium nitride on silicon (RF GaN-on-Si) prototypes.

As the long-term incumbent RF power technology, silicon-based laterally diffused metal-oxide semiconductor (LDMOS) dominated early-generation RF power amplifiers (PAs). However, GaN can offer superior RF characteristics and significantly higher output power than LDMOS for the RF PAs, with high potential especially for 5G and 6G infrastructure. Further, GaN can be manufactured on either silicon or silicon carbide (SiC) wafers.

RF GaN-on-SiC can be more expensive because of the competition for SiC wafers from high-power applications and because of its non-mainstream semiconductor processing. On the other hand, the GaN-on-Si technology under development by ST and MACOM is expected to offer competitive performance paired with large economies of scale, enabled by its integration into standard semiconductor process flows.

Prototype wafers and devices manufactured by ST have achieved cost and performance targets that would allow them to effectively compete with the incumbent LDMOS and GaN-on-SiC technologies on the market, it is reckoned. These prototypes are now moving to qualification and industrialization. ST is on target to hit these milestones in 2022. With this progress, ST and MACOM have begun discussions to further expand their efforts to accelerate delivery of RF GaN-on-Si products to the market.

"The technology has now reached performance levels and process maturity where it can effectively challenge the established LDMOS and GaN-on-SiC and we can offer attractive cost and supply-chain advantages for high-volume applications, including wireless Infrastructure," believes Edoardo Merli, Power Transistor Sub-Group general manager & executive VP at STMicroelectronics. "Commercializing RF GaN-on-silicon products is the next big milestone in our collaboration with MACOM and, with continued progress, we look forward to fully realizing the potential of this exciting technology," he adds.

"Together, we continue to make good progress in moving the GaN-on-Si technology towards commercialization and high-volume production," comments MACOM's president & CEO Stephen G. Daly. "Our collaboration with ST is an important part of our RF power strategy, and I am confident that we can win market share in targeted applications where the GaN-on-silicon technology meets the technical requirements."

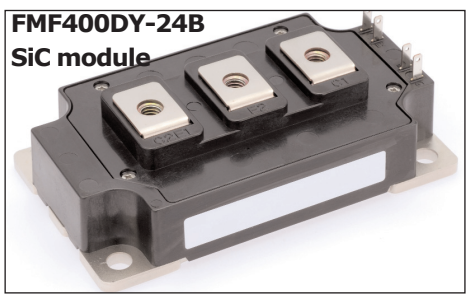
www.st.com
www.macom.com

Mitsubishi Electric adds 400A, 1200V dual module to SiC power device lineup

Newly designed, high-performing module in industry-standard 62mm x 108mm footprint

Mitsubishi Electric has launched the FMF400DY-24B, a 400A, 1200V dual silicon carbide (SiC) MOSFET power module that includes an anti-parallel, low V_f, zero-recovery-loss SiC Schottky barrier diode (SBD).

The module packages new designs into an existing industry-standard footprint (62mm x 108mm) for medical power supplies and general industrial applications. Designed for $V_{gs(on)}$=15V, the module is compatible with standard insulated-gate bipolar transistor (IGBT) gate drivers and can be seamlessly incorporated into existing mechanical layouts for easy upgrades from silicon IGBT technologies.


FMF400DY-24B SiC module

Using Mitsubishi Electric's second-generation SiC MOSFET chip technologies (suiting applications requiring high switching frequencies), the new SiC module is said to reduce power loss by about 70% compared with an equivalently rated silicon IGBT.

"This new module is in a classic package footprint, with the latest technology inside for superior function and flexibility," says Adam Falcsik, senior product manager of Mitsubishi Electric US' Power Device group. "The FMF400DY-24B adds to Mitsubishi Electric's growing lineup of SiC products."

www.mitsubishielectric.com/semiconductors/products/powermod

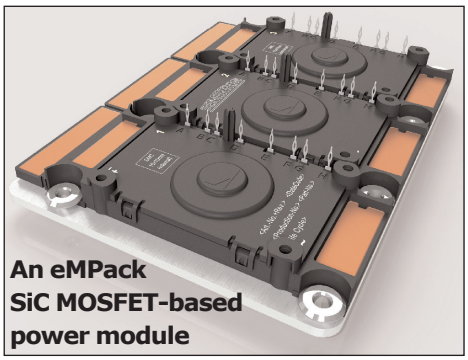
ST cooperating with Semikron to integrate SiC power technology in EV drives

Long-term engineering and component-supply deal as eMPack power module wins billion-Euro first order

STMicroelectronics of Geneva, Switzerland says it is supplying silicon carbide (SiC) technology for the eMPack electric vehicle (EV) power modules made by Semikron of Nuremberg, Germany.

This is the result of a four-year technical collaboration between the two companies to design-in ST's SiC power semiconductors for superior efficiency and industry-benchmark performance in more compact systems. ST says that SiC is rapidly becoming the automotive industry's preferred power technology for EV traction drives, contributing to greater driving range and reliability. Semikron recently announced that it had secured a billion-Euro contract to supply its eMPack power modules to a major German car maker, beginning in 2025.

"ST's industry-leading SiC device-manufacturing capabilities and in-depth expertise with the technology enabled us to integrate these cutting-edge semiconductors with our advanced manufacturing processes, which enhance reliability, power density and scalability to meet the needs of the automotive industry," comments Semikron's chief executive officer & chief technical officer Karl-Heinz Gaubatz. "As we now move towards volume production, our collaboration with ST brings the assurance of a robust supply chain that gives control over quality and delivery performance," he adds.



An eMPack SiC MOSFET-based power module

"Leveraging our SiC technology, Semikron's advanced scalable eMPack family of power modules is ready to make a major contribution towards zero-emission motoring," reckons Edoardo Merli, Power Transistor Sub-Group general manager & executive VP at STMicroelectronics. "In addition to its transformative effect in e-mobility, our SiC technology, now in its third generation, is driving increased efficiency, performance and reliability in sustainable energy and industrial power control applications."

ST claims that its third-generation SiC technology delivers industry-leading process stability and performance. Engineers from ST and Semikron cooperated to integrate the STPOWER SiC MOSFETs, which control power switching in the main EV traction inverter, with Semikron's fully sintered direct pressed die (DPD) assembly process. DPD enhances module performance and reliability and enables cost-effective power and voltage scaling. Leveraging the parameters of ST's SiC MOSFETs, supplied as bare dice, Semikron has established 750V and 1200V eMPack platforms, addressing applications from 100kW to 750kW and battery systems from 400V to 800V.

www.semikron.com
www.st.com

Rhombus using Wolfspeed's 1200V SiC MOSFETs for faster EV charging infrastructure

Bi-directional charging enabling power flow between power grid & car

Rhombus Energy Solutions of San Diego, CA, USA says that its EV2flex line of electric vehicle charging infrastructure products is to be supplied with silicon carbide MOSFETs made by Wolfspeed Inc of Durham, NC, USA, enabling greater efficiency, higher power density and faster charging times. Wolfspeed's 1200V SiC MOSFETs will power the EV2flex-120.

Rhombus' EV2flex infrastructure includes a family of products that enables fast, bi-directional charging and efficient energy storage. Vehicle-to-grid (V2G) charging supports power flow between the grid and the car, allowing a charged vehicle to become a power source when needed and ultimately enhancing the stability of the power grid.

"Wolfspeed has unequivocally demonstrated the high value of their SiC MOSFETs, and we are pleased to partner on advanced technology products," says Deanne Davidson, senior VP & general manager of Rhombus Energy Solutions. "Wolfspeed's SiC MOSFETs are a critical component for Rhombus to meet the demands in the growing DC fast-charging market for EVs."

"Bi-directional charging is a game-changing technology for the stability of the power grid, and our silicon carbide solutions will help accelerate that transformation," believes Jay Cameron, senior VP general manager of Wolfspeed Power. "Silicon carbide increases both power system efficiency and power density to create a faster, more reliable transfer of power."

www.RhombusEnergy.com
www.wolfspeed.com

Wolfspeed's March-quarter held to 37% year-on-year growth by China COVID shutdowns

Capacity constraints demand third materials factory and second 200mm device fab

For its fiscal third-quarter 2022 (ended 27 March), Wolfspeed Inc (formerly Cree Inc) of Durham, NC, USA has reported a seventh consecutive quarter of revenue growth to $188m, up 8.6% on $173.1m last quarter and 37% on $137.3m a year ago.

"Our top line was impacted [to the high-single-digits million dollar level] by COVID-19 quarantine protocols in China, which resulted in partial shutdowns at some of our packaging subcontractors and delays in some of our shipping channels," notes executive VP & chief financial officer Neill Reynolds. "Absent these shutdowns, we would have met or exceeded the top end of our [$185–195m] guidance range."

All financial figures are for continuing operations. After divesting its Lighting Products business in May 2019 and its LED Products business in March 2021, on 4 October Cree changed its name to that of its Wolfspeed business unit, focused on manufacturing silicon carbide materials as well as both silicon carbide (SiC) and gallium nitride (GaN) power-switching & RF semiconductor devices.

"Demand for our power device solutions continues to be strong, as evidenced by revenue growth of approximately 87% over the prior year," says Reynolds. "We continue to see increased demand for our silicon carbide solutions."

For RF devices, Wolfspeed is seeing positive momentum in the communications infrastructure and aerospace & defense markets.

"From a materials perspective, demand for our 150mm SiC substrate is strengthening as we see increasing demand from our customers, which resulted in strong year-over-year and sequential growth," says Reynolds. "We continue to add capacity to serve this strengthening demand."

On a non-GAAP basis, gross margin has grown further, from 35% a year ago and 35.4% last quarter to 36.3%. This is above the midpoint of the 35–37% guidance range, as lower-than-expected device revenue (due to the China shutdowns) drove modest improvements in the product mix.

Operating expenses have risen further, from $80m a year ago and $86.6m last quarter to $88.6m, due largely to investments in the 200mm SiC substrate platform and in the device businesses (supporting the ramp-up of the new Mohawk Valley fab in Marcy, NY). In May 2019, Cree began a multi-year factory optimization plan. In Durham, the firm converted an old lighting and office space into industrial space for a significant expansion of its crystal growth and epi capability (part of a 30x increase in SiC materials capacity). Also, in September 2019, Cree announced that the plan was being anchored by a new automated 200mm SiC device fabrication facility at Marcy in Mohawk Valley, New York State (expanding from the firm's existing 150mm-wafer SiC device fab in Durham).

Operating loss was $20.4m (operating margin of –11% of revenue), cut from $32m (–23% operating margin) a year ago.

Net loss has been cut further, from $24.7m ($0.22 per diluted share) a year ago and $18.6m ($0.16 per diluted share) to $14.3m ($0.12 per diluted share), which is better than the targeted $15–20m ($0.12–0.16 per diluted share).

Operating cash outflow was –$28.4m (improving further, from –$32.5m last quarter). Capital expenditure (CapEx) was $102.8m. Free cash outflow was hence –$131.2m (a further improvement from –$176m last quarter).

Additionally, Wolfspeed completed a convertible debt offering at the end of January with the issuance of $750m convertible senior notes, allowing it to fund the expansion of materials capacity at the Durham campus, and additional fab and back-end capacity to support the steepening demand for silicon carbide solutions.

During the quarter, cash, cash equivalents and short-term investments hence rose from about $700m to $1286m. So, Wolfspeed has about $1.3bn of cash and liquidity on hand to support its plans. "We will continue to be opportunistic from a capital market standpoint to ensure we have flexibility to continue to support our long-term growth path," says Reynolds.

During the quarter Wolfspeed incurred factory optimization start-up costs (primarily related to the new Mohawk Valley 200mm SiC device fab) totaling $21.4m (almost doubling from $11m last quarter). The firm originally expected $80m of start-up costs in fiscal 2022, incurred mostly in fiscal Q2 as it continues to ramp the new fab. "At this time, we believe start-up costs will be at approximately the $75m level by the end of the fiscal year," notes Reynolds.

Wolfspeed is running initial lots in the new fab. "With the official opening of Mohawk Valley at the end of April, we'll improve our ability to meet the steepening demand curve for silicon carbide devices, which will only improve as we continue to ramp production capacity," says Reynolds. "We'll start to see revenues start to more substantially come out of the fab as we get into the back half of fiscal 2023… March and June quarter next year," he adds.

"This transition [of customers] to silicon carbide devices is happening faster than we anticipated. In fact, our device opportunity pipeline continues to grow and is now well north of $25bn [up from $10bn a year ago] and is comprised of approximately 9000 different projects [up from 8700 last quarter]," says CEO Gregg Lowe. "More importantly, our sales team continues to do a phenomenal job converting these opportunities into design-ins across a wide range of applications," he adds.

Design-ins matched last quarter's record $1.6bn (up from $580m a year ago), about 70% of which were automotive-related, some of which should generate revenue in fiscal 2026. Year-to-date design-ins are $3.8bn, doubling year-on-year from $1.9bn (and exceeding full-year fiscal 2021's $2.9bn). "We have secured approximately $8.7bn of design-ins over the last three years [about 45% of which have now moved into initial production ramp, i.e. becoming a 'design-win'], representing a long tail for future revenue. This puts ever-increasing upward pressure on our long-term revenue outlook," says Lowe.

"The progress we've made at the Mohawk Valley fab, paired with another record-setting design-in total for the quarter, demonstrates how Wolfspeed is expanding its market-leading position and driving the transition to silicon carbide devices in the automotive and industrial end-markets," he adds.

"Given this, a top priority going forward is increasing capacity for both materials and devices. We'll certainly leverage our existing footprint as much as we can. This includes ongoing expansion of our materials footprint in Durham to maximize material growth while also producing as many devices as we can out of our current fab in North Carolina and pulling forward some of our fit-out time-lines for the Mohawk Valley fab… the fit out of the factory and the removing of temporary walls [to open up the ballroom] and things like that, it's all accelerating versus our previous plan."

Wolfspeed now expects net capital expenditure of about $550m in fiscal 2022 versus the previously communicated $475m. "This change is related to the timing of reimbursements from New York State for the Mohawk Valley fab," notes Reynolds. "We now anticipate receiving these reimbursements in the first half of fiscal 2023, and this does not represent a significant change in our fiscal 2022 gross CapEx spend outlook," he adds.

"The construction of this fab is not only a great accomplishment for Wolfspeed, but also has created north of 250 jobs to date for the people of Upstate New York and is attracting future talent from the surrounding universities to our partnerships with SUNY School System and others," he adds.

"Our financial results for the quarter continue to demonstrate progress towards our corporate objectives and the further adoption of silicon carbide across a wide range of applications," says Lowe.

For fiscal fourth-quarter 2022 (to end-June), Wolfspeed targets revenue growth to $200–215m (up 10% sequentially), driven by Power device revenue more than doubling as it continues to increase capacity across the supply chain. The impact on revenue of COVID-related shutdowns in China will probably be similar to that in fiscal Q3 (high-single-digits million dollar level).

Gross margin should be steady at 35.3–37.3%. "The key to our gross margin transition from the mid-30s to 50% in 2024 is largely based on three elements: optimizing Durham, transitioning from 150mm to 200mm wafers, and driving revenue through Mohawk Valley," notes Reynolds. "We continue to be on track with all three of these elements, as evidenced by our progress this quarter."

We will be needing another wafer fab sooner than we originally had anticipated. Wolfspeed will very likely need to add more materials production as well

Operating expenses are targeted to be $91m. "We anticipate operating expenses will continue to slowly increase over time due to increased headcount in R&D and sales & marketing, but expect this to become a smaller percentage of revenue as we near the middle of the decade," says Reynolds.

Wolfspeed targets a cut in operating loss to $20–11m, and net loss of $16–9m ($0.13–0.07 per diluted share).

"In 2023, we will likely spend as much or more CapEx as we did this year… geared at increasing the capacity levels," says Reynolds. "We've got unfulfilled demand exceeding our supply to the tune of around $100m," adds Lowe. "We're working real hard to grow the capacity as fast as we can."

The Mohawk Valley fab's planned annual output at full capacity (in the 2024 time-frame) is $1.5bn. At its Investor Day in November, Wolfspeed was projecting $2.1bn of total annual revenue at the company level, including about $1.4bn of device revenue. "Demand is just simply coming in stronger and our win rate is stronger than we anticipated… We will be needing another wafer fab sooner than we originally had anticipated," says Lowe.

"This next fab [larger than Mohawk Valley] is probably going to take longer to build than the original fab, which is all the supply chain issues and the tool lead-times," he notes.

"Wolfspeed will very likely need to add more materials production as well," says Lowe. "We have one factory here on campus. We have a second factory that we're expanding here on campus. What we're talking about is a third factory for materials."

"Additional capital is being spent to address materials, the Mohawk Valley fab as well as the back end," notes Reynolds. "Additionally, as we continue to grow, we continue to have the right people in place to help us manage that."

www.wolfspeed.com

Gallium Semiconductor opens Nijmegen R&D Center

VP of operations Henk Thoonen serving as site director

Singapore-based Gallium Semiconductor has opened its European R&D center in a ceremony at Kerkenbos 1224 in Nijmegen, Netherlands. The ceremony was hosted by CEO Kin Tan and VP of operations Henk Thoonen, who also serves as the Nijmegen site director. Many of Gallium Semi's customers, partners and vendors from the Europe region were in attendance to dedicate the R&D center.

"The center is designed to support the growth of our R&D team, which will focus on the development of innovative products and technologies to power next-generation mobile communications," says Thoonen.

"The city of Nijmegen continues to invest in the knowledge economy and is an attractive location for high-tech companies and its employees," comments Kin Tan.

Gallium Semi's European engineers design and develop RF semiconductor solutions to support 5G-and-beyond networks. Nijmegen is at the heart of Europe's RF power technology and enables Gallium Semi to expand its team with world-class talent, the firm reckons.

"Gallium Semi is a great addition to the vibrant semiconductor industry in the Netherlands," commented Ben van den Broek, project manager international for the East Netherlands Development Agency, at the grand opening. "Their choice of Nijmegen as its European R&D center further elevates our region's global attractiveness for its talented pool of professionals and proximity to customers," he added.

www.galliumsemi.com

Nexperia and KYOCERA AVX partner on GaN automotive power modules

GaN device technology combined with packaging expertise

Nexperia B.V. of Nijmegen, the Netherlands (a subsidiary of Wingtech Technology Co Ltd) has announced a partnership covering gallium nitride (GaN) automotive power modules with KYOCERA AVX Components (Salzburg) GmbH, which designs, develops, manufactures and supplies electronic components for the automotive industry. The agreement is the next step in the long-lasting relationship between the two companies and will focus on power components with the aim of jointly developing gallium nitride applications for electric vehicles (EV).

As passenger vehicles become increasingly electrified, the demand for power semiconductors to provide efficient power conversion at increasingly higher power densities is also growing. High-voltage power GaN field-effect transistors (FETs), when combined with innovative packaging technologies, can address the requirements for better efficiency, higher power density and reduced system cost, say the firms. GaN power devices not only offer superior performance in these applications but now also provide

the reliability, robustness and manufacturability expected of a mainstream technology serving a broad range of applications across multiple market segments. Nexperia manufactures GaN devices in its own facilities using mature mass-production techniques that have been proven to meet the reliability requirements for devices to achieve AEC-Q101 certification.

"We are very pleased to finally turn our successful and long-lasting relationship into a real partnership to strengthen KYOCERA AVX's strategy to provide high-quality automotive-compliant modules," comments Thomas Rinschede, deputy VP Sensing and Control Division at KYOCERA AVX Components (Salzburg). "Nexperia is a trusted and reliable partner who can deliver high-performance GaN and has shown a strong record in producing devices for the automotive market," he adds.

"GaN devices bring many benefits to EV applications including increased power density, improved efficiency and lower overall system cost," notes Carlos Castro, VP & general manager GaN at Nexperia. "However, optimized packaging technology is required in order to more fully realize the benefits of GaN devices, especially in high-power systems," he adds. "Nexperia recognizes the advanced technology offering and leading position which KYOCERA AVX holds in the automotive industry and believes that this joint collaboration in the development of GaN automotive power modules will enable both companies to deliver superior EV power systems solutions."

www.kyocera-avx.com
www.nexperia.com/gan-fets

NexGen showcases Vertical GaN-based power systems

Power systems for computing, lighting, industrial and e-mobility

At the Power Conversion Intelligent Motion (PCIM) Europe 2022 in Nuremberg, Germany (10–12 May), NexGen Power Systems Inc of Santa Clara, CA, USA — which was founded in 2017 to design and manufacture proprietary power conversion systems using patented Vertical GaN (gallium nitride) technologies — showcased what it says is the world's smallest, lightest and most efficient commercial power systems built on 1.2kV, 1+MHz Vertical GaN with Repeated Avalanche and >10µs Short-Circuit Protection.

Also, co-CEO Dr Dinesh Ramanathan presented NexGen's approach to power electronics at the Industry Forum on 10 May.

"NexGen is re-inventing power electronics, with the world's first GaN-on-GaN power device, NexGen Vertical GaN, the world's first 1+MHz switching digital powertrain controller, its proprietary Merlin Power Engine, innovations in magnetics and thermal designs, and deep expertise in system engineering," claims Ramanathan. "PCIM offers us the opportunity to introduce these new technologies and systems solutions to the broader market and customer base."

www.nexgenpowersystems.com

QPT launches qGaNDrive module

GaN power transistors boost HVAC motor drive efficiency

Quantum Power Transformation (QPT) of Cambridge, UK has launched its qGaNDrive module, which utilizes gallium nitride (GaN) power transistors, for motor drives in HVAC (heating, ventilation and air conditioning) systems.

"GaN transistors have always promised the best performance and efficiency over silicon MOSFETs and silicon carbide, but they are notoriously difficult to drive at speed," notes founder Rob Gwynne. "We have developed an entirely new and unique topology for driving GaN transistors allowing them to switch at speeds of up to 20MHz, delivering major benefits in power consumption and efficiency," he claims.

"Electric motor driven systems (EMDS) consume 45% of the world's energy, and yet their efficiency at typical operating speeds can be as low as 50%," says business development manager Richard Ord. "Our solution tackles performance across the range of operating speeds and could improve efficiency by up to 35%," he reckons.

The challenge of driving GaN transistors has so far restricted broader adoption and compromised performance. QPT claims that its solution fixes that problem and will accelerate GaN market share.

The qGaNDrive module integrates its core topology with GaN transistors in a fully EMC-screened turn-key power module. The firm estimates that a typical 15kW domestic heat pump could deliver a return in energy savings in 100 days or less.

QPT attended Power, Control and Intelligent Motion (PCIM) Europe 2022 in Nuremberg, Germany (10–12 May).

www.mesago.de/en/PCIM/main.htm
www.q-p-t.com

China's Innoscience and Taiwan's WPG sign global distribution agreement

Largest 8-inch GaN-on-silicon device maker represented by world's largest semiconductor distributor

Innoscience Technology of Suzhou, China has signed a global distribution agreement with WPG Holdings of Taipei, Taiwan (the world's largest electronics distributor, according to Gartner Research, with 5000 staff in 80 sales offices), giving customers worldwide access to its high- and low-voltage normally-off (enhancement-mode) GaN high-electron-mobility transistors (HEMTs).

Founded in December 2015 with main investment from CMBI, ARM, SK and CATL, Innoscience first established a mass-production 8-inch wafer line for GaN-on-silicon devices in Zhuhai National Hi-Tech District in November 2017, then inaugurated a new facility in Suzhou in September 2020. With 1400+ staff and over 300 R&D specialists, the firm now claims to be the largest integrated device manufacturer (IDM) fully focused on GaN technology, with two wafer fabs including what is claimed to be the world's largest dedicated 8-inch GaN-on-Si site. Innoscience is now delivering GaN power devices that can be used in applications including cloud computing, electric vehicles (EV) and automotive, portable devices, mobile phones, chargers and adapters.

"Our aim is to ensure that every power electronics designer — no matter where they are based — can benefit from the efficiency, power and size advantages that GaN technology brings. That is why we have invested in huge capacity — the largest in the world," claims Dr Denis Marcon, general manager, Innoscience Europe. "Distribution is also a big part of our plans, and we are excited and honoured to announce WPG — the world's largest semiconductor distributor — as our first global supply chain partner," he adds.

"GaN is set for explosive growth as all markets — consumer, communications, automotive, industrial — experience the leap forward in end-product performance they can achieve by switching from traditional silicon-based power devices to GaN," comments Nigel Watts, vice president, WPG EMEA. "Innoscience is the world's largest 8-inch GaN-on-Si device manufacturer with a capacity of 10,000 8-inch wafers per month (wpm) — which is set to grow to 70,000wpm by 2025. Therefore it is fitting that Innoscience has signed a global franchise deal with WPG," he adds. "Product is available now, and lead-times are far better than the traditional silicon alternatives. Design now and manufacture sooner."

www.wpgholdings.com
www.innoscience.com

Innoscience unveils 140W power supply design using high- and low-voltage GaN switches to deliver class-leading power density and efficiency

Innoscience Technology of Suzhou, China, which makes low-cost gallium nitride on silicon (GaN-on-Si) power solutions, has announced an ultra-high-density 140W power supply demo that uses its high- and low-voltage GaN HEMT devices to achieve efficiencies of over 95% (230VAC; 5V/28A). Measuring just 60mm x 60mm x 22mm (2.4x2.4x0.9in) the PSU has what is claimed to be class-leading power density of 1.76W/cm^3 (29W/in^3).

"By using GaN switches for both the high- and low-voltage functions on this design, we are maximizing efficiency rather than compromising it with lossy silicon devices," says Dr Denis Marcon, general manager of Innoscience Europe and marketing manager for the USA and Europe. "This is possible thanks to Innoscience's cost-effective and high-volume manufacturing processes and capabilities."

The 140W 300kHz AC/DC adapter uses a CRM tote-pole PFC + AHB topology. It features Innoscience's INN650DA140A, a 650V/140mΩ GaN HEMT in the 5mm x 6mm DFN package, for switches S1 and S2, the 650V/240mΩ, 8mm x 8mm DFN-packaged INN650D240A for S3, and the INN650DA240A, a 5mm x 6mm DFN 650V/240mΩ device for S4. S5 and S6 are delivered by the INN150LA070A, a 150V/7mΩ, 2.2mm x 3.2mm LGA part within Innoscience's low-voltage GaN HEMT range.

"This design, which targets USB PD3.1 notebooks and power tools, is a full 2% more efficient than silicon designs; this proves what can be achieved if GaN FETs are used everywhere, even in a relatively simple design," says Yi Sun, general manager of Innoscience America & senior VP of product and engineering.

www.innoscience.com

Fuji Electric
Innovating Energy Technology

Fuji Electric G-Twin UL Plug-In Series

New High Quality Product with improved safety features, easy installation and compact

TÜV Rheinland IEC JIS EN c UL us LISTED CE

Global Standard

The New Generation of Molded Case Circuit Breakers and Earth Leakage Circuit Breakers.

- ★ Built-In Compact Ground Fault for Space Saving Designs
- ★ Same Footprint! MCCBs and ELCBs interchangeable without Panel Modifications
- ★ All frame sizes (50AF-250AF) can be mounted with the same mounting pitch of 70mm
- ★ Lock Out Tag Out (LOTO) safety devices (fixed and removable types) are available as an option
- ★ Improves safety measures and easy & quick installation
- ★ UL489 and CSA C22.2 No.5 approved and certified

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Transphorm's quarterly revenue doubles year-on-year to record $4.93m

Focus on managing supply chain constraints, expanding manufacturing capacity and growing ecosystem of solution partners

For its fiscal fourth-quarter 2022 (ended 31 March), Transphorm Inc of Goleta, near Santa Barbara, CA, USA — which designs and manufactures JEDEC- and AEC-Q101-qualified gallium nitride (GaN) field-effect transistors (FETs) for high-voltage power conversion applications — has reported revenue of $4.93m, up on $4.6m last quarter and up 103% on $2.4m a year ago.

In particular, product revenue grew sequentially for the ninth consecutive quarter to a new record of over $4m, up 10% on last quarter and 190% on a year ago, due to ramping shipments of GaN devices for a broad range of power conversion applications.

Full-year revenue grew 89% year-on-year from $12.7m in fiscal 2020 to a new record of $24.1m for fiscal 2022, due to 189% growth in product revenue, based on prior targeted investments in designs for a broader market.

"The demand for our GaN solutions is strong, driven by our products' unique, easy-to-interface architecture, world-leading GaN product portfolio with a broad range of power capabilities from 45W to 5kW, and leading performance with field reliability," says president & co-founder Primit Parikh.

During the quarter, Transphorm:

- secured its largest SuperGaN high-power Gen IV FET production order to date for over 500,000 units of 3kW-class power supplies;
- secured a laptop adapter design-win from a tier 1 Fortune 100 company, including an initial purchase order of 50,000 units of SuperGaN Gen IV 240mΩ-class FETs, which are said to provide higher efficiency for 65W fast-charging adapter applications versus competing e-mode GaN FETs that require a larger 150m_ device for similar applications;
- secured pre-production purchase orders from ODMs for a large Asia mobile phone (65W) and leading worlwide e-retailer (140W) projects and
- announced the first 99%-efficient power switching demonstration from a 1200V GaN power transistor prototype.

On a non-GAAP basis, operating expenses in fiscal Q4/2022 were $4.6m, up from $4.4m last quarter and $4.5m a year ago. Full-year operating expenses rose from $15.6m in fiscal 2021 to $18.1m for fiscal 2022.

Net loss has been cut further, from $5.2m ($0.13 per share) a year ago and $4.3m ($0.09 per share) last quarter to $4m ($0.08 per share) in fiscal Q4/2022. Full-year net loss was cut from $15.5m ($0.42 per share) in fiscal 2021 to $10m ($0.22 per share) in fiscal 2022.

Cash, cash equivalents and restricted cash have hence fallen during the quarter from $41m to $34m (albeit this is still up from $9.5m a year ago, after completing equity financing totalling more than $45m during fiscal Q3).

"During the 2022 fiscal year we completed an uplisting to the NASDAQ [under the ticker symbol TGAN], dramatically improving the company's liquidity," notes chief financial officer Cameron McAulay. "Along with the additional capital we raised in fiscal Q3 of 2022, this provides expanded operational flexibility in support of our future anticipated growth."

"With a strong backlog in place, our current focus is on managing supply chain constraints, expanding our manufacturing capacity, and continuing to grow our ecosystem of solution partners," concludes Parikh.

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Navitas' revenue grows by 8.2% in Q1/2022

GaN power IC firm certified CarbonNeutral by Natural Capital Partners

For first-quarter 2022, gallium nitride (GaN) power IC firm Navitas Semiconductor Corp has reported revenue of $6.74m, up 8.2% on $7.3m last quarter and 27% on $5.3m a year ago.

However, gross margin (on a non-GAAP basis) has fallen further, from 45.5% a year ago and 44.3% last quarter to 44%, while operating expenses have risen further, from $7.8m a year ago and $10.1m last quarter to $12.5m.

Net loss was $9.6m ($0.08 per share), cut from ($0.27 per share) a year ago but up from $6.95m ($0.07 per share) last quarter.

Founded in 2014, Navitas introduced what it claimed to be the first commercial GaN power integrated circuits. Its proprietary GaNFast power ICs monolithically integrate GaN power field-effect transistors (FETs) and GaN drive plus sensing, control and protection circuits in a single SMT package to enable faster charging, higher power density and greater energy savings for mobile, consumer, enterprise, eMobility and new energy markets.

Customer/product highlights

Navitas says that it is in mass production with nine of the top 10 mobile OEMs (with 10 of 10 targeted by the end of 2022). New wins for mobile-phone chargers include:

- Samsung's flagship Galaxy S22 Ultra and S22+ smartphones (recommended, 45W for fastest charging);
- vivo's new 8"-folding-screen flagship 'X Fold' (in-box, 80W dual USB-C, 0–100% in only 37 minutes);
- Motorola edge+, as featured on the Nasdaq Tower in New York's Times Square (in-box, 68W, 1W/cc power density, 0–50% charge in only 15 minutes);
- Xiaomi AMG Mercedes Formula 1 version (in-box, 120W ultra-fast, 0–100% in only 37 minutes);
- Realme GT Neo 3, launched at the Mobile World Congress with the world's fastest charge time — 0–50% in only 5 minutes (in-box, 150W, 1.5W/cc power density).

Laptop wins include:

- Dell's new XPS Plus, launched in April (in-box, 60W);
- Xiaomi 14" and 15" laptops launched in April (in-box, 100W);
- Lenovo Legion 5 Gen 7 gaming laptops, with Nasdaq co-op promotion (recommended, 135W, 40% smaller, fast charges the massive 80WHr battery 0–100% in only 67 minutes).

"We have reinforced our number-one position in mobile fast and ultra-fast chargers — reaching over 50 million units shipped with zero reported GaN-related field failures – and we are on track with GaN, system R&D and customer developments for our expansion into broader consumer, data-center, solar and electric vehicle (EV) markets," says CEO & co-founder Gene Sheridan.

Navitas' highest-power GaN power IC (the NV6169) was launched at Power, Control and Intelligent Motion (PCIM) Europe 2022 in Nuremberg, Germany (10–12 May) with 50% more power capability for TV, game console and some data-center applications. Additional high-power GaNFast ICs are being sampled, with significant customer developments underway at data-center, solar and electric vehicle (EV) customers.

In March, based on field reliability and the results of extensive life testing, Navitas announced the industry's first 20-year limited warranty, strengthening its position to expand into higher-power and higher-reliability markets.

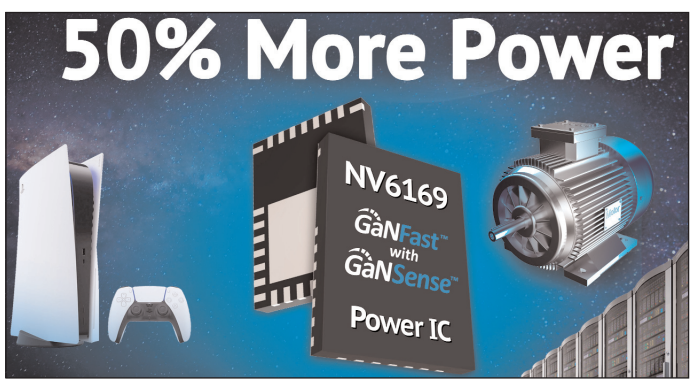
In January, Navitas published what was claimed to be the wide-bandgap industry's first sustainability report that comprehensively quantifies the positive impact of GaN power semiconductors on climate change based on global standards.

Now, Navitas has announced that it is the first semiconductor company worldwide to achieve CarbonNeutral status, as accredited by third-party industry-reference Natural Capital Partners.

For second-quarter 2022, Navitas expects revenue to grow to $8–9m. This guidance factors in some short-term impact from China COVID-related shutdown softness in the supply chain, and in demand for smartphones, offset partially by stronger sales from new customers in other regions.

Despite the slightly lower-than-expected Q2 revenue, this will be offset by subsequent accelerated customer wins and regional expansion so Navitas still expects full-year 2022 revenue to double from 2021.

www.navitassemi.com



Navitas ships 50 millionth GaN IC

GaN power integrated circuit firm Navitas Semiconductor of El Segundo, CA, USA and Dublin, Ireland has announced what it says is an industry-first achievement of 50 million units shipped – with zero reported GaN-related field failures. To celebrate, a Navitas GaN wafer was presented to customer vivo.

GaN runs 20x faster than traditional silicon and enables up to 3x the power or 3x faster charging with up to 40% energy savings in just half the size and weight. Navitas' GaNFast power ICs integrate GaN power and drive plus sensing, protection and control circuits to deliver simple, small, fast and efficient power conversion performance for mobile, consumer, enterprise, eMobility and new energy markets. Over 145 Navitas patents are issued or pending.

In January and April, vivo and Navitas aligned their visions for fast and ultra-fast charging with new products launched in mass production, all adopting Navitas' GaNFast with GaNSense next-generation GaN power ICs. As an early-adopter of GaNSense technology, vivo first launched a 120W in-box ultra-fast charger, shipped with one of the firm's latest flagship phone model, enabling 0–100% charging speed in only 19 minutes. Then, a dual-USB-C, 80W GaN charger shipped with vivo's first 8"-screen foldable phone, supporting simultaneous fast charging of two devices at a weight of just 122g. With a power density of 1W/cc, charging from 0–50% takes only 17 minutes.

"The cooperation with Navitas kicks off a new era for vivo and its historical upgrade of mobile-phone charging speed," says vivo's senior VP & chief technology officer Yujian Shi. "Users can experience ultra-fast, ultra-portable charging on our new flagship phones thanks to Navitas' GaNFast power ICs."

Since full qualification in 2018, Navitas claims to be industry leader in fast and ultra-fast chargers for consumer mobile applications. Recent announcements on high-power IC availability and dedicated design centers for data-center and EV applications indicate the firm's expansion beyond chargers, into high-reliability systems — backed by an industry-first, 20-year limited warranty.

"vivo is a pioneer in fast charging and we are very happy to present the 50M award to vivo for their partnership and vision," comments Navitas' co-founder & CEO Gene Sheridan. "The same pioneering spirit can be seen from customers in our high-power expansion markets including data-center, solar and EV applications. With over 50 million units shipped, each saving 4kg of CO_2, the faster customers can adopt GaN, the better it will be for our environment. GaN could save up to 2.6Gtons CO_2 per year by 2050."

www.navitassemi.com

Navitas upgrades GaN IC power by 50% for electric vehicle, solar and data-center applications

Navitas has launched the NV6169, a new high-power 650/800V-rated GaNFast power IC with GaNSense technology to address higher-power applications such as 400–1000W 4K/8K TVs and displays, next-generation gaming systems, 500W solar micro-inverters, 1.2kW data-center SMPS (switched-mode power supplies), and up to 4kW/5hp motor drives.

The 45mΩ NV6169 features a 36% reduction in on-resistance (RDS(ON)), delivering 50% more power than prior designs, in an industry-standard, low-profile, low-inductance, 8mm x 8mm PQFN package for high-efficiency, high-density power systems.

"Over 50 million GaN power chips have been shipped to customers including Samsung, Dell, Lenovo and Xiaomi with zero reported GaN-related field failures, and GaNSense technology enables real-time, accurate sensing of voltage, current and temperature to further improve total system performance and robustness," says Navitas' co-founder & chief operating officer/chief technology officer Dan Kinzer. "Unprotected, so-called 'discrete' GaN or silicon chips can't match Navitas' performance and reliability and, by offering the NV6169, we extend our reach into higher-power applications such as data centers, solar and electric vehicles (EVs) — with an unprecedented 20-year limited warranty to accelerate GaN adoption into these more-demanding systems."

The NV6169 is claimed to be the highest-power-rated IC from the third-generation integrated GaN platform. GaNFast power ICs with GaNSense technology feature what are reckoned to be GaN-industry-first features such as loss-less current sensing and the world's fastest short-circuit protection, with a 'detect-to-protect' speed of only 30ns (6x faster than discrete solutions). In motor-drive applications, GaN ICs deliver up to 40% energy savings versus silicon IGBTs, eliminate 30 external components, and increase system efficiency by 8%, the firm adds.

Unlike competing solutions, it is claimed, the NV6169 is rated at 650V for nominal operation plus an 800V peak-rating for robust operation during transient events. As a truly integrated power IC, the GaN gate is fully protected and the whole device is rated at an industry-leading electrostatic discharge (ESD) specification of 2kV.

GaN Systems and xFusion announce first 100W/in³ data-center power supply

GaN-based 3kW power supply unit with dimensions of 68mm x 183mm x 40.5mm

GaN Systems Inc of Ottawa, Ontario, Canada (a fabless developer of gallium nitride-based power switching semiconductors for power conversion and control applications) and computing power infrastructure and services provider xFusion Digital Technologies Co Ltd have introduced the xFusion 3kW PSU, which — with its compact dimensions of 68mm x 183mm x 40.5mm — is claimed to be the first power supply unit with power density of 100W/in^3, as well as 80 Plus Titanium efficiency of 96%. The data-center power supply — which supports 90~264V DC voltage and 180V~300V AC voltage input, 12V output — was displayed in the GaN Systems booth at Power, Control and Intelligent Motion (PCIM) Europe 2022 in Nürnberg Germany (10–12 May).

The increasing demand for more data and power combined with sustainability initiatives are driving changes in the data-center industry, notes GaN Systems. The switch to the firm's power transistors has demonstrated increased performance for products with power levels from 800W to 6kW, delivering substantial operating, financial and environmental benefits, it is claimed.

"Customers implementing GaN Systems' power semiconductors in their PSUs are seeing a continual increase in PSU power density, from 45W/in^3 to 63/in^3, 82/in^3, and now to 100W/in^3," says CEO Jim Witham. "With these power density breakthroughs and efficiency improvements, the value proposition of GaN is undeniable, and we will see more PSU companies offering these solutions."

GaN is gaining ground in data-center PSUs, says GaN Systems. With the growth of the data-center sector worldwide, operators are focused on profitability and reducing their CO_2 emissions. For each set of 10 racks in the data center, GaN-based PSUs can increase profits by $3m, reduce the cost of operating a data center, and cut CO_2 emissions output by more than 100 metric tons per year, it is reckoned. Firms designing with GaN are doubling the power density of legacy PSUs, reaching power densities of up to 100W/in^3 with 96+% efficiency, resulting in power supplies half the size and half the power loss compared to silicon-based supplies.

www.xfusion.com

GaN Systems and Phihong debut highest-power-density gaming laptop power supply

280W GaN charger provides 16W/in³ in 160mm x 69mm x 25mm case

GaN Systems and power supply company Phihong Technology have announced the debut of Phihong's 280W GaN charger (said to be the industry's highest-power-density power supply for gaming laptops). The new GaN charger was showcased in GaN Systems' booth at Power, Control and Intelligent Motion (PCIM) Europe 2022 in Nuremberg, Germany (10–12 May).

Phihong's 280W GaN gaming power supply highlights a performance level that is claimed to lead the industry in an ultra-compact case size of 160mm x 69mm x 25mm and a 700g lightweight design. At 16W/in^3 power density, the charger is 50% smaller and 30% lighter than legacy 280W gaming chargers. The 280W GaN charger is also highly efficient, with a 95% full load conversion efficiency and <0.2W no-load standby loss.

Featuring GaN Systems' power semiconductors, Phihong's 280W GaN gaming power supply combines a high-efficiency topology structure, zero voltage and zero current soft-switching technology, digital control.

GaN Systems says that its power semiconductors enable power supply manufacturers to deliver smaller, lighter-weight, cost-effective, reliable solutions. The advantages of GaN allow more efficient power density to power supplies while providing the higher power and faster charging times that are important to consumers.

"In this very mobile world, users want thin, sleek mobile devices and seek the same requirements for the chargers that go along with them. With GaN, gone are the days of the 'brick' power supply," says GaN Systems' CEO Jim Witham. "It's great to see Phihong design in GaN Systems in their AC adapters to achieve the small size and high power demanded by laptop users."

At PCIM, GaN Systems showcased Phihong's 280W GaN charger together with an array of GaN chargers for smartphone and laptop charging, up to 4x smaller than conventional chargers ranging from 45W to 280W.

www.mesago.de/en/PCIM/main.htm
www.gansystems.com/pcim-2022

GaN Systems' growth and design win momentum fuel 3x North America expansion

Firm's staffing to double again in 2022

GaN Systems Inc of Ottawa, Ontario, Canada (a fabless developer of gallium nitride-based power switching semiconductors for power conversion and control applications) has highlighted the growth of its presence in North America with a 3x increase in its Ottawa headquarters operation, the opening of a design center in Dallas, Texas, and a growing footprint across the USA and Europe. The expansion comes after a recent increase in the Asia Pacific and is driven by the firm's continued growth in revenue and design momentum, particularly with industry leaders across its target markets. The firm says that the expansion enables it to serve more customers and supports more designs across all target markets around the globe.

GaN Systems' Ottawa headquarters and engineering hub have grown by 3x and are expected to reach 200 employees in the coming year. With the recent opening of a new design center in Dallas, Texas, the firm's overall headcount doubled in 2021 across Asia, Europe and North America, and is on target to double again in 2022.

The milestones follow three years of exponential growth, 3x expansion of its Taiwan office, and a $150m round of growth capital funding led by Fidelity Management & Research LLC with participation from strategic investors such as USI, Vitesco Technologies, and BMW. GaN Systems says that these achievements showcase the momentum behind gallium nitride and the growth profile expected to continue for years to come.

"We are the first to ramp GaN into electric vehicle (EV) production and currently support production programs across our target markets — consumer, enterprise, automotive, and industrial," says CEO Jim Witham. "Our exponential growth and technology leadership have driven the need to add more talented technology veterans across all disciplines to keep pace with our design-win momentum," he adds. "Our expansion in the Americas and Asia reflects our commitment to servicing our growing customer base worldwide and supporting innovation across our key industries."

GaN Systems has added technology veterans across all key disciplines, including engineering, sales and marketing. The firm is strengthening its in-house capabilities with system-level expert engineering, and design teams focused on power conversion from 30W to 150kW in packages ranging from discrete chips to high-power modules, application expertise in consumer chargers, data-center power supplier units (PSUs), and automotive powertrains.

GaN Systems says it is widening its reach worldwide as customers in automotive, consumer electronics, data centers, and industrial and renewable industries seek ways to improve or create more sustainable and energy-efficient power systems that use fewer materials. GaN is vital in creating these products, the firm reckons, delivering greater energy conversion efficiency and power density than legacy silicon-based power systems.

The GaN power market doubled in 2020 and will surpass $1bn in 2026, highlighting the growth of smartphone fast chargers and leading the way for telecom and automotive markets, according to market analyst firm Yole Développement's report 'GaN Power 2021: Epitaxy, Devices, Applications and Technology Trends'.

www.gan-systems.com

HG adds Wide Yield as new strategic investor

Hong Kong-based HG Semiconductor Ltd has gained new strategic investor Wide Yield Investment Holding Ltd, supporting its expansion to building a 'third-generation semiconductor' industry chain platform.

Star Eagle Enterprises Ltd disposed of 100,500,000 shares (about 17.83% of the total issued shares of HG) to Wide Yield Investment for a total of HK$302,103,000.

Through strategic investor introduction, HG Semiconductor believes that its shareholding structure and financial position will be further strengthened, enabling it to develop and deepen its presence i n the gallium nitride (GaN) sector. HG aims to continue to build on its existing strengths, accelerating growth in its GaN business, generating continuous and stable returns for shareholders in the long term.

HG Semiconductor is principally engaged in semiconductor product business in China, including the design, development, manufacturing, subcontracting services and sale of LED beads, a new generation of GaN chips, GaN components and related application products, as well as fast-charging products. Leveraging its expertise in LED manufacturing, HG is accelerating its R&D and expansion into GaN-related products, targeting the integration of design, manufacturing and sales of chips, as well as providing solutions with higher efficiency and competitive system cost.

Last November, HG made a strategic investment in GaN Systems Inc of Ottawa, Ontario, Canada (a fabless developer of gallium nitride-based power switching semiconductors for power conversion and control applications).

www.hg-semiconductor.com

Semiconductor Innovation for Net Zero project gains £2.45m funding

SIN_0 housed at Swansea University's Centre for Integrative Semiconductor Materials

A new research and innovation facility based at Swansea University in Wales has received a funding boost of £2.45m to host a project that will trial innovative emission reduction strategies to help the semiconductor industry deliver on net-zero ambitions.

The new Semiconductor Innovation for Net Zero (SIN_0) project will be housed at the industry-focused Centre for Integrative Semiconductor Materials (CISM), which is funded by the UK Research Partnership Investment Fund (UKRPIF).

Net Zero is an £18.9m pilot funding initiative designed to support capital activities that will reduce the carbon emissions of UKRPIF-funded research facilities, making the research processes they support more environmentally sustainable. Funded activity will also support the core aims of the wider UKRPIF program, including enhancing higher-education (HE) facilities to support world-class research and strengthening partnerships between providers and other organizations active in research. UKRPIF and UKRPIF: Net Zero are managed by Research England — part of UK Research and Innovation (UKRI) — on behalf of the four funding bodies — Research England, the Scottish Funding Council, the Higher Education Funding Council for Wales (HEFCW), and the Department for the Economy, Northern Ireland.

Due to be completed in September, CISM's focus will be the creation of 'over-the-horizon' semiconductor technologies to support Net Zero, such as advanced solar cells and efficient power electronics for the electrification of transport. CISM is part of the regional CSconnected compound semiconductor cluster of industry, university, RTO (research and technology organization), and government partners driving forward the semiconductor sector in South Wales.

Artist's impression of the CISM building.

The SIN_0 project aims to extend that agenda to deploy and test innovative emissions-reduction strategies in energy generation and storage, and resource and waste stream management. SIN_0 will not only trailblaze the decarbonization of advanced research infrastructure like CISM but also aims to de-risk the interventions that the semiconductor manufacturing industry will need to employ to reduce the carbon footprint of this critical sector rapidly and dramatically.

SIN_0 is one of nine Net Zero projects at UK universities (begun in April and running until March 2023) that are set to reduce the carbon footprint of research facilities, through the £18.9m funding boost. The investment will support universities to enhance, upgrade and adapt research centers and facilities to reduce their carbon emissions, and make research processes more environmentally sustainable.

"Our mission is to not only deliver our own institutional net-zero ambitions, but also to support the semiconductor industry within our region and the CSconnected partners as, together, we develop the technologies that will decarbonize manufacturing and help Wales and the world to meet our net-zero targets," says Swansea University's vice-chancellor professor Paul Boyle.

"By piloting these innovative approaches to tackling net-zero in infrastructure, we hope that this scheme will help us to learn more about what works so that we and the HE sector can factor this into future activity and build upon the already successful UKRPIF model," says Research England executive chair David Sweeney.

"Our Environmental Sustainability Strategy commits UKRI to supporting the research sector to reduce its negative environmental impacts," says professor Duncan Wingham, executive chair of NERC (the Natural Environment Research Council) and sponsor for Environmental Sustainability and Net Zero in UKRI. "This funding will help these leading national centers and facilities develop innovative solutions to reducing energy demand and increasing the use of renewable power in some unique research environments."

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

II-VI extends implanter disk refurbishing services to Asia

Multi-million-dollar expansion in Taiwan, to come online in July

Engineered materials and optoelectronic component maker II-VI Inc of Saxonburg, PA, USA – which claims to have the world's largest ion implant foundry with disk refurbishing services – is extending its ion implanter disk refurbishing services to Asia, with a multi-million-dollar expansion in Hsinchu City, Taiwan (to come online in July).

The acute shortages of semiconductor devices in the global supply chain are driving strong demand for refurbishment of wafer fabrication equipment, notes the firm. The expansion in Taiwan will effectively double II-VI's global disk refurbishing capacity. Batch implanter tool owners in Asia can benefit from a rapid turnaround service that will enable them to maintain their tools in operation and sustain their production output, it adds.

"The market demand for used ion implant equipment already exceeds availability by about a factor of ten, including in Asia," says Sohail Khan, executive VP, New Ventures & Wide-Bandgap Electronics Technologies. "Our 25 years of expertise and innovations in disk refurbishment enable our customers to achieve an average of 30% savings on cost of ownership over OEM service. By coming to us, customers will reduce their maintenance costs and get the most out of their ion implanter equipment from higher reliability and longer service life."

II-VI says that, as a global provider of foundry ion implantation services and support, it implants tens of thousands of wafers per week and adds tools and capacity as required to support customers' changing needs. The firm adds that its technical expertise, quality program and broad range of tooling offer a flexible outsourcing option for ion implantation, serving production manufacturing and R&D environments.

II-VI maintains a large complement of high- and medium-current and high-energy production implanters handling 2-inch to 12-inch substrates. The firm provides ion implantation services for silicon and compound semiconductor wafers, including heated ion implantation for silicon carbide (SiC) wafers.

II-VI participated as an exhibitor at the 36th International Conference on Compound Semiconductor Manufacturing Technology (CS MANTECH) in Monterey, CA, USA (9–11 May).

www.ii-vi.com/product/ion-implantation

AXT Q1 revenue grows 26% year-on-year, driven by 45% growth in InP

InP furnaces being added to ease capacity constraints

For first-quarter 2022, AXT Inc of Fremont, CA, USA has reported a ninth consecutive quarter of revenue growth, to $39.7m (near the top end of the guidance range of $38–40m). This is up 5% on $37.7m last quarter and 26% on $31.4m a year ago, highlighting market share gains and expansion into new applications and tier-1 opportunities.

Of total revenue, the proportion from the Asia Pacific region was 73%, Europe was 16%, and North America was 11%. The top five customers generated about 29% of total revenue, one of which just edged over 10%. "Our continued revenue diversity demonstrates that our growth is not overly dependent on one large customer or application," notes CEO Morris Young.

"We have reached an inflection point in our business, where our investments in technology, business operations, and customer relationships are contributing to our growth," says Young. "We are particularly pleased with the continued strong growth of our indium phosphide products."

Total substrate revenue was $31.7m, up 10.8% on $28.6m last quarter and 35.5% on $23.4m a year ago. By product category, germanium substrates was $4.2m (level with last quarter), but GaAs was $12m (up 6.2% on $11.3m) and InP was a record $15.5m (up 18.3% on $13.1m last quarter, and up more than 45% on a year ago). This "puts us well on track to achieve indium phosphide revenue growth of 30% or more this year," says Young.

Revenue was $7.9m from AXT's two consolidated raw material joint venture companies BoYu (which makes high-temperature pyrolytic boron nitride crucibles and pBN-based tools for organic LEDs) and JinMei (which supplies high-purity materials including gallium and germanium, as well as InP poly and other materials). This is down on $9.1m last quarter, after very strong growth throughout 2021, with prices remaining volatile.

"The consolidated raw material companies are being selective in the business they support in order to drive improved gross margin performance in our business," says Young. "We were pleased to see the increase in contribution to profit from the unconsolidated raw material companies, which represent additional positive leverage in our model. This is a strong benefit of our vertical integration strategy," he adds. "While high raw material prices had a negative impact on our cost of goods sold (COGS) for AXT and its competitors, AXT is able to offset some of the impact of the higher prices through the revenue generated by our joint ventures. We also have the benefit of supply guarantees and insight into the pricing trend… These have proven highly valuable to our business over the last two decades."

On a non-GAAP basis, gross margin was 33.8%, still down on 36.9% a year ago but recovering further from 32.4% last quarter, due to growing volume, a favorable product mix (due to growth in InP), and a strong focus on yield improvements and manufacturing efficiencies. "We continue to believe that we can get back to the 35% range later this year," says chief financial officer Gary Fischer.

Operating expenses have risen further, from $7.2m a year ago and $8.1m last quarter to $8.6m.

Net income was $4.3m ($0.10 per share, above the expected $0.07–0.09), up from $4.1m ($0.09 per share) last quarter and $4.2m ($0.10 per share) a year ago.

Capital expenditure (CapEx) was $6.3m, due to adding InP furnaces (since AXT "can't quite meet the demand from one of our good customers," says Fischer), as well as some wafer processing equipment in the GaAs and germanium lines.

During the quarter, cash, cash equivalents and investments fell from $51.8m to $44.3m.

"Total revenue growth is coming from a diverse set of applications and customers across telecom infrastructure, data-center, industrial, consumer, healthcare, automotive, and other markets — giving us confidence in the sustainability of our business model throughout 2022 and beyond," says Young.

For Q2/2022, AXT expects revenue of $38–41m, and net profit per share of $0.08–0.10. Gross margin should be similar to Q1.

"Our key markets have entered a new cycle of innovation and application development that is driving opportunity expansions and diversify our revenue base," says Young. "This is supported by the strong order pattern we are currently experiencing. Demand from several of our tier-1 customers is robust, and we're working hard to scale our production accordingly," he adds. "Through the scaling of our operations, investing in our product roadmaps, and strengthening of our capital structure, we are executing on a strategy that positions us well for the healthy growth and profitability throughout 2022 and beyond."

STAR Market listing update

On 10 January, China-based wafer manufacturing subsidiary Beijing Tongmei Xtal Technology Co Ltd's application for an initial public offering on the Shanghai Stock Exchange's Sci-Tech innovAtion boaRd (STAR Market) was accepted for consideration. After queries from the Shanghai Stock Exchange's Review Board, Tongmei submitted a revised application (accepted for review on 18 April). AXT notes that the process of going public on the STAR Market includes several periods of review and is a lengthy process. Tongmei expects to accomplish this in second-half 2022.

www.axt.com

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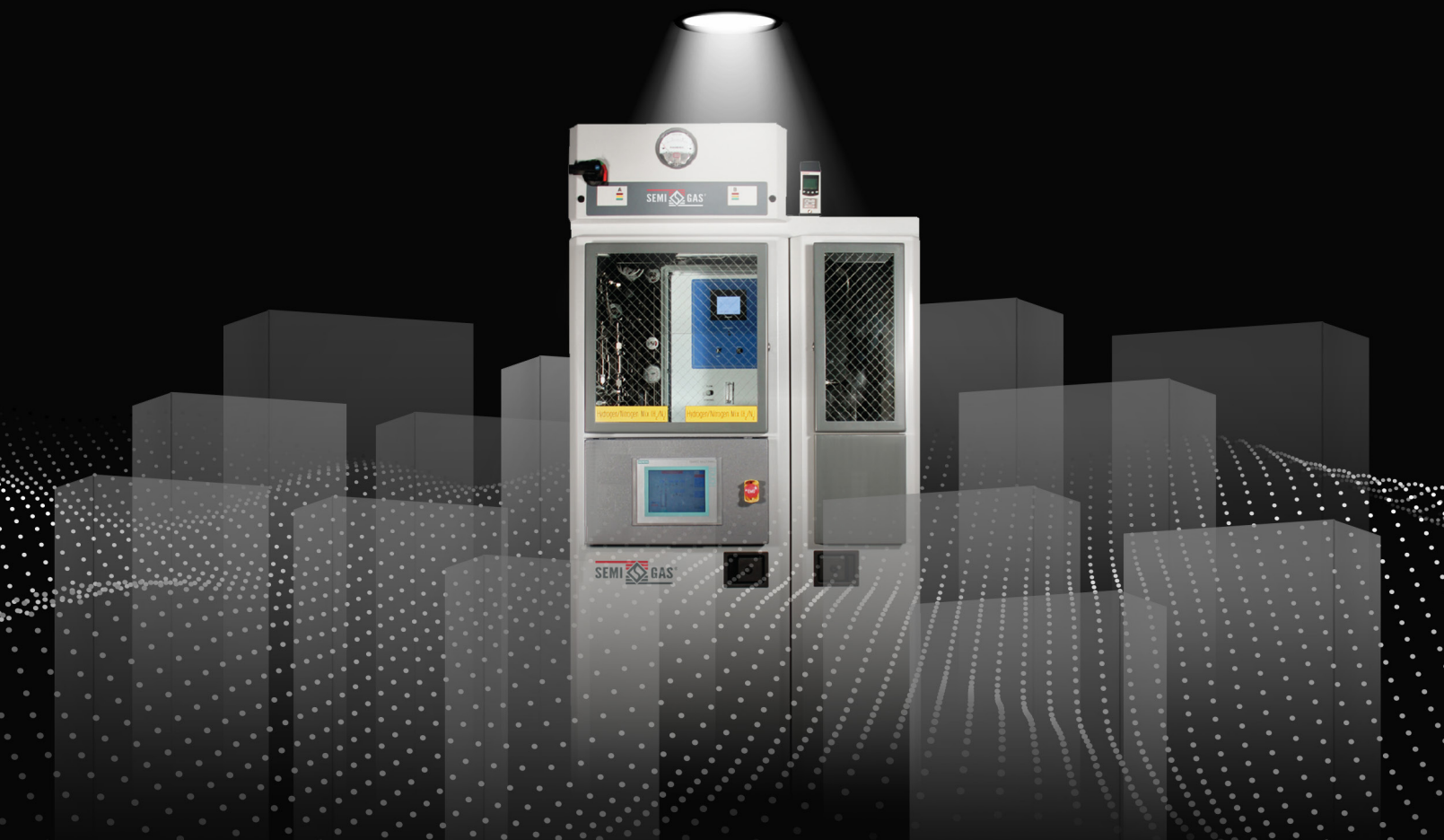

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Aixtron expands MOCVD market share to 75% in 2021

MOCVD equipment market grew by 28% from $438m in 2020 to $561m in 2021

Deposition equipment maker Aixtron says that it was able to expand its market share in metal-organic chemical vapor deposition (MOCVD) in 2021 and is the largest supplier of MOCVD tools worldwide for the sixth consecutive year. According to the report 'Semiconductor Wafer Fab Equipment, Worldwide, 2021' issued in April 2022 by market research firm Gartner, Aixtron held a 75% share of the market, while competitors from China and the USA had significantly lower market shares of 14% and 11%, respectively. At the same time, the global market for MOCVD tools grew by 28% from $438m in 2020 to $561m in 2021.

Aixtron's equipment is used in the production of power semiconductors made of gallium nitride (GaN) or silicon carbide (SiC), lasers for 3D sensing and optical data communication, and in the production of red LEDs. Increasingly, it is also being used in the manufacture of micro-LEDs. The firm notes that its growth is being driven by the megatrends of sustainability, digitalization and electrification.

"Aixtron has put a clear focus on MOCVD technology for compound semiconductors in the last years," notes CEO Dr Felix Grawert. "These devices offer immense advantages over traditional silicon-based semiconductors," he adds. "As a result, the devices produced on our equipment are conquering more and more new areas of application. This opens up significant growth areas for us — over many years and across our entire technology portfolio."

CCS 3x2 MOCVD system to be supplied to Boise State

System to deposit 2D materials and GaN structures for flexible hybrid electronics

Aixtron SE of Herzogenrath, near Aachen, Germany says that subsidiary Aixtron Ltd will deliver a deposition system from their Close Coupled Showerhead metal-organic chemical vapor deposition (CCS MOCVD) product range for compound semiconductor materials to the Boise State University. The CCS 3x2 is an essential part of an infrastructure expansion awarded to Boise State University, Idaho.

With a capacity of 3x2" wafers, the CCS 3x2 system being delivered to Boise's Micron Center for Materials Research will have a maximum operating temperature of 1400°C, which will enable the deposition of graphene and hexagonal boron nitride (hBN) on sapphire as well as novel structures for gallium nitride (GaN)-based ultraviolet light-emitting diodes (UV LEDs). Equipped with a wide variety of metal-organic and gas channels, the system will enable Boise State University to deposit the most advanced 2D materials. In addition, the system includes Aixtron's proprietary ARGUS and EPISON in-situ metrology technologies, which are proven key enablers for the uniform, repeatable wafer-scale growth of 2D materials.

With help of the CCS 3x2, Boise State aims to enable up-to-date manufacturing of advanced flexible hybrid electronics using 2D–3D heterostructures. The goal is to use the Aixtron system to research and overcome the challenges of large-scale synthesis and integration of 2D materials into full semiconductor device process flows.

"The Aixtron system is a major part of our research infrastructure expansion," says David Estrada, Boise State's associate director for the Center for Advanced Energy Studies and associate professor in the Micron School of Materials Science and Engineering. "The Aixtron Close Coupled Showerhead metal-organic vapor phase epitaxy system is capable of wafer-scale growth of atomically thin semiconductor materials as well as more traditional semiconductor films."

The CCS 3x2 tool is expected to be the only system at a US university dedicated and configured for wafer-scale 2D and nitride-based compound semiconductor growth. It will prepare the future semiconductor workforce at the undergraduate and graduate levels for the US-based semiconductor industry.

In close cooperation with Aixtron, the Boise State research team will leverage unique material properties, artificial intelligence (AI) algorithms and what are described as trailblazing microfabrication techniques for the creation of novel technologies that will drive future applications.

"We are happy to tighten our bonds with the Unites States and the academic world by providing an industrial-grade R&D reactor to Boise State University," says professor Michael Heuken, VP Advanced Technologies at Aixtron. "Our CCS 3x2 equipment delivers best-in-class results for 2D materials at wafer scale in multiple applications," he adds. "It is also the only system technology that can be configured for combined 2D and GaN research while also allowing the growth of van der Waals heterostructures."

www.aixtron.com

Riber's revenue falls 25% in Q1 due to deferred billing for major Services & Accessories order

Strong rebound expected in Q2; orders up 32% year on year

For first-quarter 2022, Riber S.A. of Bezons, France — which manufactures molecular beam epitaxy (MBE) systems as well as evaporation sources and effusion cells — has reported revenue of €2.4m, down 25% on €3.2m a year ago.

Of total revenue, 50% came from Europe, 39% from Asia, and 11% from North America.

Revenue came entirely from Services & Accessories, with the temporary contraction due to deferred billing for a major order (so revenue should bounce back strongly in second-quarter 2022).

While no revenues were recorded for MBE Systems, this reflects the production cycle for machines that have been ordered for 2022 and is not an indication of the firm's performance over the full year, says Riber.

During Q1, Riber recorded six orders for MBE systems, confirming the significant upturn in new orders despite the persistent obstacles for granting export licenses for certain contracts in Asia.

Riber recorded six orders for MBE systems... despite the persistent obstacles for granting export licenses for certain contracts in Asia

The order book hence totaled €22.8m at the end of March, up 32% from €17.3m at end-March 2021. Specifically, the Systems order book has risen by 74% from €9.6m a year ago to €16.7m (comprising nine systems, with eight to be delivered in 2022). The Services & Accessories order book has fallen by 20% from €7.7m to €6.1m, faced with a high basis for comparison.

Riber is hence forecasting growth in both revenue and profitability for 2022 compared with 2021.

In addition, due to a strong pipeline of prospects for both systems and services, Riber expects to continue to record new orders during second-quarter 2022.

www.riber.com

amcoss supplies coating & developing wafer process system to Jenoptik

System to be used for lithography in high-power, edge-emitting laser manufacturing

amcoss GmbH of Feldkirch, Austria (which develops and makes customized processing equipment for coating, developing, temperature control and cleaning, as well as lift-off and etching of substrates and masks) has supplied high-power, edge-emitting laser manufacturer Jenoptik with a fully automatic amc 2000 wafer processing unit for coating and developing wafers. Jenoptik will use the equipment in lithography processing at its site in Berlin-Adlershof, Germany.

"The amcoss equipment is a replacement tool. Our goal is to significantly increase capacity and yield, compared to the tool we have been using so far, which will noticeably raise productivity," says Dr Jürgen Sebastian, site manager at Jenoptik Berlin, which produces high-power diode lasers for medical applications, materials processing, R&D, and pump sources for solid-state lasers. "Furthermore, we need optimized wafer centering and more flexible application possibilities for 3" and 4" wafers," he adds. "With amc 2000 we are sure to reach these goals and to even increase quality and efficiency in wafer processing."

amcoss' amc 2000 for fully automatic, simultaneous coating and developing of wafers and substrates of varying diameters.

amcoss says that its wafer processing equipment is configured according to individual customer needs, so that each tool is unique. "We do not build mass products, but each of our machines is a highly complex single piece," says company owner David Erne.

"So, amc 2000 for Jenoptik has been designed for highest throughput. With its dual arm handler and four loadport stations for parallel operation of up to four processes, it absolutely is a high-throughput tool." In addition, a space-saving, integrated alignment-on-the-fly prealigner may alternatively be used, if flat orientation is necessary.

amcoss says that the amc 2000 system's flexible layout makes it a bridge tool. Jenoptik can now simultaneously process different wafer sizes — namely the required 3" and 4" diameters — without the need for adaptation when changing size. By fitting the tool with five dispense lines with a unique single-nozzle-gripper system and an additional syringe, flexibility is increased even more, adds the firm. Various hot-plates and cool-plates, a special vapor prime hotplate and an efficient EBR system complete the configuration.

In addition to the new amcoss wafer processing tool, an amc 2500 system has also been installed at the Jenoptik site in Dresden.

www.amcoss.com
www.amcoss-systems.com

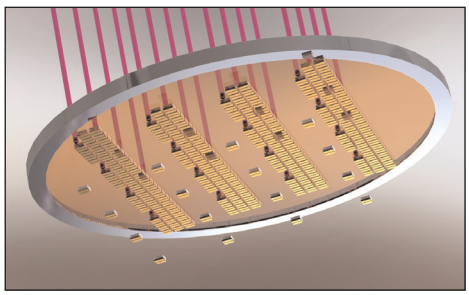
K&S receives multiple orders for LUMINEX system

Laser-based mini/micro-LED die transfer enables assembly of advanced displays

Singapore-based Kulicke & Soffa Industries Inc (K&S) — which designs and manufactures semiconductor, LED and electronic assembly equipment — has received two purchase orders, from two separate customers, for its latest advanced display system, LUMINEX (a laser-based mini- and micro-LED die-transfer solution launched last November).

The system is capable of single die transfer, multi-die transfer and mass transfer supporting sorting, mixing, re-pitching and placement process steps. The broad flexibility addresses the growing advanced display value chain and supports the needs of LED, OSAT, panel and display suppliers.

K&S says that mini-LED backlit displays represent only 3% of display capacity currently but will accelerate to 20% penetration levels by 2025. During this same period, mini-LED direct-emissive technologies are set to grow to 18% by 2025, creating strong growth prospects for the firm's growing portfolio of advanced display solutions.



Laser-Enabled Advanced Placement (LEAP) technology embedded in LUMINEX.

"Adoption continues to accelerate, and we continue to support several active customer engagements across the advanced display value chain," says Nelson Wong, senior VP of global sales and supply chain. "We are also positioned well to enable growth in the micro-LED market with an ongoing customer engagement."

According to market analyst firm TrendForce, 4.7 million 4" mini-LED wafer equivalents will be deployed in backlighting applications in 2026. In parallel, about 4.6 million 4" mini-LED wafer equivalents will be deployed in direct-emissive displays by 2026.

K&S also expects that, over the coming years, micro-LEDs will enable next-generation premium direct-emissive displays, further accelerating long-term prospects within its advanced display portfolio.

www.kns.com

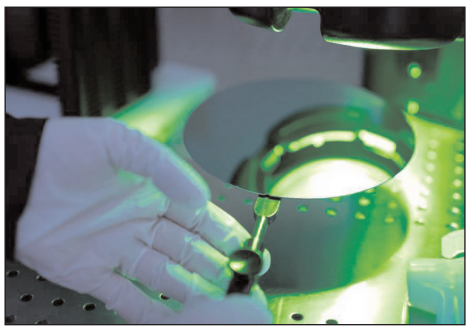
IQE partners with Porotech to enter micro-LED market

PoroGaN display technology to be developed, scaled & commercialized

Epiwafer and substrate maker IQE plc of Cardiff, UK has announced a strategic partnership with Porotech (a spin off from the Cambridge Centre for Gallium Nitride at the UK's University of Cambridge that has developed porous GaN material).

The focus of the partnership is to develop, scale and commercialize Porotech's unique wafer technology that achieves all three colours (RGB) on a single 200mm or 300mm GaN-based wafer for ultra-high-density and efficient micro-LEDs, the applications for which include augmented/mixed/virtual reality (AR/MR/VR), wearable devices, smart displays and large-scale direct-view displays.

The intention is for IQE to be Porotech's epitaxial wafer foundry



partner, providing GaN metal-organic chemical vapor deposition (MOCVD) capacity for the volume production of Porotech's PoroGaN micro-display technology platforms. Together, the companies aim to develop and productionize 200mm manufacturing platforms as well as 300mm wafer formats.

"This partnership marks IQE's entrance into the micro-LED market with a unique platform," says IQE's CEO Americo Lemos. "The micro-LED market presents a significant opportunity for our business. IQE's proven heritage in GaN epitaxy and our industry-leading footprint in high-volume wafer manufacturing, combined with Porotech's PoroGaN micro-display technology platform, will create a compelling and differentiated product offering," he believes.

"IQE's deep heritage and innovation in MOCVD epitaxial growth technologies, as well as its mass-production capability, are optimized for very small high-brightness micro-LED pixels that match perfectly with Porotech's platform," comments Porotech's CEO & co-founder Dr Tongtong Zhu.

www.iqep.com
www.porotech.com

MICLEDI presents 300mm micro-LED arrays for augmented reality glasses at Display Week

Samples of blue array by mid-2022; green and red in second-half 2022

MICLEDI Microdisplays B.V. of Leuven, Belgium — a fabless developer of micro-LED display modules for augmented reality (AR) glasses — demonstrated its technology at the Display Week 2022 event hosted by the Society for Information Display in San Jose, CA, USA (8–13 May).

As creators of what are claimed to be the first micro-LED arrays-for-AR built on a 300mm CMOS manufacturing platform, MICLEDI says that it enables more compact, power-efficient devices that address the needs of future AR glasses in terms of display size, resolution, brightness, image quality, power consumption and cost.

AR headsets are currently heavy, bulky and costly, and deliver poor image realism and low resolution. Nearly every leading technology firm is investing in AR to drive the future of their consumer offerings, and micro-LED displays are a mission-critical component. MICLEDI says that its technology and manufacturing process overcome the challenges with first- and second-generation AR glasses to achieve the features that consumers will require for visually immersive AR.

At Display Week, MICLEDI's chief technology officer Dr Soeren Steudel gave a presentation 'MicroLED Display Integration on 300mm Advanced CMOS Platform' highlighting the reality and manufacturability of MICLEDI's proprietary 300mm manufacturing flow.

Having first demonstrated its blue FHD arrays at the Consumer Electronics Show (CES 2022) in January, MICLEDI recently released 'passive matrix' samples of its next-generation blue arrays. These are manufactured in the firm's proprietary 300mm reconstitution and hybrid wafer-to-wafer bonding flow, including a base CMOS metallization wafer, enabling customers to illuminate and characterize different portions of the array. By mid-2022, the firm expects to release samples of its blue array with its proprietary pixel-by-pixel lensing system designed to narrow the apex angle of each pixel for maximum brightness. Samples of green and red arrays are expected in second-half 2022.

"In just the last few months, we have made significant progress toward commercial readiness, as evidenced by the number of enthusiastic inquiries from, and ongoing conversations with, a wide range of tier-1 OEM manufacturers with special interest in the AR space," says CEO Sean Lord. "Display Week is a premier opportunity for us to showcase our world-class 300mm micro-LEDs, discuss with customers our new high-volume, low-cost manufacturing partner GlobalFoundries, and engage our customers for next-generation samples coming throughout the balance of 2022."

www.micledi.com

Porotech demonstrates tunable-colour DynamicPixelTuning technology

Fully tunable color on a single pixel for micro-displays

At the Society for Information Display (SID) Display Week 2022 event at the San Jose Convention Center, CA, USA (10–12 May), Porotech (a spin off from the Cambridge Centre for Gallium Nitride at the UK's University of Cambridge that has developed porous GaN material) unveiled DynamicPixelTuning on its PoroGaN micro-display platform. This makes it possible to create full-color or tunable-colour displays using identical pixels from a single wafer — achieving color uniformity while eliminating complex fabrication processes.

The firm reckons that the development can accelerate the commercialization of micro-LEDs, mini-LEDs and LEDs to deliver display products for augmented/mixed/virtual reality (AR/MR/VR) applications, smart wearable devices, smart displays and large-scale direct-view displays.

Porotech claims to be first to unlock dynamic color tuning of LED chips and pixels, with its PoroGaN platform making it possible for each individual LED on an epiwafer to emit all colors of the visible spectrum.

At this stage, the Porotech proof-of-concept displays are tunable mono-color, with uniform brightness and color for display products in the micro (μm) and nano (nm) pixel space. But the company's proprietary PoroGaN platform and Dynamic Pixel technology are paving the way to a monolithic full-color RGB display very soon.

The PoroGaN platform also enables a one-step wafer-to-wafer bonding process — removing key manufacturing barriers for full and tunable color micro-display fabrication, increasing yields and reducing production costs and time to market.

"PoroGaN's wavelength-agnostic optoelectronic properties also simplify electronic and optoelectronic system design integration," says CEO & co-founder Dr Tongtong Zhu.

Micro-LED and mini-LED display fabrication remains challenging due to the multi-phase processes currently required to manipulate elements at the micro- and nano-scale. "With Porotech's porous GaN technology and scalable architectures, the PoroGaN platform significantly simplifies the mass-transfer or pick-and-place process," says Zhu.

"In the case of micro-displays, it eliminates the need for transfer by allowing wafer-scale bonding of epiwafer to backplane in a single step," he adds. "The simplification of the process delivers high-efficiency and high-yield solutions, leapfrogging full-color micro-LED and mini-LED displays as viable mass-market products for next-generation display applications."

The PoroGaN platform is configurable to LED epiwafers for both micro-LED and mini-LED chip processing. Other configurations include chip-on-wafer, chip-on-tape and tunable material platforms.

At Display Week, Porotech demonstrated its technology in the I-Zone section. Zhu was also among the speakers at the event's Business Conference on 9 May.

www.porotech.co.uk

DynamicPixelTuning technology wins Innovation Zone Award — Best Prototype Category at Display Week

Porotech has won the Innovation Zone Award — Best Prototype Category at the Display Week 2022 event hosted by the Society for Information Display (SID) in San Jose, CA, USA (8–13 May).

Focused on next-generation display applications, Porotech's PoroGaN technology platform enables ultra-small and efficient micro-LED chips that can emit all colors of the visible spectrum with a single GaN material system.

The firm's DynamicPixelTuning technology, powered by its PoroGaN micro-display platform,

was voted by the industry professionals in the exhibition as the game-changing innovation. The technology is said to unlock dynamic color tuning of LED chips and pixels and is set to resolve the existing micro-LED challenges in performance and manufacturability for augmented/mixed/virtual reality (AR/MR/VR) applications.

"Winning this award signifies the deep technology work in GaN-based semiconductor materials and structures carried out by our team at Porotech to innovate and further develop into our micro-LED display portfolio," says CEO & co-founder Dr Tongtong Zhu.

www.displayweek.org

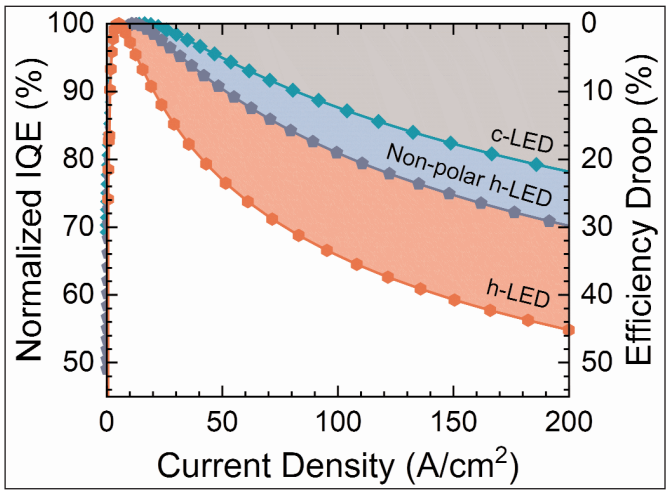
Efficiency droop halved in cubic- versus hexagonal-phase InGaAlN LEDs

Coexistence of strong internal polarization and large carrier effective mass accounts for half of efficiency droop in h-LEDs

It is widely accepted that the large Auger coefficient is the main cause for the large (~50%) efficiency droop in traditional hexagonal-phase indium gallium aluminium nitride (InGaAlN) LEDs. Yet this explanation is inadequate to account for the low efficiency droop in gallium arsenide (GaAs)- and gallium phosphide (GaP)-based LEDs, as those have similar Auger coefficients.

Now, researchers Can Bayram, Jean-Pierre Leburton and Yi-Chia Tsai at the University of Illinois at Urbana-Champaign (UIUC) have shown that the coexistence of strong internal polarization and large carrier effective mass accounts for about 51% of the efficiency droop under high current densities in hexagonal-phase InGaAlN green LEDs (h-LEDs) compared with cubic-phase InGaAlN green LEDs (cLEDs) – see Y.-C. Tsai, J.P. Leburton, C. Bayram, 'Quenching of the Efficiency Droop in Cubic Phase InGaAlN Light-Emitting Diodes', IEEE Trans. Electron Devices (2022); https://doi.org/10.1109/TED.2022.3167645.

Previously, the efficiency droop reduction in non-polar h-LEDs was attributed to the decrease in carrier leakage from the active region, overlooking the interplay between internal polarization and Auger recombination. Indeed, recent experiments suggest that the efficiency droop reduction in non-polar h-LEDs is in fact due to carrier delocalization (a situation different than in polar h-LEDs) that results in stronger electron-hole wavefunction overlap, lower quantum well carrier densities, and lower Auger recombination rates. The UIUC team found out that large carrier effective mass promotes carrier localization and degrades the band-to-band optical transition matrix element.



Normalized internal quantum efficiency (IQE) (left y-axis) and efficiency droop (right y-axis) as a function of current density. Red hexagons and green rhombuses refer to hexagonal-phase (h-) and cubic-phase (c-) InGaAlN LEDs; blue pentagons refer to nonpolar h-LED grown on m-plane GaN substrates.

According to this new interpretation, the researchers show that switching from polar h-LEDs to c-LEDs quenches the efficiency droop from 45% to 22% (i.e. a 51% reduction) due to polarization elimination and effective mass reduction. It is further found that the quantum efficiency of c-LEDs is much more immune to the Auger electron-hole asymmetry, the increase in Auger coefficient, and thus efficiency degradation mechanisms. Hence, cubic-phase InGaAlN green LEDs offer an appropriate solution for quenching the efficiency droop.

https://obqledsim.ece.illinois.edu
https://icorlab.ece.illinois.edu

CreeLED sues Star Headlight & Lantern

Patent infringement alleged regarding DLITE product

CreeLED Inc of Durham, NC, USA (a company of SMART Global Holdings of Milpitas, CA) has filed a patent infringement lawsuit in the US District Court for the Western District of New York against Star Headlight & Lantern Co Inc. The lawsuit asserts that Star has infringed Cree LED's rights in four US patents (nos. 8,884,510; 9,048,396; 9,865,780; and D718,258) by selling a DLITE product that incorporates six infringing LED packages.

Cree LED specializes in supplying a broad portfolio of high-performance LED chips and components. Together with its predecessor Cree Inc, the firm has a 30-year track record of innovations and industry firsts. This history in technology and innovation has distinguished Cree LED as one of the LED industry's strongest brands. Cree LED's contributions to LED development and design serve as the basis for Cree LED's expansive portfolio of US and worldwide patents covering an array of innovative technologies.

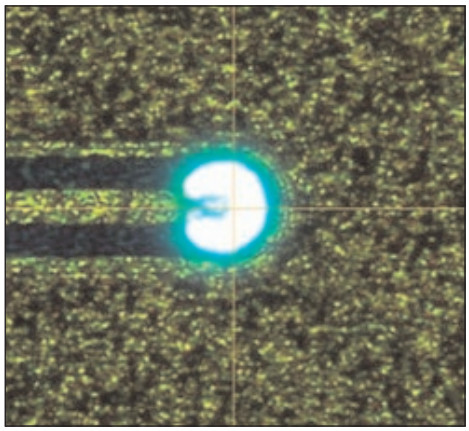
As a US-based firm that has extensively invested in R&D, quality and product innovation, Cree LED says that it is committed to protecting and enforcing its valuable intellectual property rights.

www.sghcorp.com

Kubos' cubic GaN LEDs 20 times faster than hexagonal GaN for visible light communications

Spun out of the University of Cambridge in 2017 — with an exclusive license to develop and commercialize its proprietary cubic-phase gallium nitride (GaN) intellectual property — Kubos Semiconductors Ltd of Cambridge, UK, in collaboration with researchers at the universities of Manchester and Cambridge, has identified the potential for its material to deliver LEDs capable of switching at significantly faster speeds than those produced in the hexagonal crystal phase. Carrier lifetimes in cubic GaN quantum wells have been measured at <0.5ns, which is more than 20 times faster than typical c-plane hexagonal GaN LEDs (≈10ns). Along with other beneficial properties of cubic GaN, these shorter carrier lifetimes offer the potential to develop LEDs across the visible spectrum that can be switched at very high speeds (>1GHz).

"These measurements suggest cubic GaN LEDs could be used in visible light communications (VLC) applications enabling higher-speed connectivity, and we are already seeing some early commercial interest in this area," says technical director & founder professor David Wallis.



Kubos' 25μm (radius) cubic GaN LED, with a quantum well peak in the 'green gap'.

Kubos is developing its cubic GaN technology to produce improved-efficiency green and amber LEDs and red micro-LEDs for a range of lighting and display applications, and its potential to significantly reduce carbon emissions attributable to solid-state lighting is widely acknowledged. The firm has calculated that this could save as much as 120 million tons of CO_2 emissions on an annualized basis (equivalent to the emissions of 32 coal-fired power stations each year). But the possibility of playing an additional role in delivering faster switching speeds in communications applications is groundbreaking.

"The communications sector of the LED market is a progressive and exciting application area," comments CEO Caroline O'Brien. "The opportunity to significantly improve LiFi and electronic optical backplane communication speeds, for example, opens a whole new segment for Kubos in an already large and growing addressable LED and micro-LED market."

According to data published by MarketsandMarkets in November 2020, the VLC market is expected to grow to $80.3bn by 2025, with 'less energy consumption by LEDs' one of the key factors fueling this growth.

www.kubos-semi.com

Nitride settles UV-LED patent litigation against Digi-Key

Firm continues enforcement against UV-LED suppliers in USA

Japan's Nitride Semiconductors Co Ltd (which was spun off from Tokushima University in 2000) has entered into a settlement with global electrical components distributor Digi-Key Corp. Nitride filed the patent litigation against Digi-Key in the US District Court for the District of Minnesota, asserting infringement of its ultraviolet light-emitting diode (UV-LED) patent.

In collaboration with professor emeritus Shiro Sakai at Tokushima University, Nitride developed what it claims was the first high-efficiency UV-LED as early as 2000. It has since continued to manufacture and sell UV-LED products, and says that it has invested heavily in R&D to develop and enhance its UV-LED technology.

To protect its UV-LED patented technology, Nitride initiated its patent enforcement campaign starting in 2017. Subsequently, in 2020, a judgment was issued by the US District Court for the Northern District of California against RayVio Corp for infringing Nitride's UV-LED patent. That judgment was also in Nitride's favor with respect to the validity of its patent. The US Patent & Trademark Office has also confirmed the validity of the key claims of Nitride's patent in its final judgment on an Inter Parte Review case filed by RayVio.

Further, patent lawsuits against Lite-On Technology Corp and Crystal IS Inc are pending in the US District Court for the Western District of Texas and in the US District Court for the Northern District of New York, respectively, where Nitride is trying to enforce its UV-LED patent.

Nitride says that, since it considers its intellectual property rights to be vitally important company assets, it will take any action necessary to enforce its patent against infringers in any country and uphold its patents and other intellectual property rights.

www.nitride.co.jp

Lumileds introduces LUXEON HL1Z CSP LED

Efficacy of 137lm/W from 1.4mm-square package

Lumileds LLC of San Jose, CA, USA says that its newest high-power CSP LED — the LUXEON HL1Z — is an un-domed, single-sided emitter that delivers high luminous efficacy (137lm/W or more) from a very small package just 1.4mm square.

The top emission prevents 'cross-talk' and contributes to the superior color-over-angle performance and color consistency. Compactness and directional emission allow engineers to create tight arrays and precisely control the beam, which enables smaller optical solutions and a path for system cost reduction, says the firm. The LUXEON HL1Z is particularly suitable for high-center-beam candle power applications such as high-end retail spots, tunable white solutions, after-market automotive, and other high-density array lighting.

"Demand for the next generation of high-power LEDs is increasing as the need for higher intensity, beam steering, compact arrays, color tuning, and high-center-beam candle power solutions become the drivers of new applications," says product manager Alvin Yeoh. "Emitters like HL1Z provide new design freedom without sacrificing quality or efficacy."

The LUXEON HL1Z is available immediately through Lumileds distribution network in correlated color temperatures (CCTs) from 3000K to 6500K and color rendering indexes (CRIs) of 80 and 90. Additional CCT/CRI combinations will follow over the coming months and are available for pre-order.

www.lumileds.com/products/high-power-leds/luxeon-hl1z

LUXEON HL2Z undomed CSP high-power LED launched

Lumileds has introduced the LUXEON HL2Z, an un-domed CSP (chip-scale package), single-sided, high-power LED that is said to significantly reduce system costs while delivering high flux density, high luminance and precise beam control. It delivers luminous flux of over 315 lumens and efficacy of more than 160 lumens per Watt from a compact 2.3mm-square package that is just 0.36mm high.

Adopters of the new package include M3 Innovation, whose MAKO Sports Lighting Solution uses the LUXEON HL2Z to deliver 150,000 lumens from each of its modules designed to illuminate athletic fields, parks, stadium fields, and other outdoor facilities.

"With LUXEON HL2Z we were able to completely re-think what can be achieved in a sports lighting solution," says M3 Innovation's executive officer Joe Casper. "The power, optical control, and design possibilities are what made the MAKO disruptive in the market," he adds.

"Customers that are engineering street lights, stadium lights and other high-luminance directional applications benefit from an un-domed source as it makes it easier to increase optical efficiency and to realize narrow beam angles and complex light distributions," says product manager Alvin Yeoh. "With LUXEON HL2Z, everything from array configuration design to DLC qualification is simplified and system costs can be lower by 20% or more," he claims.

In addition to the available LM80 data, ray-set data and visual inspection prove the quality of LUXEON HL2Z's color consistency across the beam, enabling it to support high-quality illumination indoors or outdoors.

LUXEON HL2Z is specified for R9>40 for 70CRI, R9>0 for 80CRI, and R9 >50 for 90CRI parts, so solutions with HL2Z can qualify for DLC standard or Premium listing.

The LUXEON HL2Z is available through Lumileds' distribution network for CCTs of 3000–6500K and with CRIs of 70, 80 and 90.

www.lumileds.com/products/high-power-leds/luxeon-hl2z

LUXEON CoB Core Pro LEDs launched for retail lighting

Lumileds has launched the LUXEON CoB Core Pro range. With a color point that is below the black-body locus and aligns with the color point of conventional (ceramic discharge metal halide) solutions, typical CRI of 92, R9 greater than 50, and typical luminous efficacy of 152lm/W (for a CCT = 3000K, junction temperature T_j=85C, 90CRI, and 15mm light-emitting surface), the new CoB range is targeted at retail and hospitality recessed and track lighting solutions.

"The hallmarks of a good retail lamp — sparkle, and great color reproduction — can now be had in a CoB LED with even greater efficacy than before," says Keen Oun Yap, senior product manager. "For retailers that have remained on the sideline for just the right color point and better efficacy, the time has come to make that switch to a Lumileds CoB solution," he adds. "No mercury, no startup lag, no heat and no color drift, just excellent color consistency over time and lower energy consumption."

With light-emitting surfaces of 9–19mm and output of 700 lumens to more than 5000 lumens, the range of applications that can be addressed ranges from shops and shop windows to offices, hotels, restaurants and many others.

www.lumileds.com/products/cob-leds/luxeon-cob-core-pro

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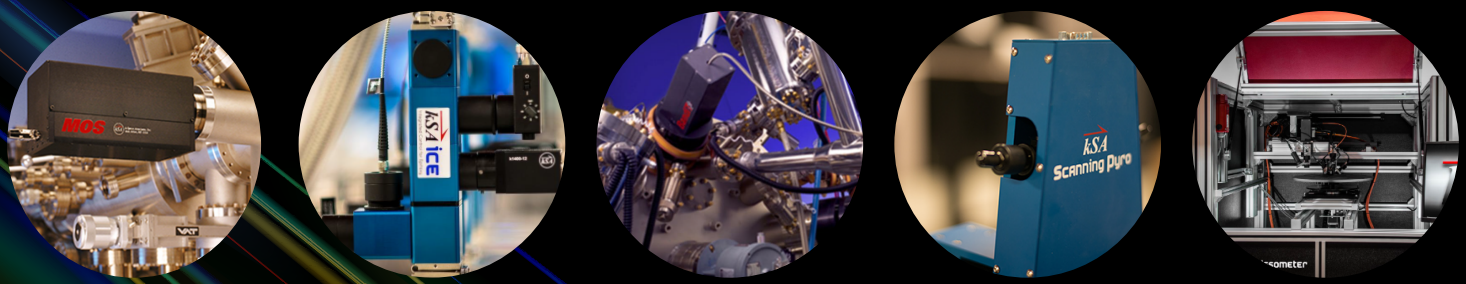

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Vector Photonics' LIFT grant brings life testing of 3D metal printing PCSELs in-house

Photonic-crystal surface-emitting laser (PCSEL) firm Vector Photonics Ltd of Glasgow, Scotland, UK says that the LIFT grant from UK Government agency Innovate UK (which provides funding and support for business innovation as part of UK Research and Innovation) has enabled it to develop an in-house accelerated life testing (ALT) capability for its high-power PCSELs.

The 1030nm PCSELs are being developed for next-generation 3D metal printing as part of the project BLOODLINE (Bright Laser diOdes fOr aDvance metaL addItive maNufacturing systEms), which is also funded by Innovate UK but within the international Eureka project framework. Vector Photonics says that its high-power PCSELs have a unique combination of increased power, reduced cost and improved performance, enabling fast, high-resolution, 3D metal printing with less post-production finishing.

"The LIFT grant, which is for £100,000, comes from Innovate UK's resilience fund, helping companies recover from the impact of COVID," says principal development engineer Dr Calum Hill, who secured the LIFT grant. "We have used it to fast-track the development of our own in-house, life-test capability. By bringing this service in-house, we have helped accelerate the commercialization of high-power PCSELs, as outsourcing often causes delays."

The BLOODLINE project has linked Vector Photonics with Japan-based laser epitaxy manufacturer QD Laser Inc (a spin-off from Fujitsu Laboratories Ltd) for wafer supply; a group of leading, industrial equipment manufacturers for product assessment; and the UK's Compound Semiconductor Applications (CSA) Catapult for other testing requirements.

https://gtr.ukri.org/projects?ref=79455
www.vectorphotonics.co.uk

University of Glasgow appoints research associate to lead KTP with Vector Photonics

Scotland's University of Glasgow has appointed Adam McKenzie as a research associate leading its Knowledge Transfer Partnership (KTP) project with Vector Photonics. McKenzie will analyse PCSEL reliability and failure capabilities to inform new product development and accelerate commercialization. A robust accelerated life-test (ALT) 'burn-in' system for PCSELs will be developed and Glasgow University's Kelvin Nano-characterisation Centre (KNC) will provide the facilities for failure mode analysis.

"Adam brings six years industrial, semiconductor growth and characterization experience to the project, with expertise in InP- and GaAs-based photonic devices," says Vector Photonics' chief technology officer Richard Taylor. "He was most recently a process engineer at Sivers Photonics, where he drove MOCVD [metal-organic chemical vapor deposition] production, development and R&D operations. His expertise extends to InP-based overgrowth processes and the development of InGaAsP and AlGaInAs epitaxy."

McKenzie is finalizing his PhD thesis 'MOVPE Growth for GaAs-Based PCSELs', which has given him extensive industrial-based design and characterization knowledge of PCSEL structures and epitaxial regrowth processes. Undertaken while at Sivers Photonics, his research was funded by an Industrial Fellowship from the Royal Commission for the Exhibition of 1851 and resulted in a research prize from the IET (Institution of Engineering and Technology).

Sivers Photonics wins order to supply laser sources

Sivers Semiconductors AB of Kista, Sweden (which supplies chips and integrated modules) says that its subsidiary Sivers Photonics of Glasgow, Scotland, UK has begun a partnership agreement with a new customer by signing a contract worth over $617,000 to deliver next-generation laser sources.

The collaboration with the technology business will initially focus on the development and supply of customized lasers across a range of wavelengths, helping to enable the customer to develop its future roadmap.

Sivers Photonics notes that it has experience in designing customized laser chips for a variety of global customers and advanced applications. The new project will utilize this expertise, with volume production opportunities for the business, along with possible further projects as part of the partnership.

"We look forward to a long-term partnership as these exciting projects continue." says Sivers Photonics' managing director William McLaughlin.

"This is the third large Fortune 100 technology company that has chosen to work with Sivers Semiconductors for photonics' laser sources," notes Sivers Semiconductors' group CEO Anders Storm.

www.sivers-semiconductors.com

First commercially available 200mm VCSEL wafer

Unit economics enables expansion of 3D sensing beyond smartphone

Epiwafer and substrate maker IQE plc of Cardiff, UK has announced what is said to be the world's first commercially available 200mm (8") vertical-cavity surface-emitting laser (VCSEL) epiwafer.

IQE reckons that the increase in wafer diameter to 200mm will enable a step-change in unit economics for compound semiconductors, allowing expansion to new foundry partnerships (including silicon-based foundries). Furthermore, it enables the integration of compound semiconductors on silicon, allowing adoption across a wider range of devices and applications.

IQE notes that 3D sensing was made economical within premium smartphones in 2017 when it developed and scaled VCSEL epiwafers from 100mm to 150mm. The introduction of 200mm creates opportunities beyond the smartphone, into a broad range of intelligent connected devices and also enables applications in the metaverse.

"This is a critical milestone and establishes IQE as the global leader in scaling compound semiconductor technology to larger diameters," reckons CEO Americo Lemos. "As we set out in our fiscal-year 2021 results in March, a key focus area is growing our business by extending our roadmap to 200mm to establish new foundry partnerships," he adds. "This advancement will expand the market for both wireless and photonics applications and service the growing demand for compound semiconductors as macro trends such as 5G and the metaverse proliferate and capture more value for our technology."

www.iqep.com

NUBURU and Essentium partner to launch first blue laser-based wire feed metal 3D printers

High-power, high-brightness blue laser technology and metal additive manufacturing platform to speed metal part production

High-power blue laser technology firm NUBURU Inc of Centennial, CO, USA (which was founded in 2015) and industrial additive manufacturing (AM) firm Essentium Inc of Austin, TX (which makes industrial 3D printers and materials) are partnering to develop and manufacture a blue laser-based metal AM platform. The new Essentium printer will enable manufacturers to create production-grade metal parts with high resolution and fast throughput, NUBURU says.

Under the multi-year, multi-million-dollar agreement, Essentium may integrate NUBURU's proprietary blue laser technology with its high-speed extrusion (HSE) 3D printing technology for product development in the first phase, and manufacturing in the second phase. The new AM platform is designed to deliver breakthrough throughput for extremely high part quality and broad-scale use in major industrial markets, including automotive, aerospace and defense.

As a part of the contract, NUBURU will also license its core 3D printing application patents, based on its foundational patent 'Methods and systems for welding copper using blue laser' (US10,940,562B2 and JP2019562226A).

NUBURU claims that its blue laser is well suited to materials processing applications within AM. Critical materials such as copper, stainless steel and aluminum reflect much of the infrared wavelengths transmitted by traditional industrial lasers, which leads to lower print speed and quality. NUBURU says that its blue laser technology enables printing with 10x the build speed and the ability to print with a very high metal density without any post processes.

"Our high-power, high-brightness blue laser technology, along with our 3D printing IP, will help Essentium build a powerful metal 3D printer with a wide range of applications," reckons NUBURU's co-founder, CEO & president Mark Zediker Ph.D.

Essentium says that its HSE 3D printing platforms enable an industrial-scale additive manufacturing solution that allows the generation of production-floor-ready parts at scale quickly and cost-effectively. Supported by eight patents to date, the technology provides energy-efficient deposition, eliminating porosity and minimizing warpage during a build. The new platform will produce parts comparable to castings and forgings with minimal post-processing required.

"NUBURU is the leader in blue laser technology, and their expertise will help enable gains in speed and power within our new platform," comments Essentium's chief development officer & co-founder Elisa Teipel Ph.D. "We are looking forward to working with their team and leveraging their technology, enabling Essentium to commercialize a new metal 3D printing platform."

www.nuburu.net

www.essentium.com

TRUMPF introduces 760nm and 763nm VCSELs for spectroscopic oxygen sensing

Integrated and robust temperature-controlled VCSEL in TO packages provide performance reliability in industrial applications

TRUMPF Photonic Components GmbH of Ulm, Germany (part of the TRUMPF Group) — which makes vertical-cavity surface-emitting lasers (VCSELs) and photodiodes for the consumer electronics, datacoms, industrial sensing, heating and automotive markets — is introducing its next generation of VCSEL for spectroscopic oxygen sensing.

Spectroscopic sensing solutions can be claimed as the highest-performing sensing technique to monitor relevant parameters such as oxygen concentration, the firm says. The new generation of 760nm and 763nm VCSELs in TO packages even increase performance reliability, enabled by TRUMPF's new production and processing platform.

The benefit of offering solutions at wavelengths of 760nm and 763nm is that there are no influences from background gases, as no gas other than oxygen shows high absorption at these emission wavelengths.

"We provide integrated, smart VCSEL solutions for easy integration of the components into demanding production systems," says VP marketing & sales Ralph Gudde. "TRUMPF not only contributes its laser-source know-how, but also combines it with application, optics and assembly know-how," he adds.

O_2 sensing from petroleum to medical industry

The new 760nm and 763nm VCSEL solutions serve various industrial applications to detect oxygen concentration. "O_2 sensing solutions are not only used in demanding industrial environments but also in automotive or medical settings," says Gudde. "Our VCSEL solutions with active temperature and polarization control therefore offer a large detection range with high resolution and an accuracy of almost 100%," he adds. In power plants or the petroleum industry, for example,

VCSEL in TO package. The hermetically sealed TO housing protects the electronics and allows easy handling and operation in demanding ambient conditions.

the VCSELs support exhaust gas analysis. On the other hand, in the packaging industry, VCSELs support the determination of oxygen in sealed packages such as water bottles. The application fields extend to the medical sector, where the O_2 sensors are used in medical devices such as respirators, ventilators or incubators.

The well-established technique to serve these applications is tunable diode laser absorption spectroscopy (TDLAS). TDLAS and single-mode VCSELs are a perfect match, says the firm. The VCSELs offer high accuracy and controllability with their absolute symmetrical beam shape, narrow line-width and distinct polarization. Therefore, the VCSEL solutions enable TDLAS to be a high-performance sensing technique that offers unbeatable measurement speed with in-situ measurement in less than a second. Non-contact laser measurement covers a huge temperature range and allows determination of process pressure and temperature at the same time. This is made possible by the low thermal wavelength coefficient of the VCSEL material and the integrated thermoelectric cooler (TEC). The small size of the VCSEL, combined with its increasing functionality, make it suitable to address the demand for hardware miniaturization.

Made for any environmental conditions

Integrated sensor solutions in a TO housing not only reduce system complexity and enable high-end sensing solutions with cost advantages, the hermetically sealed, rugged housing also minimizes the risk of damage that can be caused by external factors in demanding ambient conditions. Additionally, there is hardly any thermal sensitivity of the sensor, as the packages are be equipped with integrated temperature control with TEC and thermistor. Applications demanding a large temperature window can be performed, as the user can regulate the laser temperature precisely in order to control the wavelength.

O_2 sensing with VCSEL. The new generations of 760nm and 763nm VCSELs in TO packages increase the performance reliability of O_2 measurements.

www.trumpf.com/s/VCSEL-solutions

Siemens collaborates with GlobalFoundries to provide silicon photonics design verification

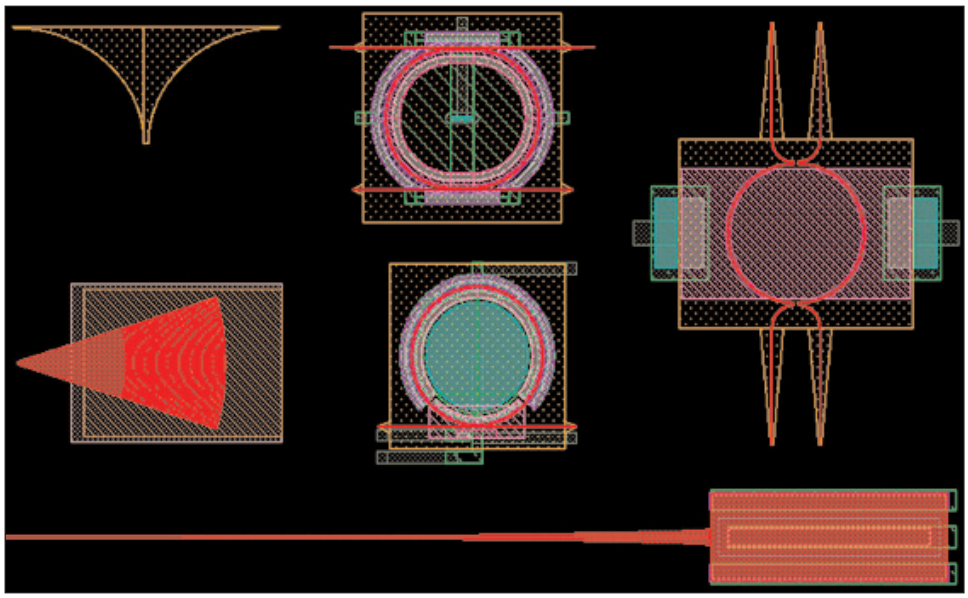
Siemens Digital Industries Software of Plano, TX, USA says that its Calibre nmPlatform now enables designers to leverage the newest silicon photonics platform of GlobalFoundries (GF) of Malta, NY, USA (which has operations in Singapore, Germany and the USA). GF's next-generation, monolithic platform GF Fotonix is the first in the industry to combine its differentiated 300mm photonics and RF-CMOS features on a silicon wafer, delivering best-in-class performance at scale.

The GF Fotonix process design kits (PDKs) include Calibre nmDRC software for design rule checking (DRC) and Calibre nmLVS software for layout versus schematic (LVS) verification. Both Calibre tools are fully certified by GF, so mutual customers designing for the new GF Fotonix platform can continue to use the Calibre nmPlatform for silicon photonic devices as they have used for previous offerings.

"Siemens EDA is pleased to extend our mutual solution with GF into the emerging silicon photonics market," says Michael Buehler-Garcia, VP of Calibre Design Solutions product management. "While silicon photonic designs and their subsequent inclusion into multi-die offerings introduce new verification complexities, these complexities are addressed in the Calibre silicon photonics design kits, which require no change to how designers traditionally use Calibre."

GF Fotonix consolidates complex processes that were previously distributed across multiple chips onto a single chip by combining a photonic system, radio frequency (RF) components and high-performance complementary metal–oxide–semiconductor (CMOS) logic on just one silicon chip.

"Our collaboration with Siemens EDA is another example of how GF is partnering with industry leaders to deliver innovative, time-to-market solutions for our customers," says Mike Cadigan, GF's senior VP for Customer Design Enablement. "The combination of Siemens' Calibre tools, for both design verification and post tape-out operation, with the GF Fotonix solution, can help designers efficiently create the powerful, flexible and power-efficient solutions required in today's next-generation data-center, computing and sensing applications."



Siemens' Calibre nmPlatform now enables designers to leverage the newest GlobalFoundries silicon photonics platform.

Silicon photonics enables firms to bring fiber optics directly into integrated circuits. However, silicon photonic devices contain curved layouts, rather than the linear Manhattan grid features found in traditional CMOS designs. Applying traditional CMOS DRC to silicon photonic layouts yields numerous false positive errors that design teams must often spend weeks tracking down. To address this challenge, GF leverages Siemens' Calibre eqDRC software, which allows rule checks to use equations in place of, or in addition to, linear measurements. This helps enable more accurate results, leading to significantly fewer errors, so design teams can spend far less time and fewer resources debugging their designs.

Similarly, the curvilinear nature of photonic structures, together with the general lack of source netlists for optics, poses a challenge when performing LVS checking. Traditional IC LVS technology extracts physical measurements from well-understood electronic structures and compares them to the intended corresponding elements in the source netlist. However, with curved structures it is difficult, if not impossible, to discern where one structure begins and another ends. With the new GF Fotonix process design kit with Calibre LVS, this obstacle is resolved with the use of text and marker layers to discern regions of interest.

Silicon photonic devices are often implemented in an individual die on a specific process node, then stacked and packaged with the rest of design components in multiple dies using advanced heterogeneous packaging technologies. GlobalFoundries says that, by using the complete core Calibre offering, total verification cycle times can be greatly reduced.

www.globalfoundries.com
www.siemens.com/software

POET's loss rises in Q1 as product development and introduction programs expand

Customer engagement expands with sampling and qualification programs

For first-quarter 2022, POET Technologies Inc of Toronto, Ontario, Canada — a designer and developer of the POET Optical Interposer and photonic integrated circuits (PICs) for the data-center and telecom markets — has reported a net loss of $5.4m ($0.15 per share), up $3.7m ($0.10 per share) last quarter and $4.1m ($0.13 per share) a year ago. Net loss included R&D costs of $2.2m, up from $2m last quarter and $1.3m a year ago. The firm added engineering headcount as its product development and new product introduction efforts expanded. POET also engaged with new suppliers, through non-recurring engineering (NRE) and qualification programs, to ensure that the supply of required products and services will meet the company's standards and will be available as needed.

Cash outflow from operating activities was –$3.7m, up from –$2.5m a year ago and –$3.2m last quarter.

POET says that, during the quarter, it achieved the following milestones:

- Named to the 2022 OTCQX Best 50 (a ranking of top performing companies traded on the OTCQX Best Market last year).
- Entered into an agreement with Celestial AI to provide multi-laser integrated external light source (ELS) modules using its advanced packaging platform based on the POET Optical Interposer. The agreement includes a contract for continued platform development, along with a purchase order for initial quantities of the advanced modules.
- Announced a collaboration with Liobate Technologies to incorporate advanced Thin-Film Lithium Niobate (TFLN) modulators onto POET's optical engines supporting power-efficient ultra-high-bandwidth electro-optic conversion for data-center and telecom applications. This multi-phase, co-development project is initially focused on delivering and commercializing a POET 400/800Gps Transmit and Receive optical engine.
- Announced the launch of its 400G FR4 and 800G (2x400G FR4) Receive (RX) optical engines based on the POET Optical Interposer.
- Completed previously announced consolidation of its common shares and commenced trading on Nasdaq under the ticker symbol 'POET'.
- Joined the Singapore Hybrid-Integrated Next Generation micro-Electronics (SHINE) Center in the College of Design and Engineering at the National University of Singapore (NUS).

"The first quarter has been an active period of sampling and expanding customer engagement," says chairman & CEO Dr Suresh Venkatesan. "We were able to leverage our success at the Optical Fiber Communication conference (OFC 2022), where we demonstrated our 200G FR4 Transmit and 400G FR4 Receive optical engines," he adds. "POET received significant notoriety for being the only company to showcase a chip-scale integrated FR4 optical engine, offering substantial size, energy efficiency and cost benefits compared to alternative solutions based on the DR4 standard, resulting in heightened interest from companies that we have not been engaged with previously. We are focused on advancing our efforts to convert this interest to customer orders in the coming quarters."

www.poet-technologies.com

II-VI Inc and Coherent refile Premerger Notification and Report Form

Merger now expected mid-2022, pending regulatory approval in China

Engineered materials and optoelectronic component maker II-VI Inc of Saxonburg, PA, USA and Coherent Inc of Santa Clara, CA (which provides lasers and laser-based technology for scientific, commercial and industrial applications) have refiled their Premerger Notification and Report Form ('HSR Notification') with the Federal Trade Commission and the US Department of Justice, in connection with the pending acquisition of Coherent by II-VI.

The HSR Notification, which triggers a 30-day review period, was made prior to the one-year expiration of II-VI's and Coherent's initial HSR Notification filed last year. The parties continue cooperative discussions with the State Administration for Market Regulation of China (SAMR), and the decision to refile the HSR Notification is due to the parties' updated view of the anticipated timing of formal approval from SAMR.

Other than the foregoing, there are no other open regulatory closing conditions to the proposed merger, and II-VI and Coherent now expect the closing of the merger to occur prior to 30 June.

www.ii-vi.com

NeoPhotonics Q1 revenue grows 47% year-on-year, despite chip supply chain shortages

Return to net profit driven by 70% revenue growth in 400G-and-above products

For first-quarter of 2022, 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 reported revenue of $89.3m, up 11% on $80.6m last quarter and up 47% on $60.9m a year ago due to more than 70% growth in 400G-and-above capable products to $54m (61% of total revenue up from 56% last quarter and 52% a year ago). This is despite the impacts of semiconductor chip shortages. Supply chain shortages negatively impacted revenue by about $10m, but these were primarily shortages of analog and power semiconductors.

"Our business remains on a strong growth path," says chairman & CEO Tim Jenks. "We are now shipping production 400ZR coherent DCO module products to leading customers, and we have extended our product reach to higher speeds and to new applications, such as communications in low earth orbit (LEO) satellites," he adds.

Product milestone achieved during the quarter include:

- announcing cumulative shipments of more than 1 million single and quad 53Gbaud PAM4 driver ICs for 100G DR1 and 400G [DR4 and FR4] hyperscale data-center networks;
- sampling Open ZR+ QSFP-DD small-form-factor pluggable coherent modules for metro-regional applications designed to enhance performance in hyperscale data-center and telecom networks;
- demonstrating that the firm's QSFP-DD and OSFP coherent modules interoperate with multiple vendors' products in the OIF 400ZR Interoperability Demonstration at the Optical Fiber Communications conference (OFC 2022);
- demonstrating indium phosphide (InP) components capable of 120Gbaud operation supporting 800G applications within and between data centers (LR, ZR, and ZR+);
- introducing a radiation-tolerant version of the Ultra-Pure Color Tunable Laser with enhanced flexible software to extend operating life in a radiation environment enabling use in low Earth orbit (LEO) applications.

On a non-GAAP basis, gross margin has risen further, from 22.4% a year ago and 26.6% last quarter to 31.2%, as the first-quarter increase in under-utilization charges (per normal seasonal patterns) was more than offset by the improved product mix and lower purchase price variance.

We have overcome the loss of the majority of our revenue from our prior largest customer [Huawei] due to Department of Commerce restrictions, with growth from leading customers in high-growth markets. While we continue to see strong demand for our products, we also expect continuing challenges with IC chip supply shortages

Operating expenses have risen further, from $21.5m a year ago and $23.3m last quarter to $25m, due to higher research & development (R&D) and general & administrative (G&A) expenses. However, as a proportion of revenue, this is a cut from 35.3% a year ago and 28.9% last quarter to 28%.

Operating income was $2.8m (operating margin of 3.1% of revenue), compared with losses of $1.8m (–2.2% margin) last quarter and $7.8m (–12.9% margin) a year ago.

Net income was $2.3m ($0.04 per share), compared with losses of $3.4m ($0.06 per share) last quarter and $7.5m a year ago ($0.15 per share) a year ago.

During the quarter, cash and cash equivalents, short-term investments and restricted cash rose by about $1m to $107m.

"Our 47% year on year revenue growth, non-GAAP operating profit and significant growth from western customers reflects our success in pivoting our business," says Jenks. "We have overcome the loss of the majority of our revenue from our prior largest customer [Huawei] due to Department of Commerce restrictions, with growth from leading customers in high-growth markets," he adds.

"The Lumentum transaction, announced last November, remains on track, having been approved by our shareholders and received anti-trust clearance from US regulators. Lumentum is an ideal partner to serve our customers on a larger scale and we look forward to securing regulatory approval in China and closing the transaction," continues Jenks.

"Looking forward, while we continue to see strong demand for our products, we also expect continuing challenges with IC chip supply shortages, which could materially impact our results near term," cautions Jenks.

www.neophotonics.com

Lumentum's quarterly revenue falls 5.7% year-on-year

Supply-constrained revenue loss rises from $50m to $65m, and $100m expected next quarter

For its fiscal third-quarter 2022 (ended 2 April), Lumentum Holdings Inc of San Jose, CA, USA (which designs and makes photonics products for optical networks and lasers for industrial and consumer markets) has reported revenue of $395.4m, down 11.5% on $446.7m last quarter and 5.7% on $419.5m a year ago.

"Strong demand and solid execution by our team around the world resulted in all third-quarter financial metrics being at the high end of our guidance range," says president & CEO Alan Lowe. This was despite the industry-wide shortages of third-party-supplied semiconductors constraining production so that the gap between Lumentum's supply and demand for its products suppressed revenue by more than $65m (up from $50m the prior quarter).

Commercial Lasers segment revenue was a near-record $51.2m (12.9% of total revenue), up 3.9% on $49.3m last quarter and 62% on $31.6m a year ago, driven primarily by fiber lasers serving automotive and industrial applications, as well as ultrafast lasers for manufacturing semiconductors and consumer electronics.

In contrast, Optical Communications segment revenue has fallen further, to $344.2m (87.1% of total revenue), down 13.4% on $397.4m last quarter and 11.3% on $387.9m a year ago. Specifically, Telecom & Datacom revenue was $243.5m, down 9% on $267.1m last quarter and $255.8m a year ago, due to IC supply shortages for Telecoms despite very strong demand. However, pump laser revenue was near record highs. Also, despite capacity constraints in Datacoms, externally modulated lasers (EMLs) rose to 70–75% of Datacom revenue (aided by increased manufacturing capacity now coming online). Industrial & Consumer revenue (including 3D sensing and lasers sold into industrial applications) was $100.7m, down on $130.3m last quarter (due to 3D sensing seasonality) and $132.1m a year ago, as about five years of Lumentum having an outsized market share in 3D sensing is now undergoing some share normalization.

Driven primarily by lower revenue and higher supplier costs, gross margin (on a non-GAAP basis) was 49.5%, down from 51% last quarter and 49.9% a year ago.

In particular, Optical Communications segment gross margin was 49%, down on 50.8% last quarter and 50.1% a year ago, due primarily to lower revenue as well as product mix. The Commercial Laser segment gross margin was 52.9%, down slightly on 53.1% last quarter but up from 47.2% a year ago due to higher volumes.

Operating expenses were $90.7m 4m (22.9% of revenue), up from $86.4m last quarter but cut from $92.1m 4m a year ago.

Operating income was $104.9m (operating margin of 26.5% of revenue), down from $141.6m (31.7% margin) last quarter and $117.1m (27.9% margin) a year ago. However, operating margin was above the expected 24–26%.

Net income was $88.9m ($1.19 per diluted share), down from $120.2m ($1.60 per diluted share) last quarter and $99.7m ($1.26 per diluted share) a year ago, but at the top of the guidance range of $1.01–1.19 per diluted share.

Strong demand and solid execution by our team around the world resulted in all third-quarter financial metrics being at the high end of our guidance range

Cash generated from operations was $76.6m (down from $206.5m last quarter). Nevertheless, cash, cash equivalents and short-term investments rose by $541.7m during the quarter, from $2022.4m to $2564.1m.

In March, Lumentum issued $861m worth of 0.50% convertible notes due in 2028, yielding net proceeds of $854.1m (after deducting $6.9m in issuance costs). Of this, $200m was used to repurchase 2 million shares of the firm's common stock in privately negotiated transactions, and $124m was used to repurchase a further 1.3 million shares. (The firm has hence repurchased 7.8 million shares over the last 12 months, including 5.8 million shares purchased for $487m under the board-authorized $1bn share buyback program, leaving $513.5m remaining under the program.)

In fiscal Q3/2022, Lumentum also funded a $30m loan to support the revenue growth of NeoPhotonics Corp, whose acquisition remains on track for calendar second-half 2022. "We are working diligently with antitrust authorities in China, with their approval being the final key closing condition for the transaction," says Lowe.

For fiscal Q4/2022, Lumentum expects revenue to grow both sequentially and year-on-year to $405–430m (driven primarily by Telecom product shipments), with operating margin of 26.5–28%, and diluted earnings per share $1.25–1.40 (all records for a fourth quarter).

"Though component supply is increasing, demand is growing even faster," notes Lowe. Lumentum expects more than a $100m revenue impact as a result of the gap between demand and supply in Q4, up significantly on the $65m gap in Q3. "While we expect these [IC] supply shortages to continue to improve with the diligent work of our team and our suppliers, given the accelerating demand environment, we will likely see customer demand

outpacing third-party material supply into calendar 2023," he adds. "We believe this demand is durable due to customers being at the initial stages of their network upgrades," adds chief financial officer Wajid Ali.

Industrial & Consumer revenue is expected to be down sequentially, with typical consumer product seasonality.

However, Telecom & Datacom revenue is expected to be up quarter-on-quarter by $50m (up 20%, with EMLs growing faster than 20% and telecom growing slower than 20%). This growth is due to the improvements in IC component supply, although this will still be significantly below the level of customer demand. "While we're able to grow that business by 20% quarter-on-quarter, the demand is growing even faster than that," says Ali. "We continue to work diligently with our suppliers and on alternative sources of supply to alleviate shortages," says Lowe. Also, additional EML capacity is fully online in fiscal Q4 (which will impact calendar 2023).

Commercial Lasers segment revenue is expected to grow again quarter-on-quarter to a new record, driven by new products and the overall market expansion.

"I am highly optimistic about our outlook and believe market inflections beneficial to Lumentum in our addressable markets will drive double-digit revenue growth in fiscal 2023 and beyond," Lowe adds.

www.lumentum.com

Lumentum exhibits at LASER World of PHOTONICS

VCSEL arrays showcased for 3D sensing applications

At the LASER World of PHOTONICS 2022 trade fair in Munich, Germany (26–29 April), Lumentum showcased demonstrations with partners as well as its latest laser solutions for industrial and 3D sensing markets.

The latest additions to the firm's portfolio include the M Series of high-performance multi-junction vertical-cavity surface-emitting laser (VCSEL) arrays for automotive and industrial 3D sensing applications (announced in early April).

Specifically, Lumentum displayed a range of VCSEL-based illumination solutions and partnership demonstrations for intelligent 3D sensing consumer, automotive and industrial applications, including mobile, access control, industrial Internet of Things (IoT), extended reality and autonomous driving.

Lumentum's automotive-qualified M Series includes high-performance multi-junction VCSEL arrays for short- to long-range mobility and industrial light detection and ranging (LiDAR) applications. The M Series, which includes the M51-100, is easily integrated into customer platforms and can replace edge-emitting lasers in existing mechanically scanned systems or be arrayed into configurable illumination sources for addressable, solid-state electronic scanning LiDAR systems, says the company.

In addition, Lumentum's portfolio of next-generation 3D sensing-enabling VCSEL solutions, including its 10W flood illuminator module, was featured in partnership displays at the Lumentum stand.

www.world-of-photonics.com/en

NREL raises one-sun solar cell efficiency record to 39.5%

Triple-junction cell exceeds efficiencies of record six-junction device

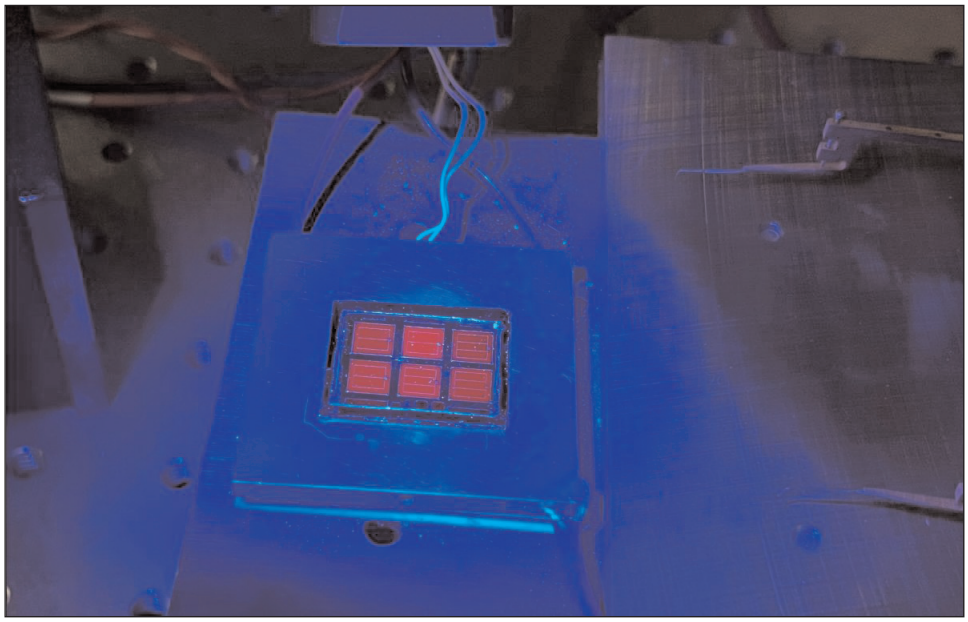
The US Department of Energy's National Renewable Energy Laboratory (NREL) has raised the efficiency record for solar cells (under standard one-sun global illumination) to 39.5% ('Triple-junction solar cells with 39.5% terrestrial and 34.2% space efficiency enabled by thick quantum well superlattices', Joule vol6, issue5 (18 May 2022), p1121). NREL previously set a record in 2020 with a 39.2%-efficient six-junction solar cell using III-V materials.

"The new cell is more efficient and has a simpler design that may be useful for a variety of new applications, such as highly area-constrained applications or low-radiation space applications," says Myles Steiner, a senior scientist in NREL's High-Efficiency Crystalline Photovoltaics (PV) Group and principal investigator on the project. He worked alongside NREL colleagues Ryan France, John Geisz, Tao Song, Waldo Olavarria, Michelle Young, and Alan Kibbler.

Several of the best recent solar cells have been based on the inverted metamorphic multi-junction (IMM) architecture that was invented at NREL. This newly enhanced triple-junction IMM solar cell has now been added to the Best Research-Cell Efficiency Chart, which shows the success of experimental solar cells, including the previous three-junction IMM record of 37.9% established in 2013 by Sharp Corp of Japan.

The improvement in efficiency followed research into quantum well solar cells, which utilize many very thin layers to modify solar cell properties. The scientists developed a quantum well solar cell with unprecedented performance and implemented it into a device with three junctions with different bandgaps, where each junction is tuned to capture and utilize a different slice of the solar spectrum.

The top junction is made of gallium indium phosphide (GaInP), middle junction of gallium arsenide (GaAs) with quantum wells, and the bottom junction of lattice-mismatched gallium indium arsenide (GaInAs). Each material has been highly optimized over decades of research.



The record solar cell shines red under blue luminescence. Photo: Wayne Hicks.

"A key element is that, while GaAs is an excellent material and generally used in III-V multi-junction cells, it does not have quite the correct bandgap for a three-junction cell, meaning that the balance of photocurrents between the three cells is not optimal," says France, senior scientist and cell designer. "Here, we have modified the bandgap while maintaining excellent material quality by using quantum wells, which enables this device and potentially other applications."

The NREL scientists used quantum wells in the middle layer to extend the bandgap of the GaAs cell and increase the amount of light that the cell can absorb. Importantly, they developed optically thick quantum well devices without major voltage loss. They also learned how to anneal the GaInP top cell during the growth process in order to improve its performance and how to minimize the threading dislocation density in lattice-mismatched GaInAs, discussed in separate publications. Altogether, these three materials inform the novel cell design.

III-V cells are known for their high efficiency, but the manufacturing process has traditionally been expensive. So far, III-V cells have been used to power applications such as space satellites, unmanned aerial vehicles (UAVs), and other niche applications. NREL has been working toward drastically reducing the manufacturing cost of III-V cells and providing alternate cell designs, which can make these cells economic for a variety of new applications, it is reckoned.

The new III-V cell was also tested for how efficient it would be in space applications, especially for communications satellites, which are powered by solar cells and for which high cell efficiency is crucial. Efficiency was 34.2% for a beginning-of-life measurement. The present design of the cell is suitable for low-radiation environments. Higher-radiation applications may be enabled by further development of the cell structure.

www.sciencedirect.com/science/article/abs/pii/S254243512200191X
www.nrel.gov/pv/cell-efficiency.html

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First Solar selling Japan project development and O&M platforms to PAG

Cadmium telluride (CdTe) thin-film photovoltaic (PV) module maker First Solar Inc of Tempe, AZ, USA has agreed for funds managed by PAG Real Assets (PAG) of Tokyo, Japan, to acquire its 293MW$_{DC}$ utility-scale solar project development platform, and a solar operations and maintenance (O&M) platform with about 665MW$_{DC}$ under management, in Japan. The transaction is expected to close in second-quarter 2022 for the project development platform and the second-half 2022 for the O&M platform, in each case after obtaining regulatory approvals, the receipt of third-party consents, and satisfying other customary closing conditions.

PAG is an Asia Pacific-focused private investment manager with more than $50bn in assets under management. Subject to closing of the project development platform acquisition, PAG is expected to add First Solar's project development platform to its existing portfolio of solar farms in Japan, creating one of Japan's largest renewable operators with over 600MW$_{DC}$ of capacity. In 2021, PAG acquired two projects being developed by First Solar in Japan with total capacity of 50MW$_{DC}$. Upon each respective closing, most of First Solar project development and O&M staff in Japan will join PAG.

"First Solar has an unmatched reputation in this region and we are pleased to have such an experienced, professional team join the PAG family," comments PAG's executive director & president Jon-Paul Toppino. "This transaction further positions PAG as a leading player in renewable energy in Japan and will serve as a key building block for our future investment in the sector," he adds.

"PAG's commitments to integrity, transparency and sustainability, and its experience managing and operating a wide range of assets, make it the ideal acquirer of our industry-leading platforms in Japan," believes First Solar's CEO Mark Widmar. "The sale of these platforms marks the completion of First Solar's strategic shift to focus on developing, scaling and selling our advanced module technology."

First Solar is the only US-based firm among the world's ten largest solar manufacturers. The firm is building two new manufacturing facilities in the USA and India, which will double its nameplate manufacturing capacity to 16GW$_{DC}$ in 2024.

www.pag.com
www.firstsolar.com

Scout orders 378MW of First Solar's PV modules

First Solarhas signed an agreement to supply 378MW$_{DC}$ of its CdTe photovoltaic solar modules to renewable energy developer and owner-operator Scout Clean Energy of Boulder, CO, USA (a portfolio company of Quinbrook Infrastructure Partners). The deal was booked prior to the release of First Solar's first-quarter 2022 earnings in April.

Scout has over 1200MW of operating assets, and is actively developing a portfolio over 12,000MW of solar PV, battery storage and onshore wind projects spread across 21 US states. The firm plans to use the First Solar modules to begin construction on several late-stage projects, with the start of operations expected in 2024.

"We continue to develop and grow our portfolio of solar PV assets across the US," says Scout's founder & CEO Michael Rucker. "This deal reflects our confidence not just in the technology, but in First Solar itself. Sourcing our modules from a US-based supply partner at this challenging time solidifies our competitive advantage in meeting our customers' urgent timing needs for solar power to meet their decarbonization goals," he adds. "As we diversify Scout's asset base and grow our solar portfolio, we want to source our panels through partners that we can trust to deliver with no compromise on quality, ethical sourcing of raw materials and who is committed to ongoing innovation. First Solar readily satisfies those critical criteria for Scout."

"Experienced developers like Scout Clean Energy understand the criticality of both insulating themselves from pricing and supply volatility, and staying true to their values and principles," comments Adam Smith, VP, global business development, First Solar. "They also recognize the value of technological and supply diversity, and of a competitive product that embodies sustainability and transparency," he adds. "Together, these factors are invaluable in helping them navigate some of the headwinds that others in the industry struggle with."

First Solar is investing $680m in expanding America's domestic PV solar manufacturing capacity by 3.3GW annually by building its third US manufacturing facility in Lake Township, Ohio. The new facility is expected to be commissioned in first-half 2023 and, when fully operational, will scale the company's Northwest Ohio footprint to a total annual capacity of 6GW (making it the largest fully vertically integrated solar manufacturing complex outside China). First Solar has invested over $2bn in its US manufacturing footprint and, when its third factory is fully operational, will directly employ over 2500 people in Ohio, while supporting an estimated 15,000 indirect jobs through its American supply chain.

Rio Tinto starts tellurium production in Utah

Global mining group Rio Tinto has started producing tellurium at its Kennecott copper operation in Utah, becoming one of only two US producers of the mineral. Tellurium is listed as a critical mineral by the US Government due to its importance to the economy and energy security.

About 20 tons of tellurium will be produced annually through a new $2.9m circuit built at the Kennecott refinery. The material is recovered from by-product streams generated during the copper refining process, reducing the amount of waste that needs to be treated and discarded as mine tailings.

"We are proud to deliver a new domestic supply of tellurium to support the manufacturing of solar panels and other critical equipment here in the United States," says Rio Tinto Copper chief operating officer Clayton Walker. "About 90% of the world's tellurium resource is contained in copper ore and no other metal has more critical mineral by-products than copper. The Kennecott team is constantly looking for ways to extract new critical minerals to meet emerging demand for the clean energy transition," he adds.

Tellurium is one of ten metals and products recovered from ore extracted at Kennecott, which produces nearly 15% of US copper with the country's lowest carbon footprint.

Rio Tinto is partnering with the US Department of Energy's Critical Materials Institute (CMI) to discover further ways to economically recover critical minerals such as tellurium and lithium. The firm is also investing in new facilities to extract battery-grade lithium from waste rock at its Boron mine site in California and high-quality scandium oxide from waste streams at its metallurgical complex in Sorel-Tracy, Quebec.

www.riotinto.com
www.5nplus.com

5N Plus partners with Rio Tinto to refine tellurium

Tellurium to be refined by 5N Plus for First Solar's CdTe PV panels

Specialty semiconductor and performance materials producer 5N Plus Inc of Montreal, Québec, Canada has reached a commercial agreement to take the tellurium produced at Rio Tinto's Kennecott copper operation in Utah and refine it, for use primarily in the manufacturing of cadmium telluride (CdTe) thin-film photovoltaic (PV) modules by First Solar Inc of Tempe, AZ, USA under an existing semiconductor supply agreement between First Solar and 5N Plus. 5N Plus has been a key supplier to First Solar since 2007.

First Solar is expanding its US manufacturing capacity by 3.3GW annually, by building its third American manufacturing facility in LakeTownship, Ohio. When fully operational, the new facility will scale the firm's Northwest Ohio footprint to a total annual capacity of 6GW (making it the largest fully vertically integrated solar manufacturing complex outside of China, it is believed).

The tellurium will also be used to manufacture ultra-high-purity semiconductor substrates at 5N Plus' facility in St. George, Utah, USA to serve clients in the security and medical imaging markets.

"Our intention is to continue to pursue such strategic partnerships for the sourcing and refining of critical minerals in North America to the benefit of the critical industries we serve," says 5N Plus' president & CEO Gervais Jacques.

"This agreement with 5N Plus is an important step towards securing a North American supply chain of critical minerals to support the clean energy transition," says Clayton Walker, chief operating officer of Rio Tinto Copper. "We are proud to deliver a new supply source of tellurium for the manufacturing of solar panels and other high-tech equipment, in addition to our primary copper production," he adds.

This agreement is an important step towards securing a North American supply chain of critical minerals to support the clean energy transition. Our ability to refine additional tellurium is made possible by our investment to expand the capacity of our Montreal campus

"Our ability to refine additional tellurium for applications in the renewable energy industry is made possible by our investment to expand the capacity of our Montreal campus," notes Jacques. "Coupled with our new partnership with Rio Tinto, this allows us to accelerate our semiconductor development and manufacturing activities in North America and to further leverage our globally recognized expertise in the transformation of mining and metallurgical by-products into high-purity value-added critical minerals."

In June 2021, 5N Plus announced a major investment in its Montreal campus to expand the development and manufacturing of high-purity tellurium-bearing II-VI semiconductor compounds and substrates, essential components for several critical industries (including renewable energy). The project is expected to be completed by mid-2022.

www.5nplus.com

Microcavity QCL in CW operation at +5°C

Potential applications include photonic ICs and sensing outside the laboratory.

China's Institute of Semiconductors claims the first continuous wave (CW) operation of microcavity quantum cascade lasers (QCLs) up to a temperature of 5°C at an emission wavelength of 8μm [Qiangqiang Guo et al, ACS Photonics, volume 9 (2022), issue 4, p1172].

The researchers comment: "The CW operating temperature far exceeds the freezing point and makes it possible to produce portable systems for use outside a laboratory environment." The team sees prospects for use in photonic integrated circuits, on-chip sensing and microcavity frequency combs.

The researchers fabricated QCL material from solid-source molecular beam epitaxy on indium phosphide (InP) into high quality factor (Q) notched elliptical whispering gallery mode (WGM) electromagnetic (EM) resonators (Figure 1).

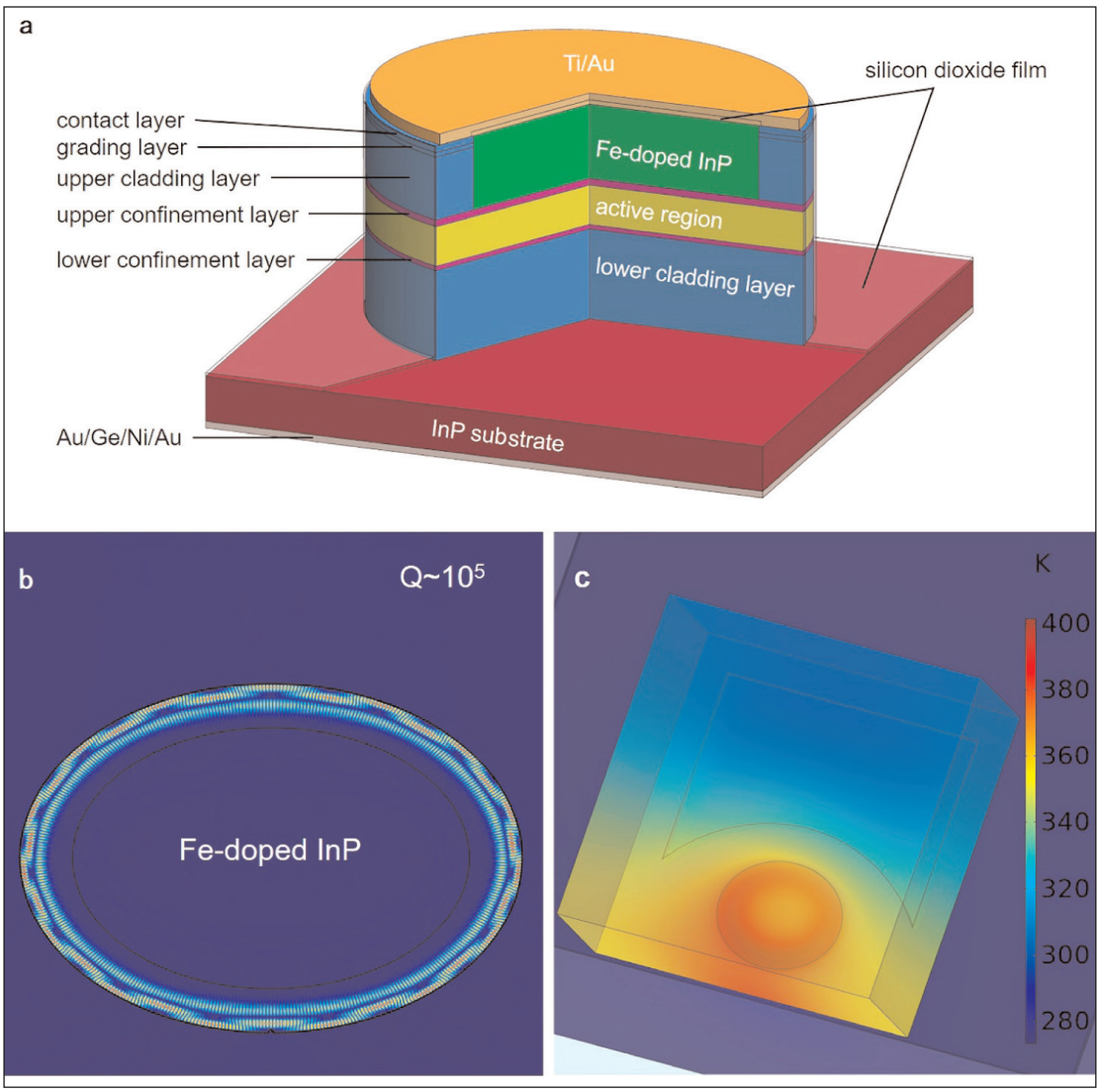

Figure 1. Structure and design of CW microcavity QCL: (a) schematic; (b) calculated mode distribution; (c) simulated three-dimensional temperature profiles.

The 40-stage QCL consisted of layers of indium gallium arsenide (InGaAs) and indium aluminium arsenide. InGaAs was also used for optical confinement.

Since the excited EM modes are concentrated at the periphery of the structure, electrical isolation was introduced in the middle of the structure in the form of semi-insulating InP produced through iron (Fe) doping. The researchers explain: "This reduces the overall injection current, thereby reducing the operating temperature in the active region. Theoretically, this design can eliminate the most unnecessary thermal dissipation, which is the primary limiting factor for CW operation of microcavity QCLs, and simultaneously provide a horizontal channel for the heat dissipation in the active region."

The Fe-doped InP, produced by wet etching to the upper confinement layer and regrowth, was also close in refractive index to the cladding layers. The sidewalls of the device were optionally passivated with silicon dioxide to suppress leakage current through thermally activated surface states.

The ellipse's aspect ratio was 1.2 with a semi-minor axis length of 80μm. The wavelength-scale notch — 2.5μm width, 1.6μm depth – was located at the intersection of the minor axis with the boundary.

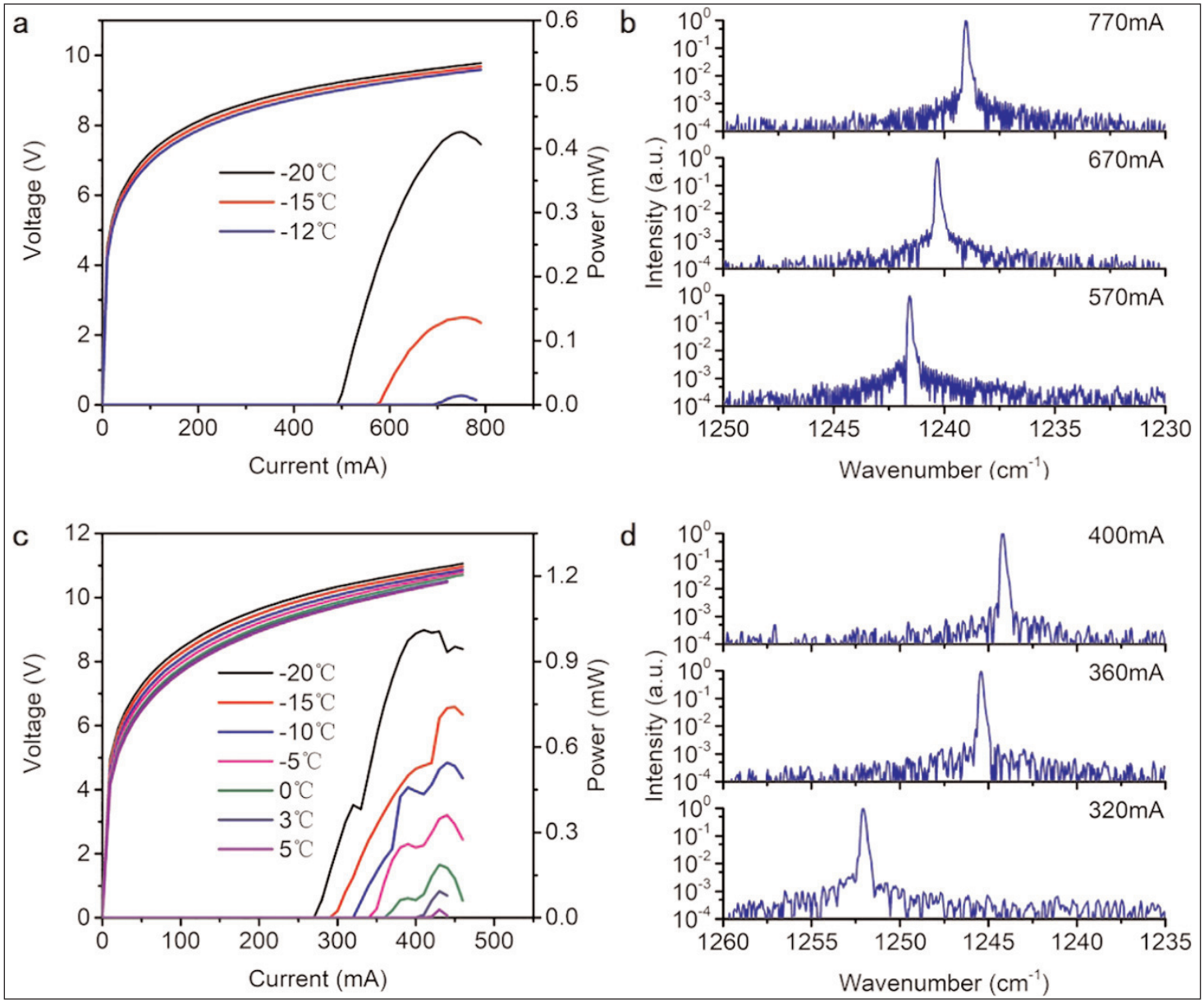

Figure 2. Electrical and optical characteristics of devices with surface passivation in CW operation: (a, c) measured power-current-voltage characteristics versus heat sink temperature (a) without and (c) with electrical isolation; (b, d) CW spectra at –20°C versus pumping current corresponding to panels (a) and (c), respectively.

The Fe-doped InP material had a 65μm semi-minor axis.

The electrical isolation scheme was found to more than double the slope efficiency in pulse-mode operation. Passivating the devices with silicon dioxide severely reduced peak output power and increased the threshold current. This was attributed to high optical loss of the passivation at wavelengths above 7μm. The output wavenumber was around 1250/cm, which corresponds to 8μm wavelength.

In CW operation (Figure 2) the side-mode suppression ratio (SMSR) was around 30dB. Devices with electrical isolation and surface passivation were able to operate at temperatures up to +5°C. The thermal conductance of this device, 729.8/cm^2-K, was much higher than for one without the electrical isolation, 276.9/cm^2-K, in line with the simulations carried out to design the lasers.

The CW threshold current was reduced by 40% when electrical isolation measures were taken. "This surprising result is due to the reduction of unnecessary heat dissipation power brought about by the electrical isolation, which effectively reduces the operating temperature of the active region," the team comments.

The wavenumber distance between modes was about 5.42/cm, again close to the simulation result of 5.53/cm. A mode hop was observed in the spectrum of the device with electrical isolation. This creates corresponding kinks in the light output power behavior. ■

https://doi.org/10.1021/acsphotonics.1c01437

Author: Mike Cooke

UV-C LEDs with external quantum efficiency up to 8%

Achieving improved performance from growth on 'face-to-face' annealed sputtered AlN templates on sapphire.

Researchers in Japan have used 'face-to-face' annealed (FFA) sputtered AlN (Sp-AlN) templates on sapphire to fabricate 263nm ultraviolet-C (UV-C) light-emitting diodes (LEDs) with state-of-the-art external quantum efficiency (EQE) [Kenjiro Uesugi et al, Appl. Phys. Express, v15, p055501, 2022].

The team from Mie University, Osaka University and University of Tokyo comments: "To the best of our knowledge, the developed UV-C LED has the highest EQE at a wavelength of approximately 265nm, even considering the state-of-the-art devices fabricated on sapphire substrates and free-standing AlN substrates."

UV-C LEDs are sought to replace bulky, fragile and hazardous mercury lamps used for sterilization and virus inactivation, needing wavelengths shorter than 300nm. Presently, UV-C LEDs have low EQEs of less than 10%. The reported LEDs achieved EQEs up to 8% when the devices were suitably packaged and encapsulated.

The team has previously used its FFA Sp-AlN growth technique to reduce threading dislocation densities (TDDs) by an order of magnitude to $4x10^7/cm^2$.

The Sp-AlN was deposited on sapphire substrate with a 0.2° off-angle in the m-direction. Two samples were grown at 700 and 750°C, respectively.

The wafers were subject FFA at 1600–1700°C for 36 hours. The FFA arrangement involves placing two wafers with the two AlN surfaces in contact 'face-to-face', avoiding thermal decomposition of the AlN at such high temperature in nitrogen at atmospheric pressure.

The resulting FFA Sp-AlN layer was 600nm thick. This was followed by metal-organic vapor phase epitaxy (MOVPE) of 200nm AlN and 300nm unintentionally doped $Al_{0.7}Ga_{0.3}N$. Life being what it is, the reduced threading dislocation density of the underlying AlN leads to increased fractions of screw- and mixed-type dislocations that present as "excessively large" hillock structures on the wafer surface (Figure 1).

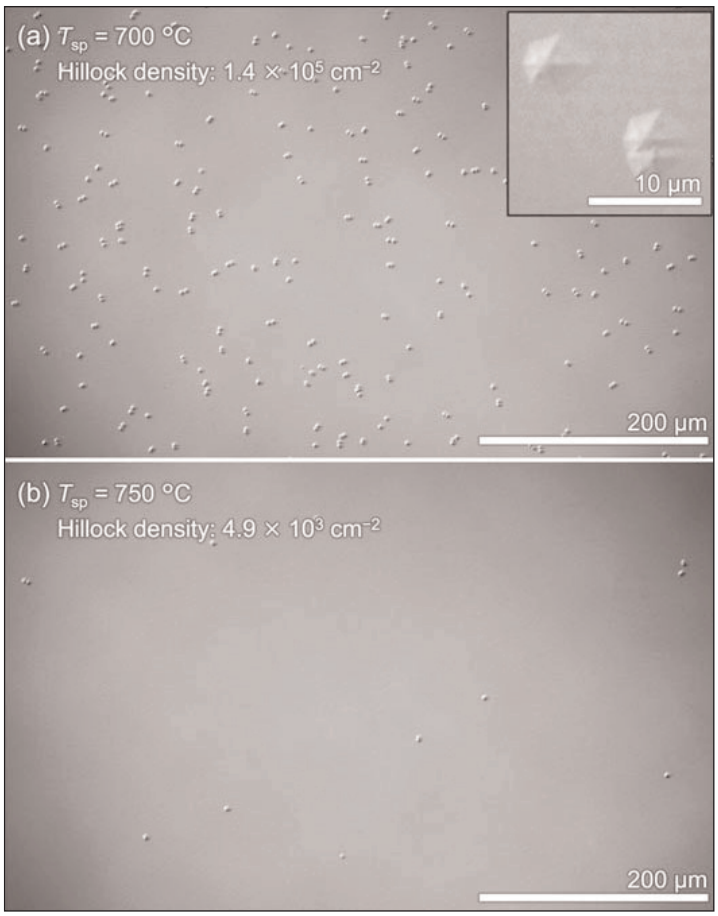

Figure 1. Nomarski microscopy images of 300nm-thick $Al_{0.7}Ga_{0.3}N$ films grown on FFA Sp-AlN fabricated at sputter-deposition temperature of (a) 700°C, (b) 750°C. Inset: magnified image of typical hillock structures.

Contact	GaN:Mg	150nm
Graded p-type	$Al_{0.95-0.40}Ga_{0.05-0.60}N$:Mg	15nm
Electron-blocking	AlN	7nm
MQW	$3x(Al_{0.44}Ga_{0.56}N/Al_{0.69}Ga_{0.31}N)$	3x(2.0/3.6nm)
Current-spreading	$Al_{0.77}Ga_{0.23}N$:Si	1.2μm
Graded buffer	UID-$Al_{1-0.77}Ga_{0-0.23}N$	100nm
Buffer	AlN	600nm
Template	FFA Sp-AlN	

Figure 2. MOVPE layer sequence.

The hillock density was affected by the sputter temperature: $1.4x10^5/cm^2$ and $4.9x10^3/cm^2$ on AlN sputtered at 700°C and 750°C, respectively. Clearly, the higher sputtering temperature is preferred. Previous FFA Sp-AlN grown at 600°C resulted in an even higher hillock density of $\sim10^6/cm^2$.

The researchers comment: "The occurrence of lower screw- and mixed-type FFA Sp-AlN dislocation densities at higher deposition temperatures can be attributed to the improvement in the c-axis orientational ordering of the AlN film in the as-sputtered state."

Working toward LED structures, the researchers then grew 1µm silicon-doped (:Si) $Al_{0.75}Ga_{0.25}N$ on FFA Sp-AlN by MOVPE. The researchers studied the effects of MOVPE growth temperature, rate, and ammonia/hydrogen (NH_3/H_2) partial pressures on the AlGaN:Si surface morphology. To maintain the Al content of the layer at 75%, the researchers also varied the trimethyl-Al/Ga precursor supply to compensate.

The study showed that the interest of low hillock density was achieved through high temperature (1100°C) and low growth rate (0.5µm/h), along with high NH_3 partial pressure (10kPa). The effect of H_2 partial pressure was insignificant. The optimized conditions reduce the difference in growth rates between the regions near and far from the screw dislocations.

The researchers comment: "Notably, the hillock density was independent of the MOVPE growth conditions for AlGaN, as it was determined by the density of the screw- and mixed-type dislocations in the FFA Sp-AlN template."

The condition for reducing hillocks had the unfortunate effect of meandering step growth and pit formation. This was tackled with a 1050°C low-temperature 100nm AlGaN:Si interlayer before growing the UV-C LED structure.

The template for the UV-C material was FFA Sp-AlN sputtered at 750°C and annealed for 51 hours at 1600–1680°C. The MOVPE layer sequence (Figure 2) included a multiple quantum well (MQW) consisting of three well/barrier pairs grown at 1050°C. The MQW was given a low silicon doping concentration of $3–5x10^{17}/cm^3$, designed to reduce non-radiative recombination center density.

The 1.2µm n-type, silicon-doped current-spreading layer was mostly grown at 1150°C, except for the last 100nm grown at 1050°C.

X-ray analysis of the material suggested a hillock density of $7.2x10^3/cm^2$. The researchers comment: "These values are the state-of-the-art low TDDs among the Al(Ga)N grown on sapphire substrates."

LEDs were fabricated with nickel/gold p-electrodes and titanium/aluminium/nickel/gold n-electrodes. The sapphire substrate was thinned and polished to 150µm. The 400µmx300µm dies were singulated through laser scribing.

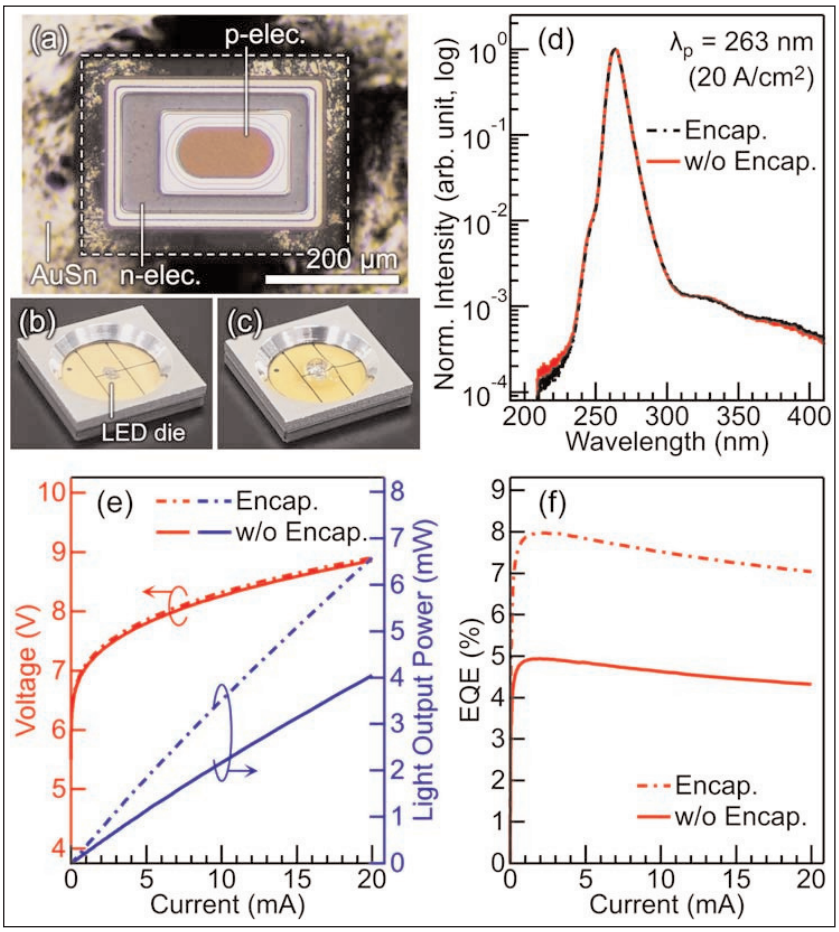

Figure 3. (a) Optical microscope image of as-mounted UV-C LED bare die in ceramic package. Dashed rectangle: edge of die. Photographs of packaged UV-C LEDs: (b) without and (c) with encapsulation. (d) Electroluminescence spectra. (e) Current–voltage–light output power, and (f) EQE results.

The chips were packaged flip-chip mounted on a 6.8mmx6.8mm sized AlN-based container-type ceramic package with gold-tin eutectic bonding and Al reflector (Figure 3). Some of the devices were encapsulated in UV-transparent silicone resin composed of poly(dimethylsiloxane) and poly(diethoxy-siloxane).

The emitted UV-C radiation's peak wavelength was 263nm. Without encapsulation the external quantum efficiency reached 4.9% at 2.0mA injection current. Encapsulation increased the peak EQE to 8.0% at 2.9mA. The corresponding output powers at 20mA were 4.0 and 6.6mW, respectively. The researchers estimate the light extraction efficiency enhancement from encapsulation at 1.6x.

The high EQEs are attributed to improved internal quantum efficiency and, possibly, carrier injection efficiency. "The uniform thickness and AlN-molar fraction of the MQWs, AlN-EBL, and p-type AlGaN:Mg are attributable to the suppressed undesirable current crowding and overflow," the team writes. ■

https://doi.org/10.35848/1882-0786/ac66c2

Author: Mike Cooke

High-Al-content p-AlGaN with 17.5meV activation energy

Using a superlattice p-contact structure results in 57% more light output power from a 280nm-wavelength deep-UV LED at an injection current of 100mA.

Peking University in China has improved the p-type behavior of high-aluminium-content aluminium gallium nitride (AlGaN) superlattices (SLs) and used the technique to improve the light output power and efficiency of 280nm-wavelength deep ultraviolet (DUV) light-emitting diodes (LEDs) [Jiaming Wang et al, Light: Science & Applications v11, p71, 2022].

The researchers comment: "It is expected that this study provides a solution for p-doping in Al-rich AlGaN, and it sheds light on solving the doping asymmetry issue in general for wide-gap semiconductors, especially for ternary and quaternary compound semiconductors."

Normally, p-type AlGaN has extremely low hole concentration and hole mobility due to the very high activation energy. This makes it difficult to create effective LEDs with holes combining with electrons from high-electron-concentration n-type AlGaN to produce photons. Asymmetry of doping ease is common in wide-bandgap semiconductors: n-type doping is much easier than p-type in III–nitrides and zinc oxide, while the reverse is the case for diamond (carbon).

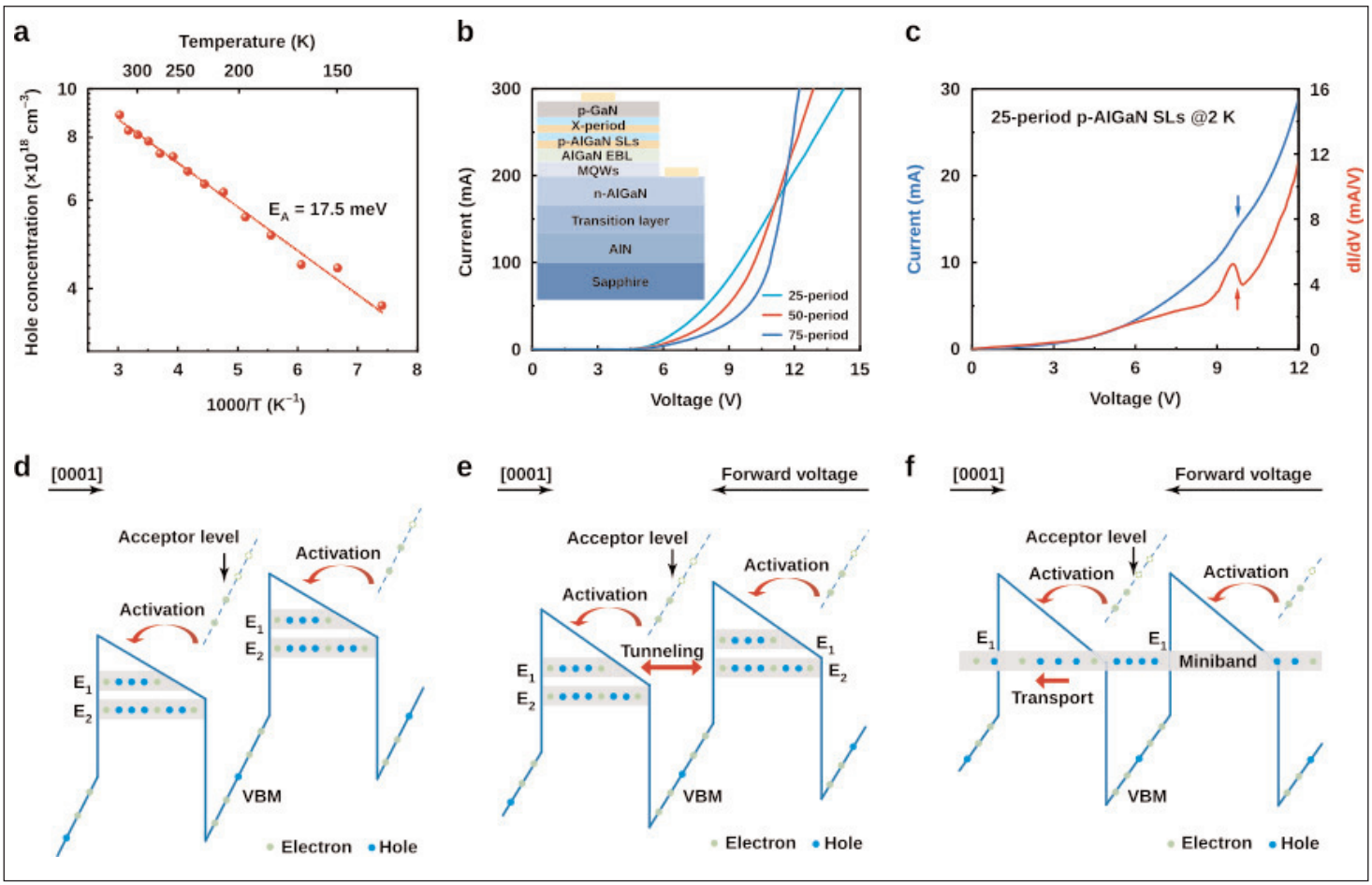

Figure 1. Electrical properties of desorption-tailored Al-rich p-AlGaN SLs. (a) Temperature dependence of hole concentration. (b) Current–voltage (I–V) curves at room temperature of DUV-LED structures (inset) with p-AlGaN SLs period numbers of 25, 50 and 75, respectively. (c) I–V and corresponding dI/dV curves at 2K of DUV-LED structure with 25-period p-AlGaN SL. (d) Upward inclining of p-AlGaN SL energy (valence-band maximum, VBM) band profile along [0001] direction at equilibrium. (e) Resonant tunneling between E1 and adjacent E2 with flattened profile along [0001] direction under forward voltage. (f) Formation of minibands at even higher forward voltage.

Periodic interruption of the metal supply to the metal-organic chemical vapor deposition (MOCVD) growth process was used to create the AlGaN SLs. The metal-organic sources were trimethyl-Ga and -Al. The nitrogen precursor was ammonia (NH_3).

The interruption results in a desorption phase where the material left behind exhibits a relative increase in aluminium content since Al atoms have a higher binding energy to N than Ga. Z-contrast scanning transmission electron microscope (STEM) analysis showed the higher-Al-content layer as consisting of 3 monolayers (MLs) of material, or about 0.75nm thickness. The researchers managed to achieve similar results for a range of base Al content AlGaN in the range 15–80% by varying the growth temperature in the range 1040–1160°C with desorption time in the range 20–100s.

Having understood the capability of the periodic interruption process, the team moved on to p-type doping with Mg. The base AlGaN material used an epitaxy process with 32s metal supply and 100s desorption, resulting in low (well)- and high (barrier)-Al-content layers of 7 and 3MLs, respectively. Energy-dispersive x-ray spectroscopy (EDS) mapping gave the respective Al contents of the layers at 46% and 63%, giving a 51% average. The doping occurred during the desorption phase of the growth using bis(cyclopentadienyl)Mg (Cp_2Mg). This was found to enhance incorporation on metal sites in the lattice, since there was no Al or Ga competition.

The Mg concentration in the $Al_{0.63}Ga_{0.37}N$ barrier layers was more than $1x10^{19}/cm^3$. The measured hole concentration in the SL was $8.1x10^{18}/cm^3$, claimed as "one of the highest values for Mg-doped Al-rich AlGaN reported to date". Temperature-dependent studies suggested an effective activation energy for the Mg doping of 17.5meV, much lower than the usual >200meV values (Figure 1). It was also lower than the energy associated with 300K 'room temperature' of 26meV.

The researchers comment: "It is inferred that the reduction of the effective activation energy is attributed to the modulation of the hole activation path." They continue: "Owing to the polarization-induced band bending in p-AlGaN SLs, the acceptor level in the barriers is quite close to the sub-band level in the wells, which then provides an energetically favorable path for the activation of Mg."

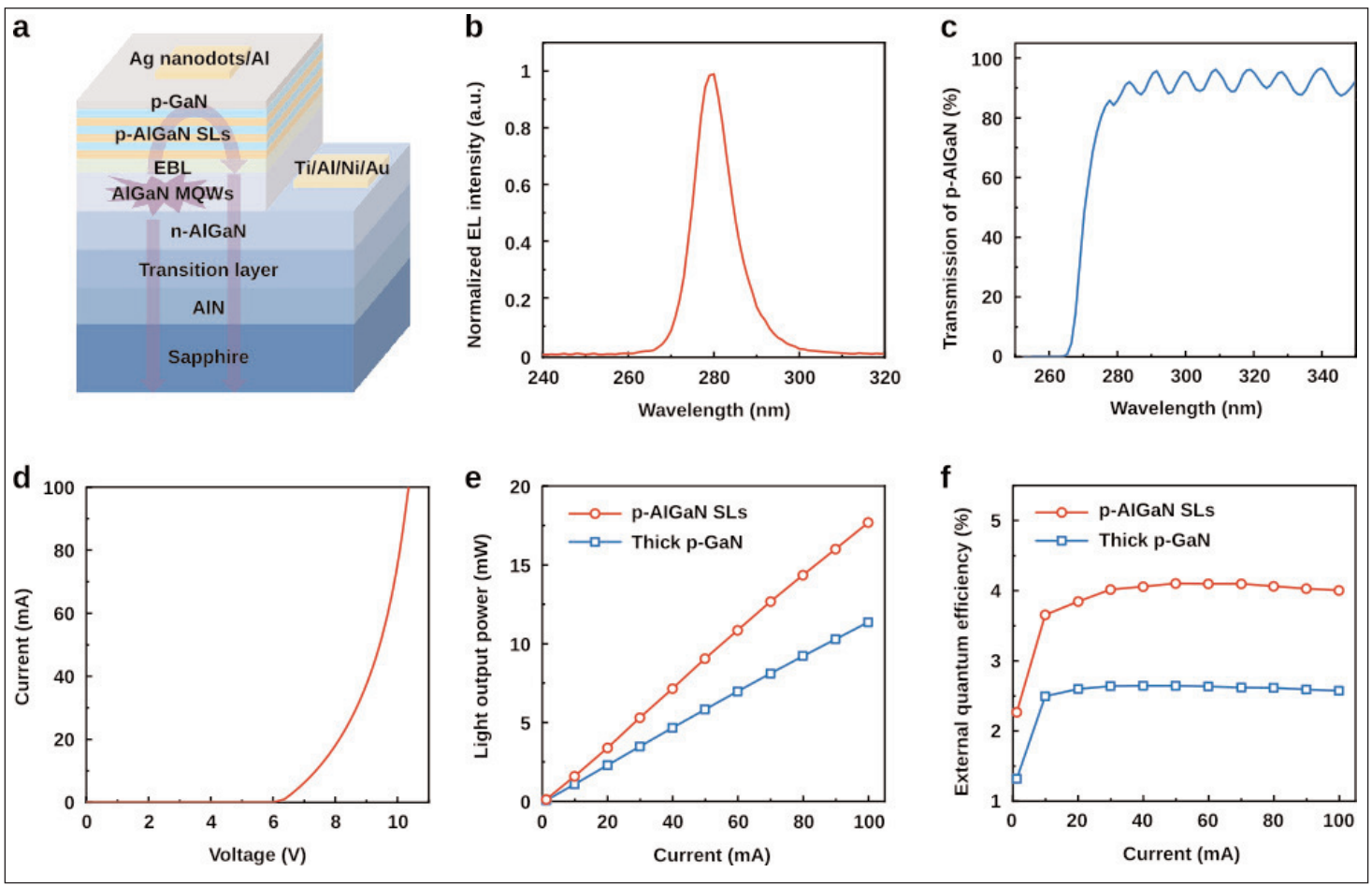

Figure 2. Performance of DUV-LEDs fabricated with desorption-tailored Al-rich p-AlGaN SLs. (a) Schematic. (b) Electroluminescence spectrum (at 100mA) of DUV-LEDs. (c) Transmission spectrum of desorption-tailored p-AlGaN SLs (without p-GaN contact layer). (d) I–V curve of DUV-LEDs with p-electrode of complex silver nanodots/Al. (e, f) Dependence of light output power and EQE on injection current for DUV-LEDs.

In terms of current-voltage performance, the devices begin to turn on around 5V with a thinner 25-period SL structure delivering more current for a given voltage early on but, as the voltage reaches 9–11V, the thicker SLs have higher injection. The researchers explain the behavior by invoking band-flattening, resonant-tunneling, and miniband-formation effects as the voltage increases.

From analysis of the derivative behavior (dI/dV), the researchers estimate the series resistances of the three studied samples at 22.7Ω, 11.9Ω and 3.8Ω for 25, 50 and 75 periods, respectively. The team write: "The inverse relationship between series resistance and SLs period (thickness) indicates a true miniband transport in SLs, where the miniband width plays a leading role." With a higher numbers of layers, the miniband is expected to become wider, resulting in higher mobility and lower series resistance.

A very low-temperature (2K) study of the 25-period structure showed a peak-valley behavior above 9V in differential conductance (dI/dV), which the researchers label "negative differential resistance", suggesting resonant tunneling. A p-GaN replacement of the AlGaN SL shows no such peak. The miniband forms when all the energy levels come into alignment. The equilibrium V=0 band profile is tilted due to charge polarization effects from the partly ionic nature of the metal–nitrogen bonds.

The researchers used the p-AlGaN superlattices on multiple quantum well (MQW) light-emitting regions to produce 280nm-wavelength DUV-LEDs (Figure 2).

Using AlGaN rather than GaN for the p-contact could also be beneficial in terms of greater transparency to the target DUV light. The ~3.4eV bandgap of GaN corresponds to a photon wavelength around 365nm, meaning that wavelengths shorter than that (e.g. 280nm) are strongly absorbed by excitation of electrons from the valence band to the conduction band.

The researchers used a reflective p-electrode consisting of silver nanodots in aluminium on a thin 8nm p-GaN contact layer so that the light could be collected from the side of the sapphire substrate. The turn-on voltage was 6.2V. The devices were encapsulated in a hemispherical lens structure.

At 100mA injection current, the light output power reached 17.7mW, a 57% improvement on devices with a thick p-GaN contact layer. The external quantum efficiency (EQE) reached 4.1%.

The researchers comment: "Through comparative analysis, the enhancement of the light extracting efficiency (LEE) contributes about two-thirds of the performance improvement, while the rest is from the enhancement of the carrier injection efficiency (CIE)."

https://doi.org/10.1038/s41377-022-00753-4

Author: Mike Cooke

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Gallium oxide on strontium titanate

Epitaxial growth on strontium titanate could lead to the seeding of thicker layers of Ga_2O_3 for high-power electronics and UV optoelectronics on silicon.

Researchers based in USA have demonstrated successful epitaxial integration of β-polytype gallium oxide (β-Ga_2O_3) on a strontium titanate ($SrTiO_3$ or STO) surface [Tobias Hadamek et al, J. Appl. Phys., v131, p145702, 2022]. The growth was demonstrated for STO in the form of either bulk material or a buffer layer on silicon (Si).

Ga_2O_3 is an ultra-wide-bandgap material with potential for high-power electronics and ultraviolet (UV) light detection. The material is transparent to visible light, offering solar-blind UV capability. The researchers also point to microwave switching and amplification as a possibility.

The ~5eV bandgap corresponds to a wavelength of 250nm in the deep UV range (<300nm) and UV-C (200–280nm), making it transparent to softer UV-A (315–400nm) and UV-B (280–315nm) electromagnetic radiation.

For high-power electronics, the high theoretical breakdown field of about 8MV/cm is extremely attractive, if it can be approached in practice.

The team from University of Texas at Austin, Arizona State University, and Staib Instruments Inc, comments: "The epitaxial integration of Ga_2O_3 with silicon serves as a template layer for subsequent fast deposition methods and could enable the fabrication of large-area wafers that, in turn, could advance Ga_2O_3-based technologies."

The researchers see their epitaxial β-Ga_2O_3 on STO being used as a seed layer for further epitaxial growth. Particularly interesting is where STO is used as a buffer layer on silicon wafers.

Although bulk Ga_2O_3 is commercially available in wafers up to 4-inch diameter, silicon wafers can be as large as 12-inches (300mm). An STO buffer prevents silicon oxidation and reaction between Ga_2O_3 and silicon during growth, which is a problem for direct Ga_2O_3 growth on silicon.

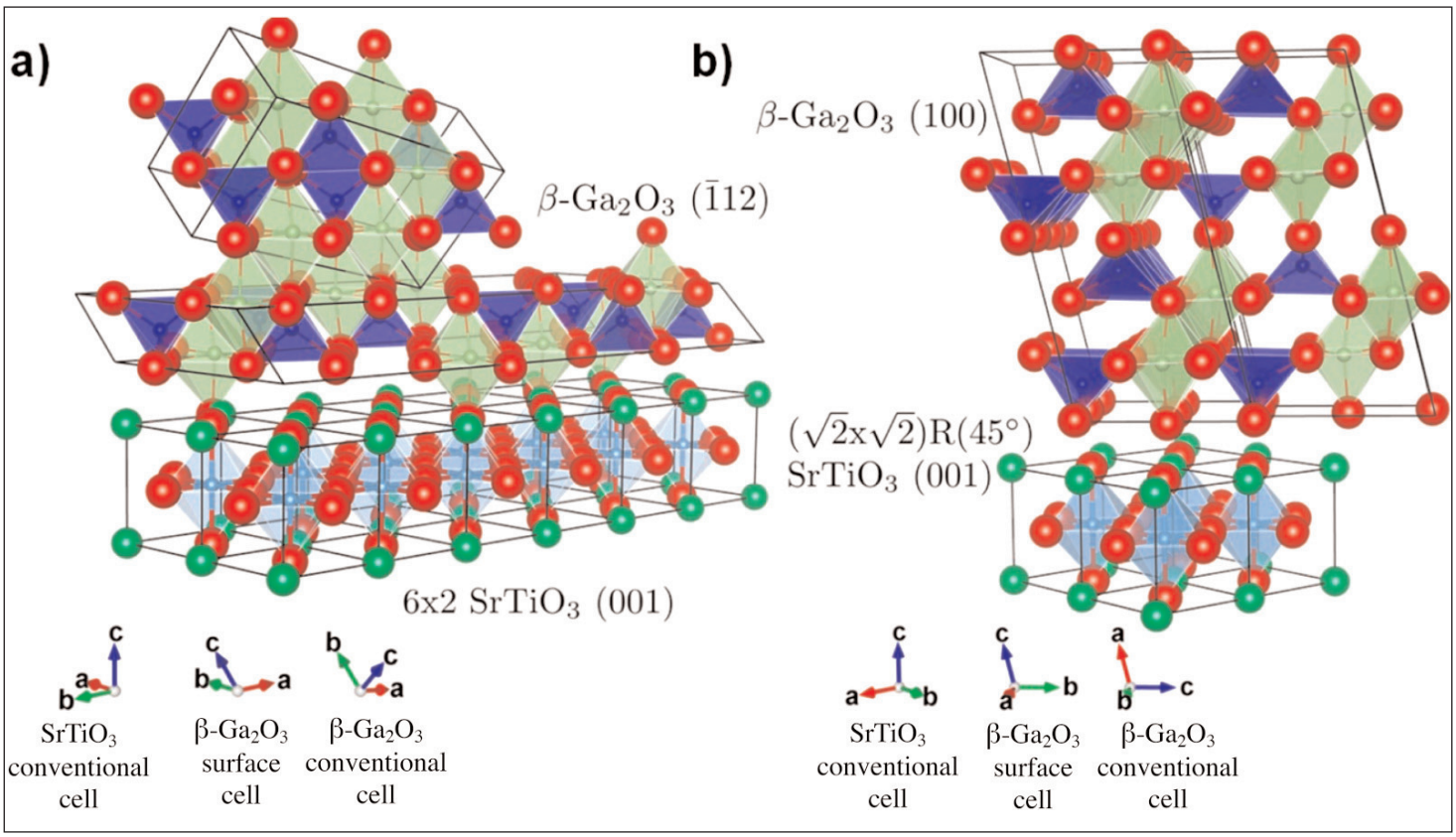

Figure 1. Lattice matching illustrated for (a) β-Ga_2O_3 ($\bar{1}12$) and (b) (100) surface-oriented cells placed on top of STO (001).

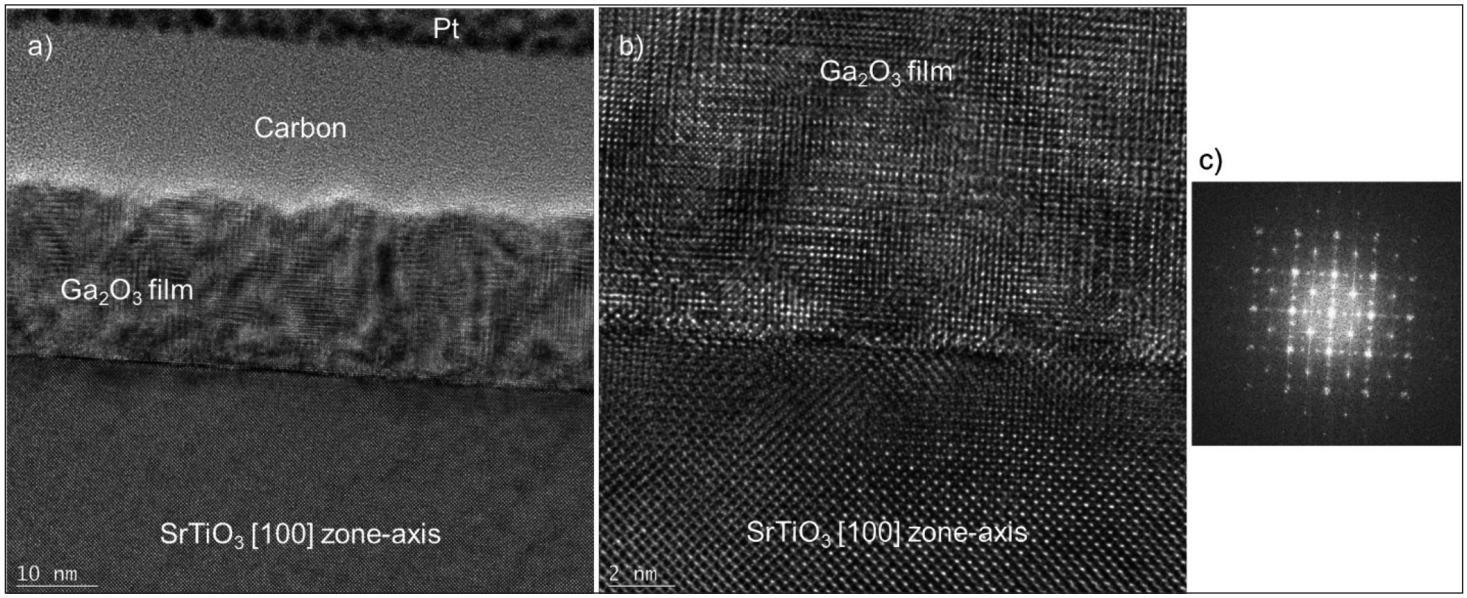

Figure 2. (a) Low-magnification TEM image of 20nm Ga_2O_3 film along [100] zone-axis of STO. (b) High-magnification TEM image. (c) Fast-Fourier-transform of image in (b); spots originating from Ga_2O_3 thin film are consistent with model obtained from XRD.

Another disadvantage of bulk Ga_2O_3 substrates is the low thermal conductivity (0.1–0.3W/cm-K), particularly for high-power systems where one expects significant Joule heating that needs to be dissipated effectively.

The researchers used plasma-assisted molecular beam epitaxy (PAMBE) on 10mm STO bulk and 2-inch STO-buffered silicon substrates. The growth temperature was 775°C at the silicon carbide heater coil, corresponding to a silicon substrate temperature of ~670°C. The STO was treated with oxygen plasma before the growth of Ga_2O_3. Before that, the surface was cleaned and rinsed in de-ionized water, resulting in a TiO_2-terminated surface.

The deposited material contained 5–10nm crystal grains of β-Ga_2O_3. "Small crystal grains result from the symmetry and the lattice mismatch between the film and the substrate," the team explains.

The Ga_2O_3 was found to be crystalline as-grown, unlike with metal-organic chemical vapor deposition (MOCVD). There were two main grain orientations, according to x-ray diffraction (XRD) analysis: (100) and ($\bar{1}$12) parallel to the (001) orientation of the STO (Figure 1). The team estimates the (100) volume fraction to be about three times that of ($\bar{1}$12). Both orientations were found to also have four in-plane rotational domain variants.

These findings were also based on measurements from reflection-high-energy electron diffraction (RHEED), reflection electron-energy-loss spectroscopy (REELS), and transmission electron microscopy (TEM) — see Figure 2 — along with density functional calculations and other measurements. ■

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Author: Mike Cooke

Speedy, durable, retentive GaN non-volatile memory

Researchers use a bipolar junction barrier to reduce degradation stresses.

Hong Kong University of Science and Technology (HKUST) reports on a gallium nitride (GaN) non-volatile memory (NVM) with good speed, retention and endurance at the same time [Tao Chen et al, IEEE Electron Device Letters, volume 43, issue 5 (May 2022), p697]. In silicon-based NVMs there tends to be a trade-off in these characteristics, creating a manufacturing 'trilemma' due to the use of Fowler–Nordheim tunneling across a tunnel oxide (TO) to change the memory state.

The researchers comment: "This work shows that the mainstream GaN-on-Si platform can also accommodate high-performance non-volatile memory devices in addition to the power and radio frequency (RF) devices, to enable highly intelligent electronic systems."

The device integrated a p-channel field-effect transistor (p-FET) with p-i-n heterojunction diode. The p-FET consisted of aluminium oxide (Al_2O_3) gate insulator on p-GaN.

The charge storage for the memory function occurred at the Al_2O_3/p-GaN interface. While in normal transistors one doesn't want interfacial trap states, for the memory function they are specifically created.

A depletion region forms at the Al_2O_3/p-GaN junction (J1) isolating the charge storage layer (CSL) from the holes in the p-channel of the FET structure.

The memory state can be changed by hole injection from the p-channel or electron injection from the diode (J2), consisting of aluminium gallium nitride between GaN layers (p-GaN/AlGaN/GaN). In particular, a

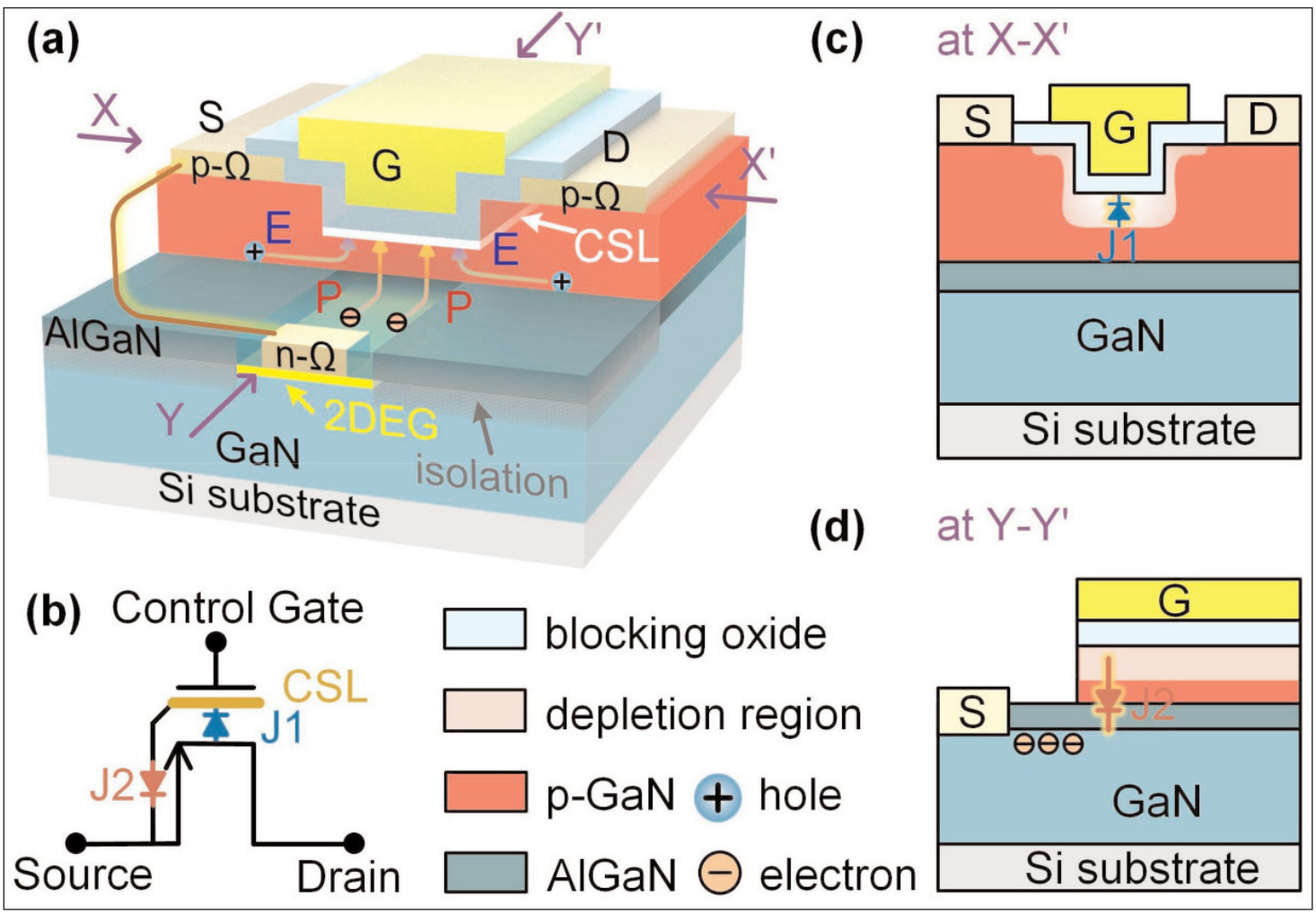

Figure 1. Schematics of GaN-based TO-free BJB memory device: (a) perspective view; (b) circuit symbol; cross-sectional view of (c) cutline X–X' and (d) cutline Y–Y'.

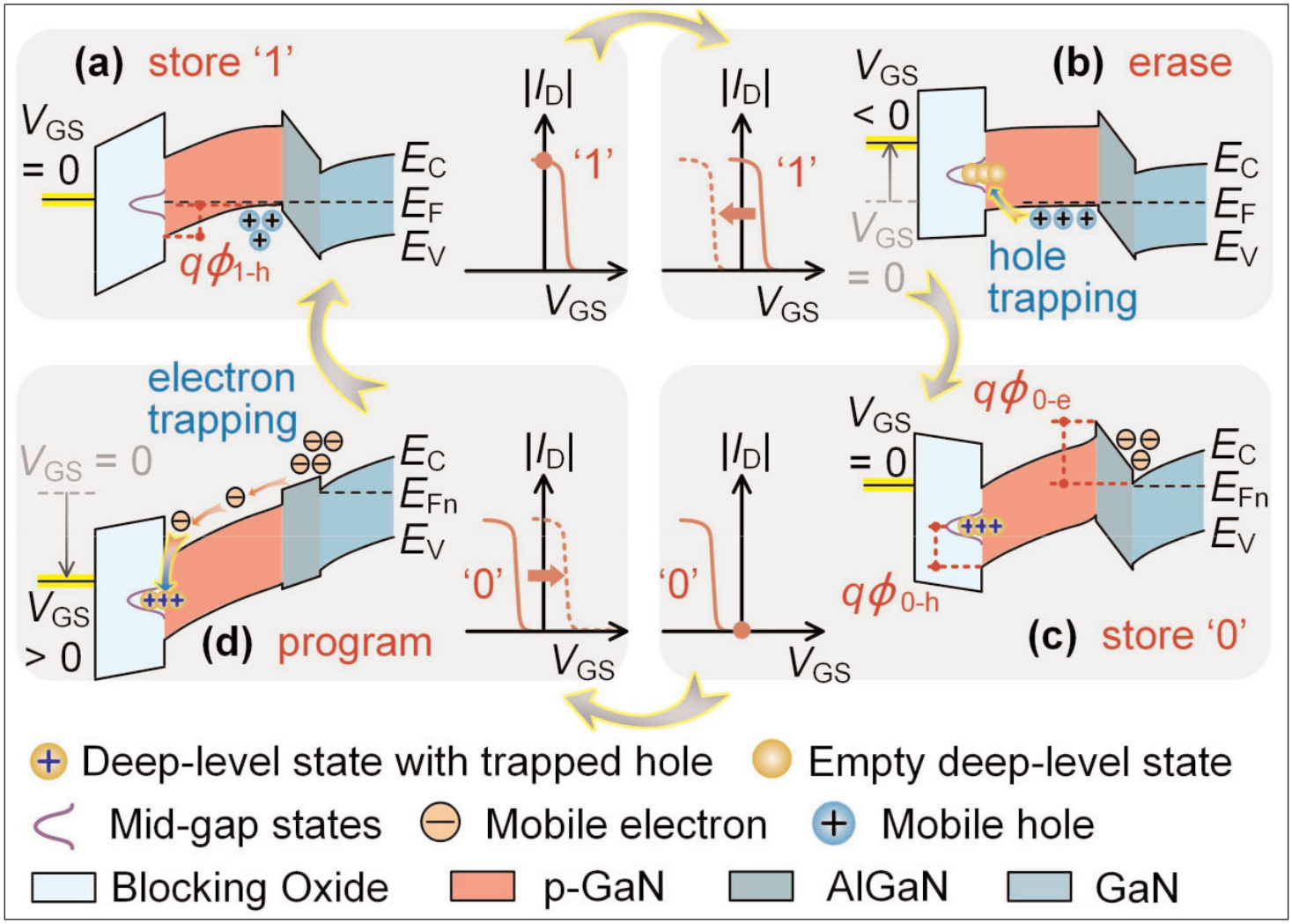

Figure 2. Energy band diagrams and schematic I_D–V_{GS} curves of memory in (a) '1' state, (b) erase stage, (c) '0' state, and (d) program stage. $q\phi_{1-h}$, $q\phi_{0-h}$ and $q\phi_{0-e}$ are hole diffusion/emission and electron injection barriers in states '1' and '0', respectively.

two-dimensional electron gas (2DEG) can form at the AlGaN/GaN junction when the overlying p-channel is fully depleted by an appropriate gate potential or when removed (Figure 2).

Conventionally, hole-based charge storage would have program/erase (P/E) steps based on gate-potential-controlled hole injection/emission, but here electron injection is also possible in a bipolar junction barrier (BJB) structure. The researchers comment: "Such junction-barrier-controlled bipolar charge injections enable fast P/E processes and facilitate to decouple the enhancement of endurance from that of speed and retention."

The charge state of the CSL was measured through the drain current (I_D) at a drain-source potential (V_{DS}) of –0.5V with 0V on the gate (V_{GS}). The low current state was labeled '0' and the high '1'.

The device material was grown on commercial GaN-on-silicon (Si) wafers aimed at enhancement-mode high-electron-mobility transistor manufacturing. The metal-organic chemical vapor deposition growth consisted of 4µm GaN buffer and unintentionally doped n-channel/2DEG, 12nm AlGaN barrier, and 85nm p-GaN.

The NVM structure was fabricated first by patterned plasma etching of the p-GaN to form a 2DEG channel region. Ohmic contacts were made to the 2DEG channel and the source–drain regions of the p-FET. More patterned etching thinned the p-GaN to 35nm in the FET gate area. The surface of the p-GaN at the gate stack interface was treated with oxygen plasma, generating high-density deep-level trap states for the CSL. The traps were covered with 20nm atomic layer deposition (ALD) Al_2O_3 blocking oxide (BO). The devices were then electrically isolated with fluorine ion implantation. The gate electrode consisted of nickel/gold.

A P/E cycle with 10V/–10V gate potential (V_P/E) achieved P/E times of 100µs/100ns. By increasing V_P to 20V, the P-time could be reduced to 100ns. The team comments: "The 100ns of P/E time is limited by parasitic effects such as the channel resistance, and thus could be further reduced by device down scaling."

Retention of the memory states was extrapolated from measurements made at high temperature, 125–200°C, to speed up degradation to a 1V difference ►

Table 1. Benchmarks of charge-based NVMs. [a]HSO: silicon-doped HfO_2. [b]Extrapolated value at room temperature.

Channel material	Gate stack	Program/erase speed	Endurance	Retention[b]
Si	SiO_2/Nitride/SiO_2	20V/10μs (P)/–20V/1ms (E)	$>10^3$	$>10^8$s
Si	SiO_2/HSO/SiO_2a	17V/300ns (P)/–16V/300ns (E)	$>10^5$	$>10^8$s
Si	SiO_2/Nitride/SiO_2	22V/1μs (P)/–16V/10μs (E)	$>10^7$	$>10^5$s
GaN	Al_2O_3/p-GaN/AlGaN/GaN	10V/100μs (P)/–10V/100ns (E)	$>10^8$	$>10^7$s

in the p-FET threshold potentials for the two memory states. The extrapolated retention came to more than 10^7s; in fact, retention was estimated at 2.17 years ($6.8x10^7$s) at 25°C. The activation energy for the temperature dependence was 0.79eV. The researchers believe this could be increased, giving even longer retention, based on the wider bandgap of GaN relative to silicon.

The endurance under P/E cycling was more than 10^6 with 20V V_P, and 10^8 for 10V. The lower V_P puts the barrier oxide under less electric-field stress, reducing degradation from this source. The degradation results in greater current leakage from the gate into the CSL.

The usual Si-based NVMs (Table 1 shows typical trade-offs relative to HKUST GaN device) use Fowler–Nordheim tunneling across an insulating oxide to charge the CSL, which needs a high electric field to P/E the state. The HKUST team believes that the electric field across the blocking oxide in its NVM "can be reduced by adopting lower doping concentration in the p-GaN or high-κ dielectric materials without sacrificing the speed and retention performance." ■

https://doi.org/10.1109/LED.2022.3161010

Author: Mike Cooke

SiC patent analysis shows firms building vertically integrated supply chains

Chinese patent applicants span the whole supply chain

Driven by the adoption of silicon carbide (SiC) technology in electric vehicle (EV) applications, the SiC power device market is growing fast. Earned by firms mainly in Europe (STMicroelectronics, Infineon), the USA (Wolfspeed, onsemi) and Japan (Rohm Semiconductor, Mitsubishi Electric, Fuji Electric), SiC power device market revenues exceeded $1bn in 2021, and are rising at a compound annual growth rate (CAGR) of 34% to more than $6bn in 2027, forecasts market analyst firm Yole Développement.

The semiconductor industry's other major nations, including China and South Korea, have unveiled their ambitions to develop their own SiC industry. Yet their ability to build the whole supply chain required for power SiC technology in the short- or mid-term has been questioned, especially regarding the establishment of a domestic supply of SiC wafers. Indeed, the entry barrier to the SiC wafer business is remarkably high, as attested by the very limited number of companies currently able to mass produce large-area and high-quality SiC wafers for power device makers, such that they can comply with the stringent device requirements expected from the EV industry.

In this context, Knowmade is releasing a new SiC intellectual property (IP) report — based on analyzing more than 13,700 patent families (inventions) filed by more than 500 different entities — that provides a comprehensive view of the power SiC patent landscape along the whole value chain, from bulk SiC and epitaxial SiC substrates to SiC devices, SiC modules and SiC circuits. Specifically, the patent corpus is split into five main supply chain segments and ten main sub-segments: bulk SiC & bare SiC wafers, SiC epitaxial substrates (including growth equipment, finishing), SiC devices (including diodes, planar MOSFETs, trench MOSFETs), SiC modules (including thermal issues, parasitics, die-attach, encapsulation), and SiC circuits.

"Patent landscape analysis is a powerful tool to identify new players in emerging industries, way before they enter the market, while providing a better understanding of their expertise and know-how in a specific technology," Rémi Comyn PhD, technology and patent analyst Compound Semiconductors and Electronics at Knowmade. "Overall, the patenting activity (patent filings) reflects the level of R&D investment made by a country or a player in a specific technology, while providing a hint

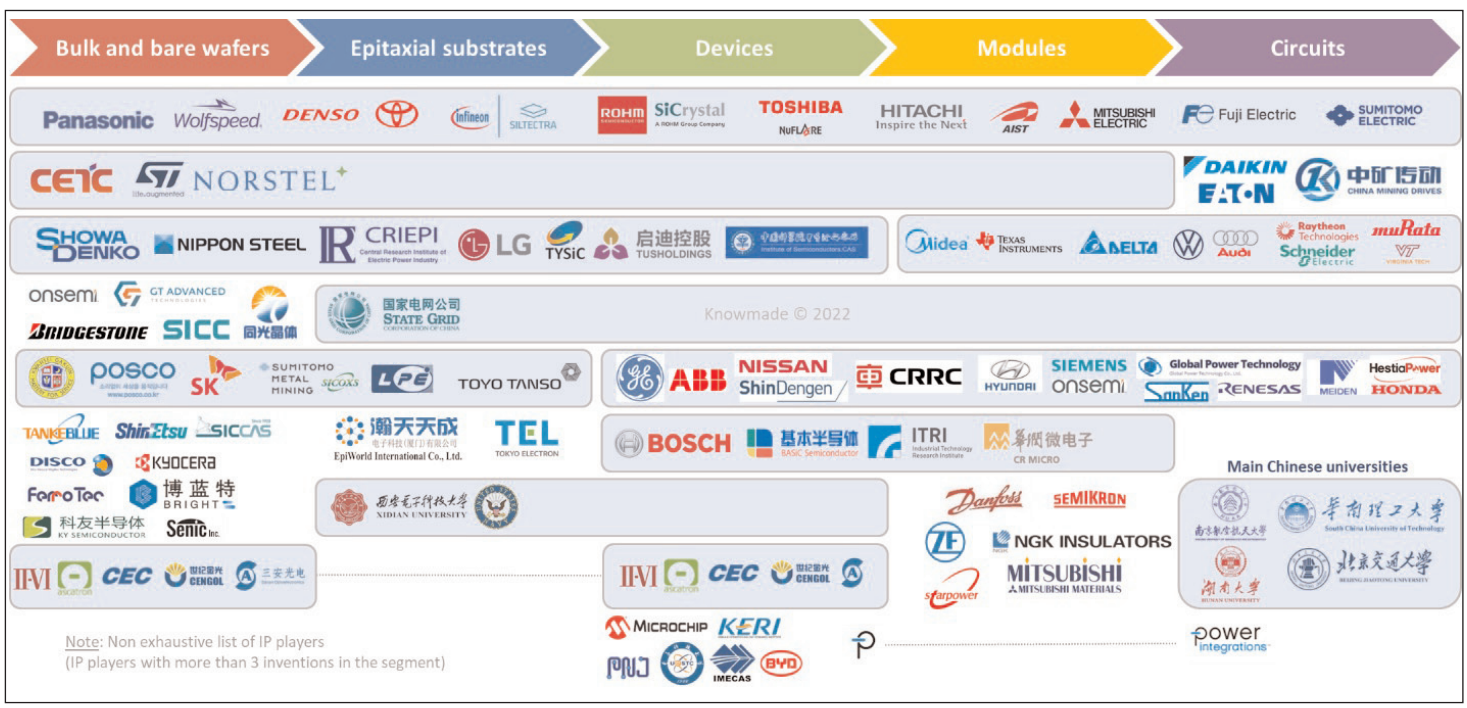

Figure 1: Main patent assignees along the power SiC supply chain.

about the technology readiness level reached by the main IP players," he adds. "What's more, the technology coverage along the value chain and the geographical coverage of the patent portfolios are narrowly related to the business strategy of IP players."

Although historical IP players (Wolfspeed, SiCrystal, II-VI) keeps filing new patents, indicating a continuous improvement of their technology, Sumitomo Electric and Showa Denko have taken over IP leadership in the SiC substrate patent landscape. Furthermore, Knowmade's analysis identifies numerous established IP players in the bulk SiC patent landscape, having the expertise and know-how to join in or spin off new companies in the SiC wafer sector (like SKC establishing Senic in 2021). Especially in China, there is an impressive number of IP players engaged in SiC substrate R&D, and some of them are now stand-out players in the bulk SiC patent landscape (SICC, Synlight Crystal, TankeBlue, San'an).

The patent landscape analysis also identifies the main companies engaged in the development of disruptive technologies addressing the cost and availability issues of SiC wafers (Soitec, Toyota Tsusho/Kwansei Gakuin University, Sumitomo Metal Mining/Sicoxs, Infineon/Siltectra, etc).

While numerous companies are focusing on building a vertically integrated supply chain to secure their SiC business in the long term, few of them have developed strong patent portfolios all along the SiC value chain, the exceptions being Toyota and Denso in Japan.

Furthermore, many companies may not have anticipated Europe or China as key markets for their power SiC business, and need to strengthen their IP position in these geographic areas. Therefore, most leading companies need to combine internal innovation capabilities with external innovation sources, for example through merger & acquisition (M&A) operations (e.g. onsemi/GTAT, ST/Norstel, Wolfspeed/APEI, Danfoss/Semikron), licensing agreements (e.g. II-VI/GE) or IP collaborations (e.g. Toyota/Denso, Audi/ABB) in order to accelerate the deployment of their SiC technology.

"What's more, a global innovation strategy is not only important in building vertically integrated manufacturing lines, thereby cutting supplier margins and securing the supply chain internally, it also enables players to not be limited in their development by technological and cost barriers at different levels of the supply chain, from material optimization to module integration." notes Comyn. "Thus, established players holding key patents at all stages of the supply chain can expect a long-term competitive advantage in the market, while newcomers are facing particularly high barriers to entry in the SiC industry," he adds. In this regard, the SiC patent landscape report describes the IP strategy of the main players to enhance their access to critical technologies all along the SiC value chain.

In the report, Knowmade focused its investigations on Chinese players shaping the emerging SiC supply chain in China. Chinese players are accelerating their patenting activity to support the development of SiC technology and, more importantly, to support the emergence of a complete domestic supply chain and secure their power semiconductor product lines. Chinese patent applicants span the whole supply chain, including relatively well-established IP players in each segment, with a great diversity of players (academic, industrial,

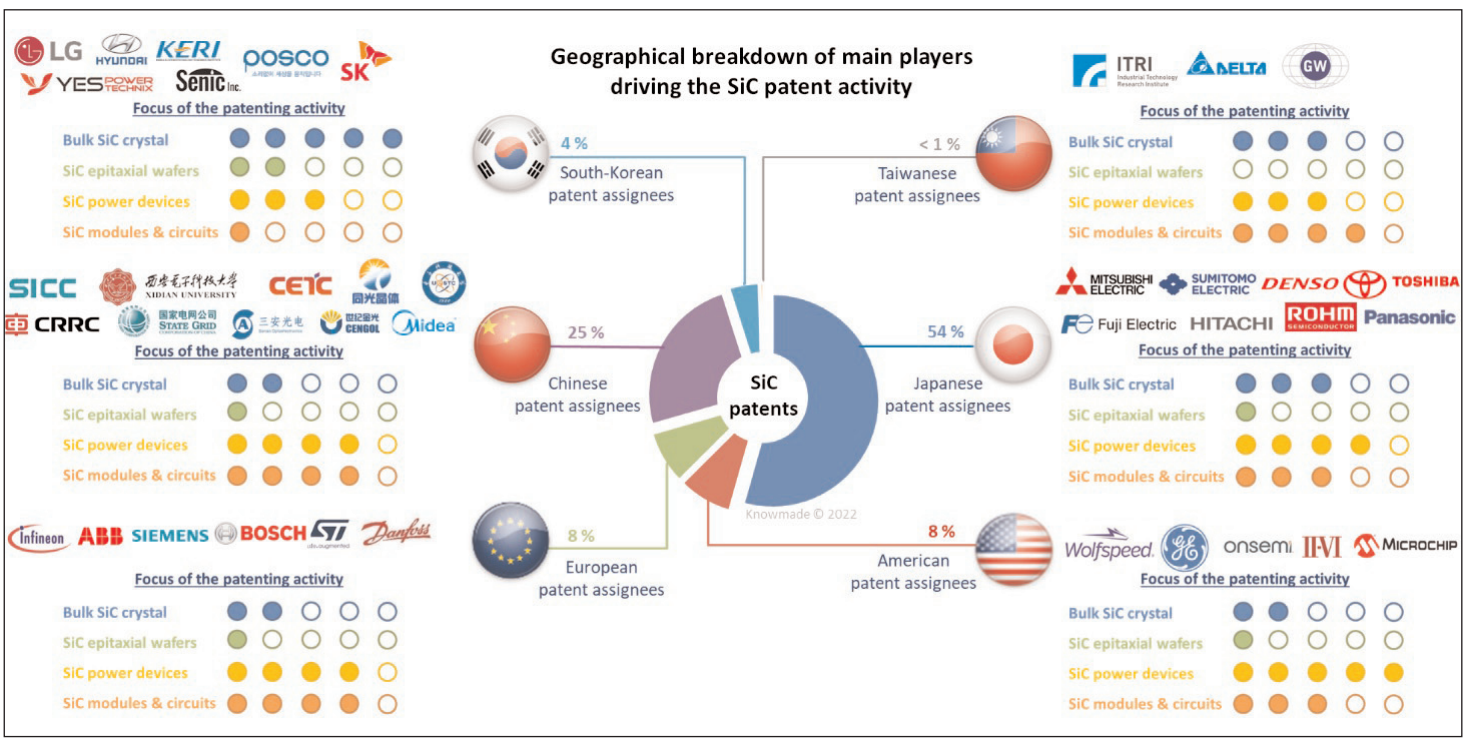

Figure 2: Geographical breakdown of main players driving SiC patent activity.

Figure 3: Main Chinese patent assignees along the power SiC supply chain.

foundry, IDM, integrator, pure player, etc) and a dense network of IP collaborations and IP transfers. As a result, the technological gap with foreign suppliers is expected to narrow in most segments of the supply chain. The breakdown of Chinese applicants' patent portfolios along the power SiC supply chain (as shown in Figure 3) demonstrates that numerous Chinese companies are now present — in terms of IP — in each segment of the supply chain. Comyn recently published an article focusing on the Chinese SiC patent landscape.

A significant part of the SiC IP report is dedicated to the in-depth analysis of the SiC patent portfolio owned by the top 10 IP players and top six power device market players: Mitsubishi Electric, Sumitomo Electric, Infineon, Rohm, Toyota/Denso, Wolfspeed, Fuji Electric, Hitachi, Toshiba, STMicroelectronics, onsemi, Panasonic. Knowmade's IP analysts provide an overview of the patent portfolio (IP dynamics, enforceability, protected countries, technology), highlighting a player's IP strategy, its strength and its potential for reinforcement. The recent patenting activity of the player is reviewed in the light of recent announcements related to SiC and related challenges. ■

www.knowmade.com/downloads/silicon-carbide-sic-patent-landscape-2022

			SEGMENTS (number of patent families)					Growth of the patent portfolio between 2016 and 2021 (% change)
Patent assignee	Ranking in the SiC power device market 2021 *	Number of patent families (inventions)	Bulk SiC	Epitaxial SiC wafers	SiC devices	SiC modules	Circuits	
Mitsubishi Electric	*6*	1222	38	56	481	511	196	54%
Toyota group (including **Denso**)		1198	409	86	530	150	37	45%
Sumitomo Electric		940	239	156	476	70	9	24%
Fuji Electric	*7*	786	9	57	531	154	60	110%
Panasonic/Sanyo Electric		409	55	28	231	37	29	8%
Infineon (including **Siltectra**)	*2*	369	18	8	205	124	20	103%
Rohm (including **SiCrystal**)	*4*	367	41	10	169	121	40	66%
Toshiba (including **Nuflare**)	*9*	366	11	44	278	39	24	60%
Hitachi (excluding **ABB power grids**)		360	15	20	179	114	55	41%
Wolfspeed	*3*	329	43	34	222	25	15	12%
onsemi	*5*	76	8	1	49	15	4	62%
STMicroelectronics	*1*	54	5	8	36	3	1	46%

* *Ranking in the SiC power device market from the Power SiC 2022 report, Yole Développement, 2022*

Figure 4: Leading players' SiC patent portfolio overview.

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Albemarle Cambridge Chemical Ltd
Unit 5 Chesterton Mills,
French's Road, Cambridge CB4 3NP,
UK
Tel: +44 (0)1223 352244
Fax: +44 (0)1223 352444
www.camchem.co.uk

Intelligent Epitaxy Technology Inc
1250 E Collins Blvd,
Richardson, TX 75081-2401,
USA
Tel: +1 972 234 0068
Fax: +1 972 234 0069
www.intelliepi.com

IQE
Cypress Drive,
St Mellons,
Cardiff
CF3 0EG, UK
Tel: +44 29 2083 9400
Fax: +44 29 2083 9401
www.iqep.com
IQE is a leading global supplier of advanced epiwafers, with products covering a diverse range of applications within the wireless, optoelectronic, photovoltaic and electronic markets.

OMMIC
2, Chemin du Moulin B.P. 11,
Limeil-Brevannes, 94453,
France
Tel: +33 1 45 10 67 31
Fax: +33 1 45 10 69 53
www.ommic.fr

Soitec
Parc Technologique des Fontaines,
Chemin des Franques, 38190
Bernin, France
Tel: +33 (0)4 76 92 75 000
www.soitec.com

The Fox Group Inc
200 Voyageur Drive, Montreal,
Quebec H9R 6A8, Canada
Tel: +1 925 980 5645
Fax: +1 514 630 0227
www.thefoxgroupinc.com

VIGO SYSTEM S.A.
ul. Poznanska 129 /133, 05-850
Ozarów Mazowiecki, Poland
Tel: +48 22 733 54 10
E-mail: ent@vigo.com.pl
ent-epitaxy.com

www.vigo.com.pl www.ent-epitaxy.com

VIGO System's Epitaxy Division produces high-grade III–V compound semiconductor epitaxial structures for photonic and microelectronic devices. With more than 35 years' experience, the division offers a broad range of epi-wafers, both in large volumes and small customised batches. It focuses on innovative products for wireless, TC, sensing or printing applications.

5 Deposition materials

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

Matheson Tri-Gas
6775 Central Avenue,
Newark, CA 94560,
USA
Tel: +1 510 793 2559
Fax: +1 510 790 6241
www.mathesontrigas.com

Nouryon Functional Chemicals B.V.
Zutphenseweg 10, 7418 AJ
Deventer,
The Netherlands
Tel. +31 652 478554
https://hpmo.nouryon.com

Praxair Electronics
542 Route 303,
Orangeburg,
NY 10962,
USA
Tel: +1 845 398 8242
Fax: +1 845 398 8304
www.praxair.com/electronics

Vital Thin Film Materials (Guangdong) Co Ltd (Vital Materials subsidiary)
18G, 18th Floor, Shenzhen Free Trade Centre, No.111 Taizi Road,
Nanshan District,
Shenzhen, Guangdong, China 518067
Tel: (+86) 0755-21651348
sales@vitaltfm.com
www.vitaltfm.com
Vital Materials is the world's leading producer of rare metals as well as the first Chinese manufacturer to deliver G11 rotary ITO target. Vital is also one of the world's three major supplier of infrared materials, a key supplier of compound semiconductor substrates, and a strategic partner of the world's largest thin film solar manufacturer.

6 Deposition equipment

AIXTRON SE
Dornkaulstr. 2,
52134 Herzogenrath,
Germany
Tel: +49 2407 9030 0
Fax: +49 2407 9030 40
www.aixtron.com

ETC (LPE subsidiary)
Via Falzarego, 820021 Baranzate (Mi),
Italy
Tel: +39 02 383 41 51
Fax: +39 02 383 06 118
www.lpe-epi.com

Evatec AG
Hauptstrasse 1a,
CH-9477 Trübbach,
Switzerland
Tel: +41 81 403 8000
Fax: +41 81 403 8001
www.evatecnet.com

FHR Anlagenbau Gmbh (Vital Materials subsidiary)
Am Hügel 2, D-01458
Ottendorf-Okrilla,
Germany
Tel: +49 35205 520-0
E-mail: sales@fhr.de
E-mail: sales@vitalchem.com
www.fhr.biz
Vital Materials is the world's leading producer of rare metals as well as the first Chinese manufacturer to deliver G11 rotary ITO target. Vital is also one of the world's three major supplier of infrared materials, a key supplier of compound semiconductor substrates, and a strategic partner of the world's largest thin film solar manufacturer.

LPE S.p.A.
Via Falzarego, 8
20021 Baranzate (Mi), Italy
Tel: +39 02 383 41 51
Fax: +39 02 383 06 118
www.lpe-epi.com

PLANSEE High Performance Materials
6600 Reutte,
Austria
Tel: +43 5672 600 2422
info@plansee.com
www.plansee.com

Plasma-Therm LLC
10050 16th Street North,
St. Petersburg, FL 33716,
USA
Tel: +1 727 577 4999
Fax: +1 727 577 7035
www.plasmatherm.com

Riber
31 rue Casimir Périer, BP 70083,
95873 Bezons Cedex,
France
Tel: +33 (0) 1 39 96 65 00
Fax: +33 (0) 1 39 47 45 62
www.riber.com

SVT Associates Inc
7620 Executive Drive,
Eden Prairie, MN 55344, USA
Tel: +1 952 934 2100
Fax: +1 952 934 2737
www.svta.com

Temescal, a division of Ferrotec
4569-C Las Positas Rd,
Livermore, CA 94551, USA
Tel: +1 925 245 5817
Fax: +1 925 449-4096
www.temescal.net

Veeco Instruments Inc
100 Sunnyside Blvd.,
Woodbury, NY 11797, USA
Tel: +1 516 677 0200
Fax: +1 516 714 1231
www.veeco.com

7 Wafer processing materials

Kayaku Advanced Materials Inc
200 Flanders Road,
Westborough, MA 01581, USA
Tel: +1 617 965 5511
www.kayakuam.com

Praxair Electronics
(see section 5 for full contact details)

Versum Materials
8555 S. River Parkway,
Tempe, AZ 85284, USA
Tel: +1 602 282 1000
www.versummaterials.com

8 Wafer processing equipment

Evatec AG
Hauptstrasse 1a, CH-9477 Trübbach,
Switzerland
Tel: +41 81 403 8000
Fax: +41 81 403 8001
www.evatecnet.com

EV Group
DI Erich Thallner Strasse 1,
St. Florian/Inn, 4782,
Austria
Tel: +43 7712 5311 0
Fax: +43 7712 5311 4600
www.EVGroup.com

EV Group is a technology and market leader for wafer processing equipment. Worldwide industry standards for aligned wafer bonding, resist processing forthe MEMS, nano and semiconductor industry.

Logitech Ltd
Erskine Ferry Road,
Old Kilpatrick, near Glasgow G60 5EU,
Scotland, UK
Tel: +44 (0) 1389 875 444
Fax: +44 (0) 1389 879 042
www.logitech.uk.com

Plasma-Therm LLC
(see section 6 for full contact details)

SAMCO International Inc
532 Weddell Drive,
Sunnyvale, CA,
USA
Tel: +1 408 734 0459
Fax: +1 408 734 0961
www.samcointl.com

SPTS Technology Ltd
Ringland Way,
Newport NP18 2TA, UK
Tel: +44 (0)1633 414000
Fax: +44 (0)1633 414141
www.spts.com

SUSS MicroTec AG
Schleißheimer Strasse 90,
85748 Garching, Germany
Tel: +49 89 32007 0
Fax: +49 89 32007 162
www.suss.com

Synova SA
Ch. de la Dent d'Oche,
1024 Ecublens, Switzerland
Tel +41 21 694 35 00
Fax +41 21 694 35 01
www.synova.ch

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
Email: sales@tecdia.com
www.tecdia.com

Veeco Instruments Inc
(see section 6 for full contact details)

9 Materials & metals

Goodfellow Cambridge Ltd
Ermine Business Park, Huntingdon,
Cambridgeshire PE29 6WR, UK
Tel: +44 (0) 1480 424800
Fax: +44 (0) 1480 424900
www.goodfellow.com

PLANSEE High Performance Materials
6600 Reutte, Austria
Tel: +43 5672 600 2422
info@plansee.com
www.plansee.com

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

10 Gas and liquid handling equipment

Cambridge Fluid Systems
12 Trafalgar Way, Bar Hill,
Cambridge CB3 8SQ,
UK
Tel: +44 (0)1954 786800
Fax: +44 (0)1954 786818
www.cambridge-fluid.com

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

Entegris Inc
129 Concord Road,
Billerica, MA 01821, USA
Tel: +1 978 436 6500
Fax: +1 978 436 6735
www.entegris.com

IEM Technologies Ltd
Fothergill House, Colley Lane,
Bridgwater, Somerset TA6 5JJ, UK
Tel: +44 (0)1278 420555
Fax: +44 (0)1278 420666
www.iemtec.com

Vacuum Barrier Corporation
4 Barton Lane,
Woburn, MA 01801,
USA
Tel: +1 781 933 3570
Fax: +1 781 933 9428
www.vacuumbarrier.com

VACUUM BARRIER VBC CORPORATION

Vacuum Barrier's vacuum-jacketed dynamic and sealed SEMIFLEX LN2 pipe delivers LN2 at bulk tank pressure in two-phase condition for on-demand supply. Our liquid/vapor phase separators deliver low-pressure LN2 to each use point for on-demand supply. Combine with SEMIFLEX Triax LN2 pipe eliminates two-phase flow to all use points.

Versum Materials
8555 S. River Parkway,
Tempe, AZ 85284,
USA
Tel: +1 602 282 1000
www.versummaterials.com

11 Process monitoring and control

Conax Technologies
2300 Walden Avenue,
Buffalo, NY 14225,
USA
Tel: +1 800 223 2389
Tel: +1 716 684 4500
www.conaxtechnologies.com

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

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

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

Vacuum Barrier Corporation
4 Barton Lane, Woburn, MA 01801,
USA
Tel: +1 781 933 3570
Fax: +1 781 933 9428
www.vacuumbarrier.com
Vacuum Barrier's vacuum-jacketed dynamic and sealed SEMIFLEX LN2 pipe delivers LN_2 at bulk tank pressure in two-phase condition for on-demand supply. Our liquid/vapor phase separators deliver low-pressure LN_2 to each use point for on-demand supply. Combine with SEMIFLEX Triax LN_2 pipe eliminates two-phase flow to all use points.

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

12 Inspection equipment

Bruker
Oestliche Rheinbrueckenstrasse 49,
Karlsruhe, 76187, Germany
Tel: +49 (0)721 595 2888
Fax: +49 (0)721 595 4587
www.bruker.com

KLA–Tencor
160 Rio Robles, Suite 103D,
San Jose, CA 94538-7306, USA
Tel: +1 408 875-3000
Fax: +1 510 456-2498
www.kla-tencor.com

13 Characterization equipment

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

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

14 Chip test equipment

Riff Company Inc
1484 Highland Avenue, Cheshire,
CT 06410, USA
Tel: +1 203-272-4899
Fax: +1 203-250-7389
www.riff-co.com

Tektronix Inc
14150 SW Karl Braun Drive,
P.O.Box 500, OR 97077, USA
www.tek.com

15 Assembly/packaging materials

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

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

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

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

16 Assembly/packaging equipment

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.quikicpak.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

Vacuum Barrier Corporation
4 Barton Lane, Woburn, MA 01801,
USA
Tel: +1 781 933 3570
Fax: +1 781 933 9428
www.vacuumbarrier.com

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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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Decatur, GA 30035,
USA
Tel: +1 770 808 8708
Fax: +1 770 808 8308
www.ClassOneEquipment.com

23 Services

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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.alshuktz.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

event calendar

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

13–17 June 2022
2022 IEEE VLSI Symposium on Technology & Circuits — Technology and Circuits for the Critical Infrastructure of the Future
Hilton Hawaiian Village,
Honolulu, HI, USA
E-mail: vlsi@vlsisymposium.org
www.vlsisymposium.org

19–24 June 2022
IEEE MTT-S International Microwave Symposium (IMS2022) and Microwave Week
Colorado Convention Center,
Denver, CO, USA
E-mail: iMS@xpressreg.net
www.ims-ieee.org

20–23 June 2022
FCMN 2022: International Conference on Frontiers of Characterization and Metrology for Nanoelectronics
Monterey Marriott,
Monterey, CA, USA
E-mail: della@avs.org
www.fcmn2022.avs.org

21–23 June 2022
Lightfair 2022
Las Vegas Convention Center,
Las Vegas, USA
E-mail: michellem@lightfair.com
www.lightfair.com/las-vegas-2022

10–14 July 2022
20th International Conference on Metal Organic Vapor Phase Epitaxy (ICMOVPE XX)
Schwabenlandhalle Fellbach, Stuttgart, Germany
E-mail: info@icmovpexx.eu
www.icmovpexx.eu

13–15 July 2022
LASER World of PHOTONICS CHINA
Shanghai, China
E-mail: info@world-of-photonics-china.com
www.world-of-photonics-china.com/en

21–25 July 2022
3rd International Congress on Advanced Materials Sciences and Engineering (AMSE-2022)
Hotel Ambasador, Opatija, Croatia
E-mail: eve4@amse-materials2021.com
www.istci.org/amse2022

21–25 August 2022
SPIE Optics + Photonics 2022
San Diego Convention Center, San Diego, CA, USA
E-mail: customerservice@spie.org
www.spie.org/opstm

24–26 August 2022
2022 IEEE International Workshop on Integrated Power Packaging (IWIPP)
World Trade Centre of Grenoble,
Grenoble, France
www.iwipp.org

advertisers' index

31 August – 2 September 2022
PCIM (Power Conversion, Intelligent Motion) Asia 2022
Shanghai New International Expo Centre, China
E-mail: pcimasia@china.messefrankfurt.com
www.pcimasia-expo.com

7–9 September 2022
CIOE 2022 (24th China International Optoelectronic Exposition)
Shenzhen World Exhibition & Convention Center, China
E-mail: cioe@cioe.cn
www.cioe.cn/en

11–16 September 2022
19th International Conference on Silicon Carbide and Related Materials (ICSCRM 2022)
Davos, Switzerland
E-mail: info@icscrm2022.org
www.icscrm2022.org

19–21 September 2022
48th European Conference on Optical Communication (ECOC 2022)
Basel, Switzerland
E-mail: info@ecoc2020.org
www.ecoco2020.org

25–30 September 2022
25th European Microwave Week (EuMW 2022) including:
52nd European Microwave Conference (EuMC 2022)
17th European Microwave Integrated Circuits Conference (EuMIC 2022)
19th European Radar Conference (EuRAD 2022)
Milano Convention Centre (MICO), Milan, Italy
E-mail: rvaughan@horizonhouse.co.uk
www.eumweek.com

16–19 October 2022
2022 IEEE BiCMOS and Compound Semiconductor Integrated Circuits and Technology Symposium (BCICTS)
Sheraton Phoenix Downtown, Phoenix, AZ, USA
E-mail: cs@cshawevent.com
www.bcicts.org

16–21 October 2022
International Workshop on Bulk Nitride Semiconductors — XI (IWBNS-XI)
Lehigh Valley, PA, USA
E-mail: iwbns-xi@gmail.com
www.iwbns-xi.org

2–6 October 2022
Light + Building Autumn Edition 2022
Frankfurt, Germany
E-mail: tickets@messefrankfurt.com
https://light-building.messefrankfurt.com

15–18 November 2022
SEMICON Europa 2022 (co-located with electronica)
Messe München, Munich, Germany
E-mail: semiconeuropa@semi.org
www.semiconeuropa.org

3–7 December 2022
68th annual IEEE International Electron Devices Meeting (IEDM 2022)
Hilton San Francisco Union Square hotel, CA, USA
E-mail: iedm-info@ieee.org
www.ieee-iedm.org

7–9 December 2022
LASER World of PHOTONICS INDIA
Bombay Exhibition Centre, Mumbai, India
E-mail: info@world-of-photonics-india.com
www.world-of-photonics-india.com/en

26–30 March 2023
2023 IEEE International Reliability Physics Symposium (IRPS)
Hyatt Regency, Monterey, CA, USA
Abstract deadline: 24 October 2022
E-mail: IRPSplanners@ieee.org
E-mail: IRPSreg@ieee.org
www.irps.org

7–12 May 2023
2023 Conference on Lasers & Electro-Optics (CLEO)
San Jose Convention Center, San Jose, CA, USA
E-mail: CLEO@compusystems.com
www.cleoconference.org

25–29 June 2023
World of PHOTONICS CONGRESS — International Congress on Photonics in Europe
ICM – Internationales Congress Center München, Munich, Germany
E-mail: info@photonics-congress.com
www.photonics-congress.com/en

17–22 September 2023
26th European Microwave Week (EuMW 2023)
Berlin Messe, Germany
E-mail: eumwreg@itnint.com
www.eumweek.com

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