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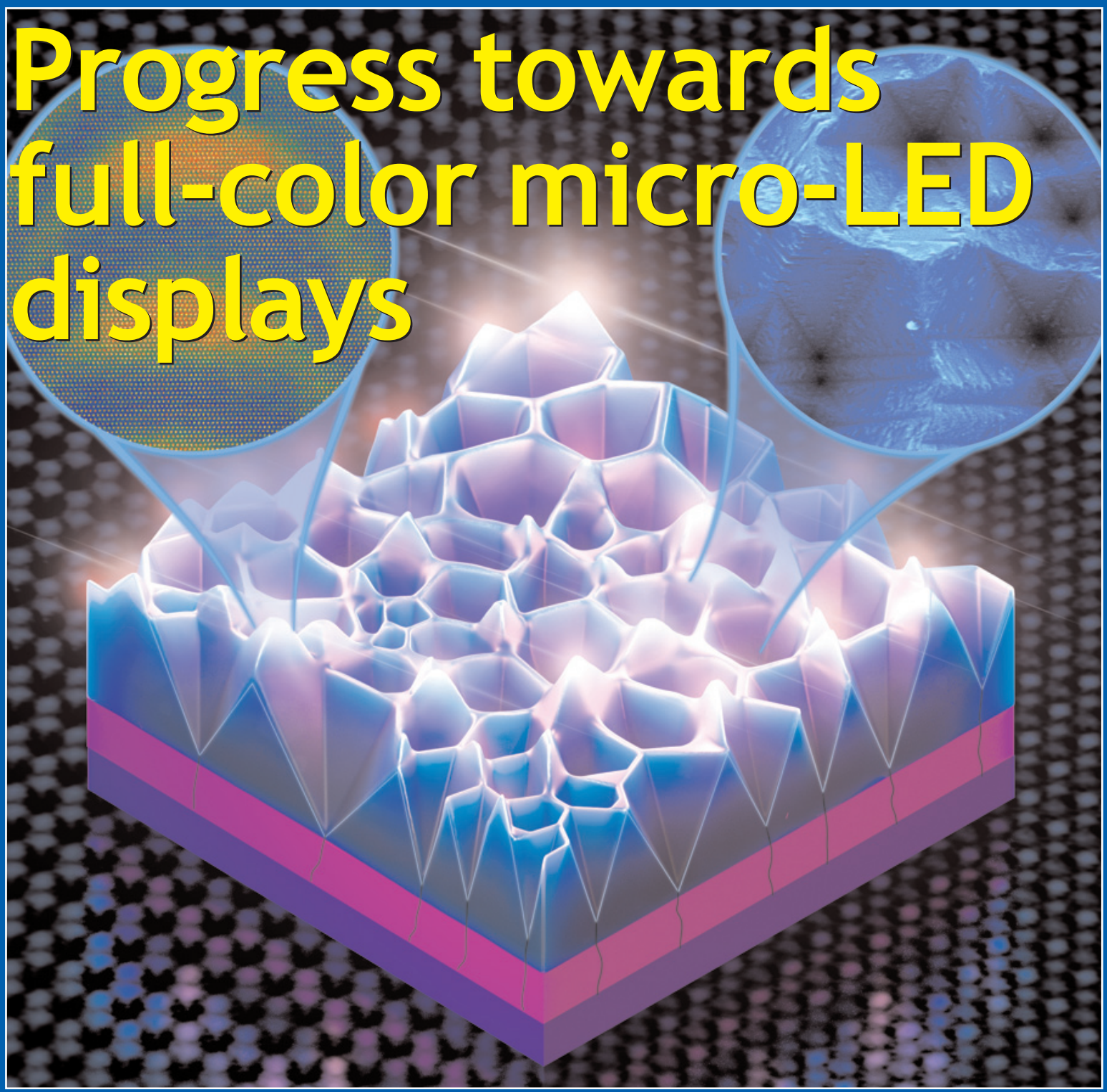

Progress towards full-color micro-LED displays

Cree becomes Wolfspeed • Oxford Instruments & ITRI collaborate
Navitas debuts on Nasdaq • IQE partners with GF on GaN-on-Si

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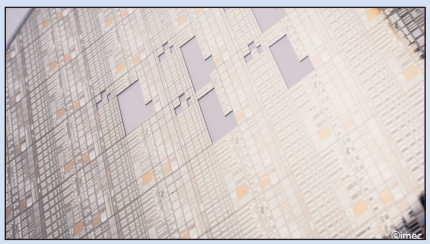
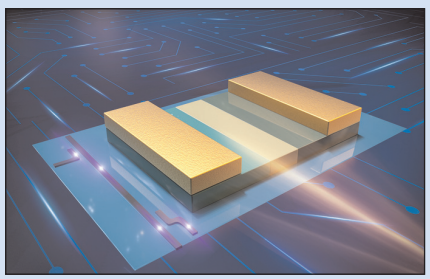
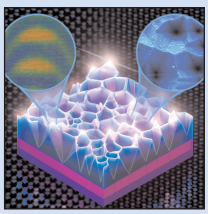
p20 GaN power IC firm Navitas has opened a new office in Shenzhen to support growth in the China region.



p24 Imec and EUROPRACTICE have announced the winners of their 2021 GaN-IC technology design contest. Winning designs are being prototyped in a 650V GaN-IC multi-project wafer run.



p52 III-V photodetector on monolithic InP/SOI platform for application in silicon photonics, fabricated at HKUST



Cover: Quantum dots have been made by making use of intrinsic defects in LED materials. Through the formation of pyramids, localized bright luminescence emanates from pyramid apexes containing indium-rich quantum dots. Credits: Singapore-MIT Alliance for Research and Technology (SMART). **p76**

editorial

Towards integration of RGB InGaN micro-LEDs for full-color displays

In this issue we focus on progress being made in micro-LEDs, particularly making them brighter and more efficient for display applications, and extending the emission wavelength of indium gallium nitride (InGaN) from the well-established blue end of the visible spectrum through the 'green gap' and into the red. The ultimate aim is the monolithic integration of arrays of RGB micro-LEDs on large-diameter silicon wafers in high volume.

University of California Santa Barbara (UCSB) has demonstrated that the metal-organic chemical vapor deposition (MOCVD) of tunnel-junction contacts rather than indium tin oxide (ITO) contacts on the p-type GaN top surface of blue micro-LEDs can (due to greater transparency) boost light output power by over 40% (at 20A/cm^2 current injection), while raising efficiency from just more than 30% to over 50% (although these benefits diminished at higher current densities) — see pages 66–68.

The high indium content required for InGaN LEDs to emit red light yields low external quantum efficiency (EQE) compared with the incumbent aluminium indium gallium phosphide (AlInGaP) for regular-sized red LEDs. However, on pages 70–71 UCSB reports that InGaN LEDs do not suffer from the degradation of efficiency suffered by AlInGaP LEDs as their size is scaled down to tens of microns (due to the increasing influence of charge recombination on the LED's mesa sidewall surfaces versus bulk effects as the mesa's perimeter-to-area ratio increases). UCSB's InGaN red LEDs maintained an EQE of about 2.4% down to 20μm (at 10–20A/cm^2 current injection). This shows "potential" for achieving the 5% from 5μm x 5μm micro-LEDs that it reckons is required for displays.

Saudi Arabia's King Abdullah University of Science and Technology (KAUST) has fabricated 17μm x 17μm red micro-LEDs (with ITO p-side contacts) with a peak emission wavelength of 630nm (at current injection of as much as 50A/cm^2), meeting the Rec.2020 requirement for red primary color emission (see pages 72–74). Although the EQE was low, the output power density of 1.76mW/mm^2 exceeds the 1mW/mm^2 of 20μm x 20μm AlInGaP red μLEDs.

Meanwhile, Cambridge University spin-off Porotech has used its porous material technology to create — on a native InGaN substrate — 960x540-pixel red micro-displays with an active area of 0.55-inches diagonally, targeting commercialization in augmented reality (AR) glasses (page 40).

The Singapore–MIT Alliance for Research and Technology (SMART) has also demonstrated the creation of red, orange and yellow InGaN micro-LEDs grown on silicon wafers, enabling the monolithic integration of RGB LEDs on the same substrate. Intrinsic V-pit defects in the material induce the formation of pyramids, whose apexes contain indium-rich quantum dots emitting at longer wavelengths (see pages 76–77). The nucleation of stacking faults further contributes to the emission of longer wavelengths. "Our work demonstrates the viability of using silicon substrates for new indium-rich structures which, along with addressing current challenges in the low efficiencies of long-wavelength InGaN light emitters, also alleviate the issue of expensive substrates," says SMART. "This breakthrough could lead to a more rapid phasing out of non-solid-state lighting sources — such as incandescent bulbs — and even the current phosphor-coated blue InGaN LEDs with a fully solid-state color-mixing solution, in turn leading to a significant reduction in global energy consumption," they add.

Mark Telford, Editor

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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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Power and compound fab capacity to top record 10 million wafers per month in 2023

Installed capacity surging by 7% in 2021, reckons SEMI

Fueled by pent-up demand for automotive electronics caused by semiconductor supply chain disruptions wrought by the COVID-19 pandemic, worldwide installed capacity for power and compound semiconductor fabs is projected to top 10 million wafers per month (WPM) for the first time in 2023, growing to 10.24 million WPM (in 200mm equivalents), then climbing to 10.6 million WPM in 2024, forecasts industry association SEMI in its 'Power & Compound Fab Report to 2024'.

China is expected to claim the largest share of installed capacity (33%) by 2023, followed by Japan at 17%, Europe and the Mideast (EMEA) at 16%, and Taiwan at 11%. These proportions are expected to change little as the industry remains on track to add more than 360,000WPM in 2024.

The report notes that 63 companies are expected to add more than 2 million WPM (in 200mm equivalents) from 2021 through 2024. Infineon, Hua Hong Semiconductor, STMicroelectronics and Silan Microelectronics will lead the way, together adding a projected 700,000WPM.

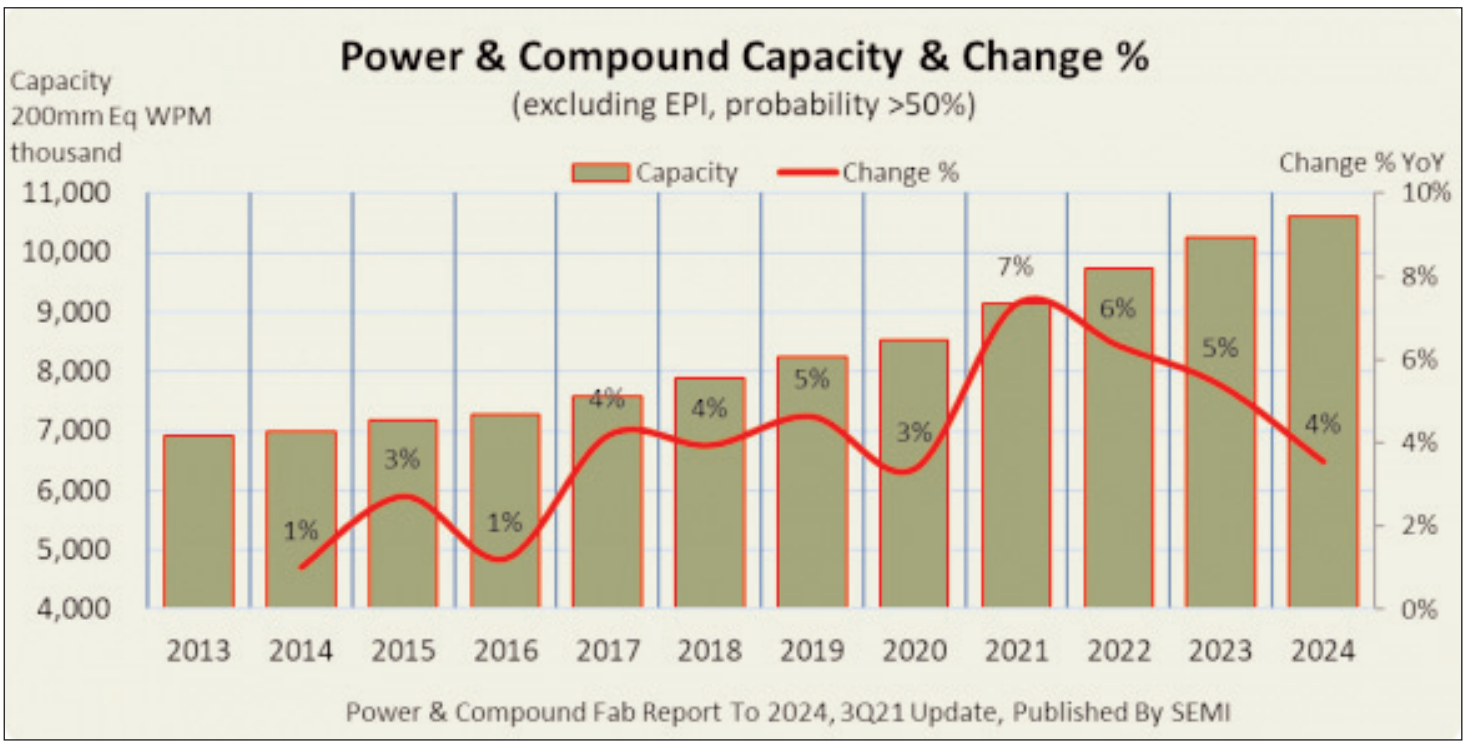
Installed capacity for the power and compound fab industry grew 5% year-over-year (YOY) in 2019 and 3% in 2020 before surging 7% in 2021. Year-on-year growth is projected to remain strong at 6% in 2022 and 5% in 2023 as the industry tops the 10 million WPM mark.

Installed capacity for the power and compound fab industry grew 5% year-over-year in 2019 and 3% in 2020 before surging 7% in 2021. Year-on-year growth is projected to remain strong at 6% in 2022 and 5% in 2023 as the industry tops the 10 million WPM mark

The industry is also adding production facilities. From 2021 through 2024, 47 high-probability facilities and lines (R&D to high volume, including epitaxial wafers) are expected to go online to bring the industry total to 755, a number that could be eclipsed if new facilities and lines are announced.

The SEMI 'Power & Compound Fab Report to 2024' covers 957 facilities and lines operational over the 12 years from 2013 to 2024, including facilities that are or will be closed, and new facilities starting operation.

www.semi.org/en/products-services/market-data/power-compound-fab-report2020



GaN power device market to grow 73% to $83m in 2021

Demand for fast chargers used for consumer electronics applications has been rising quickly, notes TrendForce. For example, smartphone brands like Xiaomi, OPPO and Vivo led the industry by releasing fast chargers in 2018, gaining consumer acceptance via their competitive advantages in cooling efficiency and compact physical dimensions. Now, notebook computer manufacturers are also expressing a willingness to adopt fast-charging technology. GaN power devices hence became the fastest-growing category in the 'third-generation' semiconductor industry, i.e. gallium nitride (GaN) and silicon carbide (SiC). TrendForce expects annual GaN power device revenue to rise by 73% year-on-year in 2021 to $83m.

Among GaN power device suppliers, Navitas is projected to achieve 29% market share (by total shipments) and overtake Power Integration for top place this year. Due to Navitas' proprietary GaNFast power IC design and relationships with its partners in the semiconductor supply chain, it has become the largest supplier of GaN power IC chips in the consumer electronics markets. The firm is currently partnering with leading global smartphone and PC OEMs including Dell, Lenovo, LG, Xiaomi and OPPO. Given the rising demand for Navitas' fast-charge ICs this year, the firm is expected to transition its chip orders in second-half 2021 from TSMC's Fab 2 (a 6" wafer fab) to 8" fabs instead, in order to overcome insufficient production capacity. Navitas also targets SAIC (Xiamen Sanan) as a supplier of foundry services. Regarding other markets for GaN, Navitas will likely target the data-center sector first by releasing related products in 2022.

Power management IC supplier PI (Power Integrations) was the long-time undisputed leader in the GaN power device market. For this year, PI launched the latest InnoSwitch4-CZ series of chips, based on its proprietary PowiGaN technology. Featured in products such as Anker's 65W fast chargers, they have received universal acclaim from the fast-charge market, says TrendForce. Also, PI's new integrated AC–DC controller and USB PD controller ICs are expected to be major drivers of PI's revenue growth this year. With an estimated market share of 24%, PI will likely take the runner-up spot in the ranking of GaN power device suppliers for 2021.

Company	2020	2021(E)
Navitas	26%	29%
Power Integrations	27%	24%
Innoscience	6%	20%
EPC	21%	14%
Transphorm	8%	6%
Infineon	5%	3%
GaN Systems	6%	3%
Other	1%	1%
Total	100%	100%

Market shares (per million chips shipped).

China's Innoscience to take third place in 2021

The market share of China-based Innoscience is projected to rise to 20% (the third biggest) this year, notes TrendForce. Its performance can be attributed mainly to the massive spike in its shipment of high-voltage and low-voltage GaN products. In particular, the firm's GaN power ICs (used for fast chargers) are entering the supply chains of tier-one notebook manufacturers for the first time. At the same time, while the company's Suzhou-based 8-inch wafer fab has already begun mass production, Innoscience will gradually expand the competitive advantage derived from its IDM business model in the fast-evolving GaN industry, reckons TrendForce. Not only is the firm currently actively cultivating its presence in applications including light detection & ranging (LiDAR), onboard chargers (OBCs) for electric vehicles (EVs), and LED power supplies, but it will also look to increase its market share even further next year via its diverse product mix.

Incidentally, the Chinese government has been increasing its support of the domestic third-generation semiconductor industry, while the ongoing China–US trade war has also forced Huawei and other companies in the downstream supply chain to reassess potential supply chain risks. Taken together, these factors have now created the perfect opportunity for China's third-generation semiconductor material and component suppliers in both qualification/validation and production of domestic substitutes, further propelling the growth of the third-generation semiconductor industry in China. According to TrendForce, China invested in about 25 projects aimed at expanding the domestic production capacity of third-generation semiconductors in 2020 (excluding GaN-based optoelectronics materials and devices). These projects totaled more than RMB¥70bn, a 180% year-on-year increase.

In particular, commercial products manufactured using silicon carbide (SiC) substrates (the most crucial materials in the third-generation semiconductor industry chain) are mostly based on 4" wafers in China, but the country is currently migrating to 6" wafers. Although the technology gap between China and its global competitors is fast narrowing, China is still noticeably inferior in terms of monocrystalline quality, resulting in a relatively low self-sufficiency rate of high-performance SiC substrates. TrendForce's data indicate that, as of first-half 2021, about seven production lines have been installed in China for GaN-on-silicon wafers, while at least four production lines for GaN power devices are currently under construction in China. On the other hand, China has at least 14 production lines (including those allocated to pilot runs) for 6" SiC wafers, notes TrendForce.

www.trendforce.com

AmpliTech to open MMIC chip design center in Texas by year-end

Bringing MMIC development fully in-house to complete development of signal amplifier 'systems on a chip'

AmpliTech Group Inc of Bohemia, NY, USA — which designs and makes signal-processing components for satellite and 5G communications networks, defense, space and other commercial applications — plans to open a monolithic microwave integrated circuit (MMIC) chip design center in Texas and has highly experienced MMIC design professionals on its team. The firm expects the facility to be fully operational by year-end.

Used in high-frequency communications applications (such as signal amplifiers and filters for mobile phones or satellites) and combining transistors and passive devices (such as resistors and capacitors) on the same chip, MMICs may be analog only, or mixed-mode analog and digital. They are also widely desired for power amplification solutions to service emerging technologies such as satellite payloads, phased-array antennas, and quantum computing. The reason for this shift in MMIC usage is that MMICs carry a smaller footprint, enabling them to be incorporated in a broader array of systems, while also reducing costs by eliminating the need for connectors and skilled labor. In mission-critical applications such as satellite communications, it is crucial that amplification components must exhibit extremely low noise interference to maintain a reliable signal while minimizing data corruption.

AmpliTech's low-noise amplifiers (LNAs) deliver what is claimed to be the lowest noise performance in the industry, at a consistent rate across frequencies, making communications systems efficient and reliable. By coalescing its amplification solutions into its MMIC product line, AmpliTech believes it will be able to provide greater value to its customers. To protect its unique designs and processes, the firm is working to secure patents for key elements of its MMIC designs and technology.

Over the past several months, AmpliTech started to implement several of its proprietary amplifier designs into MMIC components. The team's success, along with future development needs and opportunities, has made it clear that the firm's long-term growth and profitability would be best served by bringing its MMIC development efforts fully in-house. This strategic priority paved the way for the creation and launch of the design center, which will be owned by AmpliTech.

"The formation of the MMIC Design Center illustrates AmpliTech's continued focus on innovation and technology leadership, as well as our risk and cost-management disciplines," says CEO Fawad Maqbool. "We are building our company to meet the substantial demand we see for best-of-breed, low-noise amplifiers and other technologies across satellite communications, 5G/telecommunications, defense, aerospace, and other markets. Furthermore, we are confident that the capabilities, cost, form factor, flexibility and scalability of MMIC-based products will be very well received across our end markets," he adds.

"The global telecom, satcom and broader technology industry are planning huge investments to build out 5G connectivity that meets the true goal of 1Gb/s data transfer and for the launch of tens of thousands of additional low Earth orbit (LEO) or other satellites to support global data growth in the sky," Maqbool continues.

"Through our MMIC initiative, we are working to position AmpliTech as a key provider of signal amplification solutions that will enable communications networks to accomplish more at a lower cost. With our world-class MMIC designs, we endeavor to meet each customer's specific needs with highly performant, cost-effective and smaller form factor solutions with lower current consumption and better noise figures than current offerings," Maqbool says. "Our MMIC Design Center will also complement AmpliTech's ongoing new product R&D efforts by providing a pathway for translating them into higher-volume MMIC solutions."

www.amplitechinc.com

Guerrilla RF and X-Microwave partner on modular RF designs, reducing prototyping and simulation time

Guerrilla RF Inc (GRF) of Greensboro, NC, USA — a provider of monolithic microwave integrated circuits (MMICs) for wireless applications — has entered into a collaboration with X-Microwave LLC (a Quantic firm) to offer a series of new solutions that cut the development time associated with traditional component evaluation and signal chain prototyping. X-Microwave is a provider of RF and microwave modular blocks and, for the first phase of this joint effort, will feature 34 of GRF's products as drop-in X-MWblocks.

X-Microwave delivers a complete ecosystem of modular RF and microwave drop-in components, as well as a full suite of test and prototyping accessories. The initial offering of GRF-specific X-MWblocks will include RF low-noise amplifiers (LNAs), gain blocks, drivers, amplifiers with bypass, mixers and power detectors. More products will be added as they are released by GRF. Guerrilla RF's utilization of a common product footprint will help to accelerate this modular portfolio expansion.

"With catalog components representing a significant portion of Guerrilla's business, it became increasingly obvious we needed a 'force multiplier' in assisting customers with their designs. X-Microwave's modular approach is a great fit, since it mirrors our own strategy of providing core blocks that can be easily swapped in and out of designs as part of the optimization process," says Guerrilla RF's founder & CEO Ryan Pratt. "Now that our cores are part of the X-Microwave ecosystem, customers can easily piece together our solutions into full line-ups in hours versus weeks. This agile approach to system design is game changing for our customers; concepts can be optimized and proven out with real hardware at a fraction of the time it would normally take for traditional system designs," he adds.

"GRF's strong portfolio of amplifiers, mixers, power detectors and switches includes ideal building blocks for X-Microwave's prototyping and production system," reckons X-Microwave's founder & general manager John Richardson. "Virtually all of the targeted cores utilize a common footprint, making it exceptionally easy to proliferate our offering of customizable X-MWblocks. Guerrilla RF components are renowned for their excellent noise and linearity characteristics, making them ideal for systems requiring the very best RF/microwave performance," he comments.

www.xmicrowave.com

Guerrilla RF goes public in reverse merger and raises over $7m in private placement

Guerrilla RF has raised more than $7m in the initial closing of a private placement offering (led by existing investors) as well as the completion of a reverse merger transaction.

Founded in 2013, Guerrilla RF is a supplier of monolithic microwave integrated circuits (MMICs) that target wireless infrastructure applications, including 5G and automotive. The firm has a well-established revenue stream, with 2020 sales totaling $8.09m. Despite the disruption caused by COVID-19, Guerrilla RF's sales have grown by 990% over the past three years.

"Guerrilla RF's strategy is centered on developing and selling disruptive, leading-edge wireless semiconductor products. We recognize the need for an agile, focused approach to addressing the performance requirements of the wireless infrastructure market," says founder & CEO Ryan Pratt. "Our past success is a direct reflection of this strategy, and this additional capital will allow us to accelerate our development plans and enable us to aggressively expand within strategically targeted wireless applications."

Guerrilla RF has a portfolio of over 95 high-performance RF and microwave semiconductor devices. The existing product line includes ultra-low-noise amplifiers, gain blocks, driver amplifiers, mixers, RF switches, and linear PAs (power amplifiers) — the building blocks for mission-critical, performance-driven wireless applications, including 5G wireless infrastructure (macro and small-cell base stations), cellular repeaters/boosters, and automotive telematics such as SDARS/V2X/GPS/DAB, mission-critical military communications, navigation and high-fidelity wireless audio.

Guerrilla RF completed the reverse merger with Laffin Acquisition Corp, a public Delaware corporation, becaming a subsidiary of Laffin. Laffin subsequently changed its name to 'Guerrilla RF Inc' and will continue the historical business of Guerrilla RF.

All of the current members of Guerrilla RF's board of directors will remain as directors of the firm, including Ryan Pratt, David Bell, Greg Thompson, James E. Dunn, Samuel Funchess Sr., William J. Pratt and Gary Smith. In connection with the financing and the reverse merger, the firm agreed to pursue a listing of its common stock on the OTC Markets QB tier, subject to certain terms and conditions.

www.guerrilla-rf.com

Sivers Semiconductors to acquire 5G mmWave firm MixComm for $135–155m

Sivers to gain IP portfolio of RF/beam-forming chipsets for mmWave technologies including SiGe and RF-SOI

Sivers Semiconductors AB of Kista, Sweden (which supplies chips and integrated modules) has agreed to acquire fabless semiconductor company MixComm Inc of Chatham, NJ, USA (with design centres in Oregon and California) for an initial purchase price of $135m (about SEK1173m) on a debt-free basis, to be paid through a combination of $22.5m (SEK196m) in cash and $112.5m (SEK978m) in 39,335,664 newly issued Sivers shares (based on the 10-day volume-weighted average price of a Sivers share prior to signing of the agreement).

In addition, there is a performance-based earn-out of up to $20m (SEK174m) to be paid in new Sivers shares, based on the same share exchange ratio, tied to the achievement of certain commercial customer milestones within nine months from signing. The total stock and cash deal values MixComm at $135–155m (SEK1173–1347m).

Sivers now intends to effect a directed share issue to fund the cash consideration, transaction fees and expenses, and the ongoing working capital needs of the combined business.

Sivers has its two business areas: Wireless develops RF chips and antennas for advanced 5G systems for data and telecoms networks; Photonics develops and manufactures semiconductor-based optical products for optical fiber networks, sensors and optical fiber communications (Li-Fi).

MixComm is a millimeter-wave (mmWave) company developing solutions for emerging wireless applications and markets. In 2020, the firm introduced its first of a portfolio of mmWave products that deliver integration for 5G infrastructure and satellite communication.

Following completion of the acquisition, the enlarged Sivers group will have a broad joint IP portfolio of RFIC/BFIC (radio frequency/beam-forming integrated circuits) chipsets in a wide variety of mmWave semiconductor technologies, including silicon germanium (SiGe) and RF silicon-on-insulator (RF-SOI). This IP portfolio will span a broad spectrum of possible mmWave use cases such as unlicensed 5G, licensed 5G infrastructure, fixed wireless access (FWA) customer premises equipment (CPE) and satellite communications (SATCOM). The acquisition also enables the combined businesses to bring MixComm's industry-first Antenna-in-Package technology to all mmWave applications.

Through the combination, Sivers will increase its total number of design wins by about 70% to 44, as well as double the number of design wins expected to enter volume production within the next 12 months from eight to 16. MixComm currently has 18 design wins, including with a major tier-1 5G infrastructure customer, and a significant pipeline of potential new customer opportunities. MixComm has about 20 patents currently filed, granted or exclusively licensed and reported $1.3m in revenue in first-half 2021, with a strong sales pipeline for the coming year. MixComm estimates that its top three customers could generate about $70m in aggregate revenue for 2022–2024, and an incremental $70m in revenue from the tier-1 customer in 2025–2026. The acquisition is expected to drive synergies across both revenue and product development through the significant level of commercial and technical complementarity, as well as the broader geographic coverage.

Driven by the exponential growth of the wireless connectivity and telecoms sectors, the semiconductor industry is undergoing a significant technology-based transformation, notes Sivers. This is supporting the deployment of new technologies such as the implementation of 5G connectivity, providing opportunities to reach new levels of efficiency and customer value.

MixComm was founded in 2017 based on more than 10 years of development at Columbia University led by Dr. Krishnaswamy (co-founder & chief technology officer) through externally funded research projects totalling $94m across all projects and participants). The firm is an active US participant in the 5G BFIC (repeaters/base stations), SATCOM and radar verticals. Most employees hold a PhD, and the company is the only mmWave company selected to join the 5G Open Innovation Lab founded by T-Mobile and Intel. The flagship BFIC SUMMIT 2629 was the recipient of numerous 'Best Products' citations in 2020, including 'The Broadband Innovation of the Year' from the Mobile Breakthrough Awards. MixComm has established partnerships with minority investor GlobalFoundries for RF-SOI fabrication, packaging and test services, and with Richardson RFPD for distribution and logistics globally. MixComm is currently majority owned by its founders, employees and US-based Kairos Ventures (which identifies and commercializes scientific discoveries into viable businesses). Following the closing of the transaction, Kairos will become a significant shareholder of Sivers.

Completion of the acquisition is conditional upon (among other things) approval at an Extraordinary

General Meeting (EGM) of Sivers to authorize the board of directors to issue the consideration shares as well as regulatory approval by CFIUS (the Committee on Foreign Investment in the United States). The EGM is expected to be held in first-half November. Shareholders representing about 41% of the current outstanding voting rights of Sivers have committed, or indicated intention, to vote in favour of the transaction. The EGM will also propose the appointment of Kairos Ventures' chief operating & financial officer Todd Thomson to Sivers' board upon completion of the acquisition.

Completion is expected to take place by mid-Q1/2022 (subject to the fulfilment of all conditions).

The consideration shares would represent about 29% of Sivers' current outstanding share capital (assuming that the earn-out is paid in full). The shares issued to the sellers will be subject to a lock-up of 12 months for 50% of the consideration shares and 18 months for the remaining 50%.

"MixComm has in a short time period been able to build a very impressive customer list as well as sales funnel," comments Sivers' group CEO Anders Storm. "MixComm and Sivers have the same philosophy when it comes to building partnerships within the mmWave eco-system and, by adding these eco-systems together, we will create an even greater combined entity," he adds.

"Sivers and MixComm share a vision for mmWave's impact and potential. Combining with Sivers will accelerate that impact and amplify that potential," reckons MixComm's CEO Mike Noonen.

"In Sivers, we see a company that has the same philosophy as MixComm when it comes to technical excellence, out-of-the box thinking, and customer partnerships and service," says MixComm's co-founder & CTO Dr Harish Krishnaswamy. "The combined entity will not only match but, through our synergies, significantly exceed the exponential growth that the individual entities are currently seeing," he expects.

www.mixcomm.com
www.sivers-semiconductors.com

Naprotek buys RF/microwave assembly & test firm SemiGen

Naprotek LLC of San Jose, CA, USA, a provider of quick-turn electronics manufacturing, has completed the acquisition of privately held firm SemiGen Inc of Londonderry, NH, USA — an ISO- and ITAR-registered RF/microwave assembly, automated PCB manufacturing, and RF Supply Center. This increases Naprotek's capabilities to include advanced RF/microwave products, assembly and test services, and expands its reach across the USA.

Founded in 2009, SemiGen provides products and services to the RF/microwave community across markets including defense, SATCOM, space and advanced communications. Products include passive and active semiconductor components ranging from attenuators, capacitors, diodes, filters and resistors to complex thin-film circuits. Their manufacturing services span from RF/microwave and PCB assembly to performance testing and in-house ion beam foundry.

"We are excited to expand Naprotek's capabilities and geographical reach with highly engineered products and services from SemiGen," says Naprotek's president & CEO Daniel Everitt. "SemiGen brings

deep technical expertise in RF/microwave technologies, aligning perfectly with Naprotek's core offering... Our customers may now leverage full-service offerings across RF/microwave microelectronics, SMT, hybrid assembly and semiconductor products. This is a very important step in our growth strategy and was meaningfully informed by our customers' feedback and technology roadmaps," he adds.

"Together Naprotek and SemiGen offer a unique combination of technical skills, products, manufacturing services, and technology solutions," claims SemiGen's president Tim Filteau (who will continue to lead SemiGen). "This acquisition will enhance growth and enable innovation for our customers," he believes.

Naprotek, which was acquired by Edgewater Capital Partners of Cleveland, OH, USA in December 2020, is strategically growing its capabilities in high-quality, technically differentiated electronic technology solutions to better serve its customers and their high-reliability applications. Naprotek's rapid engineering change management process, commitment to quality, and personalized customer service are essential elements when time-to-market is critical, it is claimed.

"We plan to continue to add additional differentiated technology capabilities to the Naprotek platform to better service our customers within the high-reliability markets," says Edgewater partner Pete Ostergard.

www.semigen.net
www.naprotek.com

University of New Mexico creates first monolayer SiC

Isolation of 2D SiC from bulk SiC achieved via top-down wet exfoliation

Professor Sakineh Chabi of the University of New Mexico and her team recently discovered what is reckoned to be the first monolayer silicon carbide (Sakineh Chabi et al, 'The Creation of True Two-Dimensional Silicon Carbide', Nanomaterials (2021) 11(7), 1799). The newly discovered 2D SiC materials have a graphene-like hexagonal lattice, and average thickness of 0.25nm (pictured).

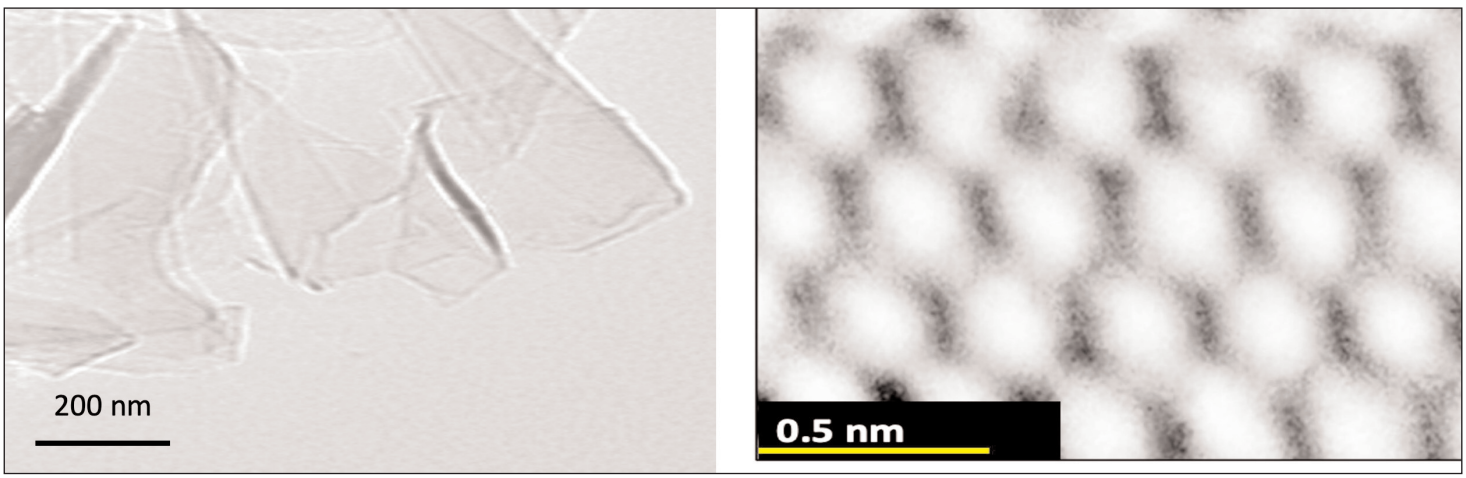
Theoretical studies have predicted that 2D SiC has a stable graphene-like honeycomb structure and is a direct-bandgap semiconducting material. Experimentally, however, the growth of 2D SiC has challenged scientists for decades because bulk silicon carbide is a strong covalently bonded material. Adjacent atoms of SiC bond together via covalent sp3 hybridization, which is much stronger than van der Waals bonding in layered materials. Additionally, bulk SiC exists in more than 250 polytypes, further complicating the synthesis process, and making the selection of the SiC precursor polytype extremely important.

Chabi led her team to demonstrate, for the first time, the successful isolation of 2D SiC from bulk SiC via a top-down approach (specifically, a wet exfoliation method). Unlike many other 2D materials such as silicene that suffer from environmental instability, the created 2D SiC nanosheets are environmentally stable, and show no sign of degradation.

2D SiC also shows interesting Raman behavior, different from that of the bulk SiC. Results suggest a strong correlation between the thickness of the nanosheets and the intensity of the longitudinal optical (LO) Raman mode. Also, the created 2D SiC shows visible-light emission, indicating its potential applications for light-emitting devices and integrated microelectronics circuits.

As a wide-bandgap semiconducting material with high thermal capability and high voltage breakdown, SiC is a leading material for high-power electronics, high-temperature applications, and quantum information processing. For example, SiC is considered to be the ideal material solution for the post-Moore era. However, the created 2D SiC material should outperform bulk SiC in several ways. As a result of reduced dimensionality, 2D SiC possesses an unusual set of electronic, optical and structural properties, such as a direct wide-bandgap feature and angstrom-level thickness, which are very important for next-generation semiconductors. Given the high maturity of SiC technologies (e.g. SiC wafers), the potential to convert 2D SiC to a real device is enormous, reckon the researchers.

https://me.unm.edu
www.mdpi.com/2079-4991/11/7/1799



Transmission electron microscopy images of the exfoliated two-dimensional SiC nanosheets. (Courtesy of Sakineh Chabi.)

NSF grants $18m to build national SiC research and fabrication facility at University of Arkansas

Grant to fund infrastructure, equipment and installation of technology for production of silicon carbide integrated circuits

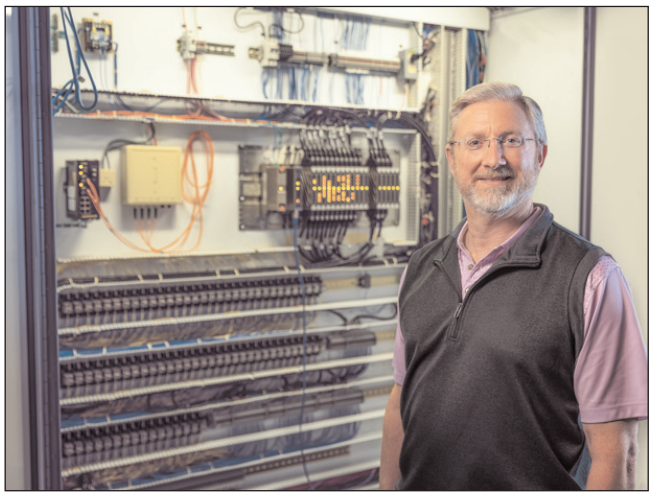
Engineering researchers led by Distinguished Professor Alan Mantooth have received $17.87m from the US National Science Foundation (NSF) to build and operate a national silicon carbide (SiC) research and fabrication facility at the University of Arkansas.

"The national impact of having a fabrication facility such as this is enormous," says Mantooth. "The country that leads the world in advancing silicon carbide semiconductor design and fabrication will also lead the race to market nearly all new game-changing technologies, including those used by the military, as well as general electronic devices that are essential to our economy," he adds.

The unique and open-access facility will fill a void in US production of integrated circuits made with silicon carbide, which is well suited for higher-temperature environments. Until recently, efforts to use SiC as a fully developed semiconductor have been stunted by the unavailability of high-quality silicon carbide wafers, says the University of Arkansas. Currently, all silicon carbide fabrication facilities in the USA are for internal use only, and US R&D of SiC integrated circuits relies on international fabrication.

The facility will provide domestic opportunities for prototyping, proof-of-principle demonstrations and device design. It will be the only openly accessible fabrication facility of its kind in the USA, meaning that its facilities and services will be available to external researchers.

The NSF funding will pay for infrastructure, equipment, technology installation and enhancements to existing facilities to accommodate new equipment. The funding will also cover three full-time staff members, a post-doctoral researcher for four years, and miscellaneous funds for set up and operation of equipment.



Professor Alan Mantooth of University of Arkansas.

Mantooth and other University of Arkansas electrical engineering researchers have decades of experience working with silicon carbide. The university research group is one of only a few capable of developing ICs made from silicon carbide, it is reckoned. Combining this expertise with cutting-edge equipment and infrastructure will enable the production of integrated circuits for lighter and faster electronic systems, which will also be more energy efficient and heat resistant.

The country that leads the world in advancing silicon carbide semiconductor design and fabrication will also lead the race to market nearly all new game-changing technologies, including those used by the military, as well as general electronic devices that are essential to our economy

Compared with industry-standard silicon, SiC is transforming the power electronics industry with its superior physical properties — an exceptionally strong physical bond providing high mechanical, chemical and thermal stability. Its wide bandgap and high thermal stability also allow SiC-based devices to function at extreme temperatures.

The facility will provide ICs, sensors and devices for military and industrial applications, such as solar inverters, electronics for cars — both electric and gas-powered — and systems used in heavy transportation and construction equipment such as bulldozers. Electronics developed at the facility will also enable systems used in geothermal and space exploration.

The facility will train the next generation of semiconductor researchers and engineers who can work in both the silicon and silicon carbide semiconductor industries. Students at all degree levels will be given research opportunities and be exposed to a high-need area of science and technology. The research will also engage underrepresented students in this new and burgeoning area of electronics.

Co-principal-investigators on this project are Greg Salamo (Distinguished Professor of Physics), Zhong Chen (associate professor of electrical engineering), Shannon Davis (business and operations manager in the Department of Electrical Engineering) and John Ransom (director of silicon carbide technology at SiC foundry X-FAB in Lubbock, Texas).

https://research.uark.edu

NREL's thermal management design boosts power density of SiC inverters for heavy-duty vehicles

PowerAmerica project with John Deere improves power density by 378% over silicon systems

As electric vehicles (EVs) grow in popularity, innovative technologies must meet the rising energy demand by significantly increasing system efficiency. Although light-duty EVs have been the focus for many electrification initiatives, heavy-duty trucks contribute 39% of greenhouse-gas emissions in the transportation sector.

Electrification of heavy-duty EVs is integral to decarbonization efforts, but vehicle components must be designed to handle more power while continuing to regulate operating temperatures.

A thermal management system developed by the US National Renewable Energy Laboratory (NREL) in collaboration with John Deere promises to significantly increase the power density of silicon carbide (SiC) inverters within heavy-duty EV applications. In heavy-duty applications, the power inverter is responsible for controlling the power flow between DC and AC electrical systems in order to run vehicle systems, accessories, and electric machines such as motors and generators. A high-efficiency inverter is a critical component necessary for environmentally friendly vehicle alternatives that reduce greenhouse-gas emissions such as hybrid, full-electric, or fuel-cell vehicles. Recent studies indicate that the improved inverter design boasts a 378% increase in power density over the previous silicon-only inverters.

"The key to NREL's design innovations for SiC thermal management is to improve the heat transfer coefficient, which allows this system to cool itself efficiently and continuously during operation with the engine coolant," says Kevin Bennion, NREL senior researcher and thermal management expert. "This design facilitates an unmatched power density and keeps the system running safely and efficiently."

In general, heavy-duty vehicles demand more power and far higher torque during operation than the average light-duty sedan. NREL's research in wide-bandgap power module thermal management helped to reduce component footprint, improve performance and efficiency, and support higher-frequency operation of SiC inverters for heavy-duty applications.

However, power outputs rely on the maximum temperature limits of the inverter's power module, which runs the risk of overheating and shutting down. As a result, NREL researchers developed a thermal management system to optimize system efficiency while regulating operating temperatures of the SiC modules directly cooled with 115°C water-ethylene glycol coolant. The technology developed by the NREL team has been extensively evaluated by the John Deere engineering team led by Dr Brij Singh.

"Starting in 2015, NREL's contributions have been extremely valuable in the successful execution and completion of impactful tasks in the DOE-funded PowerAmerica project with John Deere [`200kW 1050V_{DC} Bus SiC Converters for Heavy-Duty All-Electric Vehicles'," Singh says. "This project has resulted in the in-vehicle demonstration of the high-temperature SiC inverter technology."

Simplified solution to optimize heat transfer

A common strategy for the thermal management of EV inverters is to run a fluid coolant parallel over the component's surface to transfer heat and cool the system quickly. The advanced system designed at NREL incorporates perpendicular jet flow with mini-channel- and mini-manifold-based cooling systems to extract heat from the inverter and power module. This design enables a heat-transfer coefficient as high as 93,000 watts per square meter per degree Kelvin (W/[m^2-K]), which is over four times higher than existing commercial systems.

In addition, the NREL design uses the existing diesel engine cooling system for a simplified engine-coolant-capable architecture. Conventional heavy-duty inverters require a separate coolant system to operate successfully while ensuring the inverters' durability. By eliminating the need for a separate cooling circuit, NREL's novel thermal and thermomechanical research contributed to the inverter achieving a power density of 43 kilowatts per liter (a 378% improvement over baseline silicon systems).

Real-world improvements in fuel efficiency

The thermal and mechanical innovations in the SiC design significantly reduced the inverter footprint, creating a smaller and lighter system. The lighter overall weight and improved performance have clear benefits to fuel efficiency and operating costs.

"The SiC inverter technology stands out among all competing technologies in terms of energy efficiency, fuel economy, performance, and system integration," Bennion says. "With the premium cost of the SiC power converter, the market adoption of this new technology will likely take place where those factors are more important than the initial cost. We believe this inverter will have significant impacts in heavy-duty machinery, aviation, and military applications."

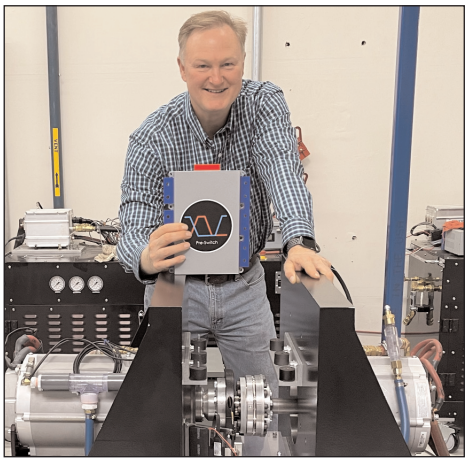
www.poweramericainstitute.org/member-projects

Pre-Switch moves to new headquarters

New facilities outfitted with 200kW dynamometer; firm ramps 100kHz e-mobility inverter reference platform

Pre-Switch Inc, a Silicon Valley-based start-up that has developed the first AI-based forced-resonant soft-switching technology enabling ultra-efficient DC/AC, AC/DC inverters running at 100kHz, has expanded into a new facility. The new premises will support the next phase of the firm's growth and accelerate the application of the Pre-Switch technology, which extends the range of e-mobility applications including electric vehicles (EVs), electric aircraft, and electric boats and other watercraft. The technology has been licensed and delivered via the CleanWave inverter reference design to leading e-mobility innovators around the world.

Pre-Switch's new facility in San Jose, California, has been outfitted with a 200kW dynamometer, a 250kW DC power supply and high-precision efficiency test stations that have been custom-built to precisely measure inverter efficiencies above 99%. The new resource will enable customers to experience the gains that can be achieved by running their inverters at 100kHz with virtually zero switching losses, and measure the motor efficiencies



Pre-Switch's CEO Bruce Renouard holding the next-generation 200kW CleanWave2 inverter reference platform (shipping in Q4/2021) in front of a 250kW dynamometer at the new HQ in San Jose.

that result from the higher-quality sine wave generated by the faster switching frequencies. "Inverter efficiency is vital, but in many applications, motor efficiency, especially at low torque where the motor mainly operates, is even more important," says CEO Bruce Renouard. "Only our soft-switching technology can deliver both, unlike hard-switching techniques which cannot get close to matching our system efficiency levels," he claims.

Just over a year ago, Pre-Switch began shipping its 200kW (space vector modulated) CleanWave evaluation inverter, announcing efficiencies exceeding 99.3% at 100kHz using only three discrete, low-cost 35mΩ silicon carbide (SiC) MOSFETs per switch location (significantly better than any other available system, it is claimed). The Pre-Switch controller analyzes multiple inputs on a cycle-by-cycle basis, making adjustments in real time to small, forced-resonant transistors, enabling perfect soft-switching. The Pre-Switch AI algorithm handles variations in system temperature, device degradation, changing input voltages and abrupt current swings.

To illustrate the benefits of the Pre-Switch approach, by utilizing the Pre-Switch technology an EV can see an increase in range of up to 12%, it is reckoned. To support this development activity, Pre-Switch has brought in more staff, strengthening the design team, in-house manufacturing, licensing and sales support — all located at the new San Jose headquarters.

www.pre-switch.com

II-VI Inc wins Excellent Partner Awards from Sumitomo

Engineered materials and optoelectronic component maker II-VI Inc of Saxonburg, PA, USA, which supplier silicon carbide (SiC) substrates and devices, has received two Excellent Partner Awards from Japan's Sumitomo Electric Industries Ltd (SEI) and its subsidiary Sumitomo Electric Device Innovations Inc (SEDI) for its fiscal year 2020.

SEI and SEDI each announced their award, respectively, on 8 September and 15 September, in recognition of II-VI's responsiveness and scalability, which contributed significantly to the expansion of Sumitomo's business.

"The awards reflect our strong partnership with Sumitomo and our ability to expand production capacity in response to their needs," says II-VI's CEO Dr Chuck Mattera.

"We will continue to strengthen the partnership between our valued suppliers and the Sumitomo Electric Industries Group and strive to further mutually expand our business," says SEI's president & chief operating officer Osamu Inoue.

II-VI and Sumitomo are also collaborating to establish a vertically integrated 150mm wafer fabrication platform to manufacture gallium nitride (GaN) on SiC high-electron-mobility transistor (HEMT) devices that will enable next-generation wireless networks. II-VI's 150mm compound semiconductor manufacturing, combined with SEDI's GaN RF device technology, will allow II-VI and SEDI to drive what is claimed to be best-in-class performance, greater scale and competitive costs for 5G RF solutions.

www.sedi.co.jp
www.ii-vi.com

Cree becomes Wolfspeed, trading on NYSE

Following a four-year transformation involving divestiture of two-thirds of the business and a repositioning of the company's overall core strategy, Cree Inc of Durham, NC, USA has officially become Wolfspeed Inc, focused on silicon carbide technology and production, with the support of a comprehensive, multi-channel integrated marketing campaign.

The firm has also transferred the listing of its common stock from The Nasdaq Global Select Market to the New York Stock Exchange (NYSE), trading under the new ticker symbol 'WOLF'.

For the past six years, Wolfspeed has served as the brand for Cree's business unit focused on silicon carbide materials as well as SiC and gallium nitride power-switching & RF semiconductor devices, for applications such as electric vehicles (EVs), fast charging, 5G wireless, renewable energy and storage, and aerospace & defense.

"We are now a pure-play global semiconductor powerhouse," says CEO Gregg Lowe. "The next generation in power semiconductors will be driven by silicon carbide technology, with superior performance that unleashes new possibilities and positive changes to the way we live," he adds.

Lowe joined the company in September 2017 with a vision and commitment to a more collaborative culture built on ingenuity and a mission to pursue a more efficient future. Now, with multi-year, long-term materials agreements totaling more than $1.3bn across several industries, a device pipeline that totals more than $15bn, and an increased production capacity 30x larger than previous facility plans, Wolfspeed says it is driving multiple industries through a shift from silicon to silicon carbide.

Wolfspeed's technology is key to the electrification of the drivetrain to support the shift to electric vehicles, wireless infrastructure to unlock the potential of smart cities, and power storage to enable broader adoption of renewable energy. Recent action from both private and public entities mandating more energy-efficient solutions accelerates an already strong demand for a more sustainable future with environmentally friendly technologies.

"Strategic additions in organizational leadership, the execution of an expansion plan that allows for significant increases in production, and a sharpened focus on our mission demonstrate we are bringing to life the vision previously laid out as we build on a 30-year history that gives us a marked and competitive advantage in the silicon carbide industry," reckons Lowe.

www.wolfspeed.com

ROHM and Zhenghai to form China SiC power module JV

On 1 October, power semiconductor maker ROHM Co Ltd and Zhenghai Group Co Ltd of Shandong Province, China have signed an agreement that in December they will establish the new China-based power module joint venture company HAIMOSIC (Shanghai) Co Ltd, to be owned 80% by Zhenghai Group subsidiary Shanghai Zhenghai Semiconductor Technology Co Ltd and 20% by ROHM.

Using silicon carbide (SiC) power devices, the new JV will employ about 120 staff engaged in the development, design, manufacturing and sales of power modules suitable for traction inverters and other applications in new energy vehicles. The deal enables the development of highly efficient power modules by combining the inverter technology of the Zhenghai Group companies, the module technology of both companies, and ROHM's SiC chips.

The modules to be developed are already scheduled to be used in electric vehicles, with mass production beginning in 2022.

Zhenghai Group and ROHM aim to work closely with the new JV to contribute to further technical innovation through the development and widespread use of SiC power modules.

"ROHM is a respected global leader in SiC devices. The establishment of a joint venture between ROHM and the Zhenghai Group to develop the SiC power module business will surely bring new changes to the power module market," believes Zhenghai Group chairman Bi Bohai. "Through more than 30 years of development, Zhenghai Group has accumulated rich industrialization experience in many industries such as rare-earth permanent magnet, regenerative medicine, automobile interior, and electronic information. The Zhenghai Group has determined to make the power module business a strategic business for the group, giving it the greatest support in terms of capital and human resources. Combining ROHM's advanced power device technology with Zhenghai's industrialization capabilities, we believe that the joint venture will contribute to the development of China's power module industry," he adds.

Zhenghai Group has a wide range of businesses in China, notes ROHM's president & CEO Isao Matsumoto. "As a leading company in SiC power devices, ROHM has been developing the world's most advanced devices and providing power solutions together with peripheral components," he adds. "The development of power modules in the new company will encourage the use of SiC power devices in new energy vehicles, which are gaining momentum in China, as well as play an important role in other application research."

www.rohm.com
www.zhenghai.com

Wolfspeed to develop and supply silicon carbide power devices for GM's future EV programs

GM's shift to using SiC for EV power electronics provides secure, long-term, domestically sourced supply

Wolfspeed Inc of Durham, NC, USA has announced a strategic supplier agreement to develop and provide silicon carbide power device solutions for Detroit-based General Motors' future electric vehicle programs. Wolfspeed's silicon carbide devices will enable GM to install more efficient EV propulsion systems that will extend the range of its rapidly expanding EV portfolio.

The SiC will specifically be used in the integrated power electronics contained within GM's Ultium Drive units in its next-generation EVs.

As part of the agreement, GM will participate in the Wolfspeed Assurance of Supply Program (WS AoSP), which is intended to secure domestic, sustainable and scalable materials for EV production.

"Our agreement with Wolfspeed represents another step forward in our transition to an all-electric future," says Shilpan Amin, GM vice president, Global Purchasing and Supply Chain. "Customers of EVs are looking for greater range, and we see silicon carbide as an essential material in the design of our power electronics to meet customer demand," he adds.

"Our agreement with GM further demonstrates the automotive industry's commitment to delivering innovative EV solutions to the market and using the latest advances in power management to improve overall vehicle performance," says Wolfspeed's CEO Gregg Lowe. "This agreement ensures long-term supply of silicon carbide to GM."

The silicon carbide power devices will be produced at Wolfspeed's 200mm-capable Mohawk Valley Fab in Marcy, New York. Launching in early 2022, what will be the world's largest silicon carbide fabrication facility will dramatically expand capacity for the company's SiC technologies, which are in increasing demand for EV production and other advanced technology sectors around the world.

The widespread adoption of silicon carbide as an industry-standard semiconductor for transportation supports the automotive industry's rapid transition to clean energy vehicles, notes Wolfspeed. Silicon carbide enables greater system efficiencies that result in longer EV range while lowering weight and conserving space. Wolfspeed adds that its technology is fueling electric propulsion systems across the entire voltage spectrum — from 400V to 800V — and beyond.

www.gm.com

Wolfspeed's 1200V SiC MOSFETs to be adopted by Shanghai's ZINSIGHT Technology

Silicon carbide to be used in advanced motor controller for air compressors in engines of fuel cell vehicles

Wolfspeed's 1200V SiC MOSFETs are to be used by ZINSIGHT Technology (Shanghai) Co Ltd — which focuses on electrical machine drive and systems based on SiC — in its advanced motor controller for ultra-high-speed air compressors in fuel cell vehicle (FCV) engines.

Consumer demand for zero-emission vehicles such as battery-electric vehicles (BEVs) and FCVs is expected to increase over the next decade as automakers and government entities shift focus away from production of internal combustion engine vehicles for a cleaner and more sustainable future. The use of silicon carbide in BEVs and FCVs results in significant cost savings, while high-efficiency power modules enable lower energy losses and higher range, says Wolfspeed.

"The air compressor is one of the most critical components in FCV engines, affecting both efficiency and volume," says ZINSIGHT's CEO Dr Shi Jingkui. "We partnered with Wolfspeed to harness its leadership in silicon carbide and ensure our technologies deliver best-in-class performance in speed, performance, efficiency, reliability and electromagnetic compatibility (EMC)."

Using Wolfspeed's 1200V silicon carbide MOSFETs, ZINSIGHT developed an ultra-high-speed motor controller for use in FCV air compressors. The 35kW HS35 solution is said to provide enhanced efficiency and energy production, achieving more precise motor control over the entire FCV speed range.

"This collaboration further diversifies our automotive pipeline as we bring silicon carbide technology to fuel cell vehicles," says Jay Cameron, senior VP & general manager for Wolfspeed Power. "Wolfspeed silicon carbide enables our customers to provide best-in-class efficiency as they help automakers lead the transition to a more sustainable future."

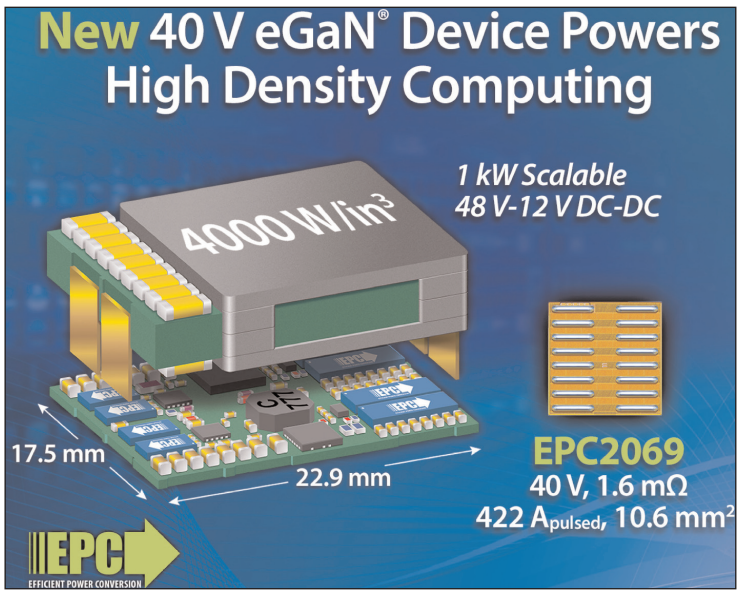
www.wolfspeed.com

EPC adds 40V, 1.6mΩ eGaN FET for high-power-density telecom, netcom and computing solutions

Efficient Power Conversion Corp (EPC) of El Segundo, CA, USA — which makes enhancement-mode gallium nitride on silicon (eGaN) power field-effect transistors (FETs) and integrated circuits for power management applications — says that it is advancing the performance capability of low-voltage, off-the-shelf GaN transistors with the launch of the EPC2069 (1.6mΩ typical, 40V) eGaN FET.

The EPC2069 is suitable for applications with demanding requirements for high-power-density performance, including 48V–54V input servers. Lower gate charges and zero reverse recovery losses enable high-frequency operation of 1MHz, and beyond, at high efficiency in a 10.6mm^2 footprint for state-of-the-art power density. The EPC2069 can support 48V–12V DC–DC solutions ranging from 500W to 2kW and exceed 98% efficiency.

The use of eGaN devices in both the primary side and the secondary side are required to achieve maximum power density >4000W/in^3.



According to Alex Lidow, EPC's co-founder & CEO, "The EPC2069 is perfectly designed for the secondary side of the LLC DC–DC converter from 40V–60V to 12V, which is becoming very common for the new 48V–54V input servers required for high-density computing applications such as artificial intelligence and gaming. This 40V device offers both smaller size and reduced parasitics compared with previous-generation 40V GaN FETs and at lower cost, thus offering designers both improved performance and cost savings."

The EPC90139 development board is a 40V maximum device voltage, 40A maximum output current, half-bridge with onboard gate drives, featuring the EPC2069 eGaN FETs. The 2" x 2" (50.8mm x 50.8mm) board is designed for optimal switching performance and contains all critical components for easy evaluation of the EPC2069.

Both the EPC2069 and EPC901 39 are available to order from distributor Digi-Key Corp.

The EPC2069 eGaN FET is priced at 2.5K u/reel at $2.73 each. The EPC90139 development board is priced at $123.75/each.

www.epc-co.com

EPC launches 50W, 12V to 60V eGaN FET-based synchronous boost converter

Efficient, simple, low-cost solution for laptop & PC monitor backlights

EPC has announced the availability of the EPC9162, a bi-directional buck or reverse-boost converter. This demonstration board features the 100V EPC2052 for the synchronous converter and the EPC2038 in the synchronous bootstrap FET circuit.

The EPC9162 is by default programmed as a boost converter operating at 12V input to 60V/50W output. However, the board can also be operated as a buck converter at 48V input to 12V/60W output. The fast switching speed of eGaN FETs significantly reduces switching losses for higher-efficiency operation, says the firm. To make it simple for a power supply designer to easily replicate this design, all supporting materials for this board including schematic, bills of materials, and Gerber files are available on the EPC website.

The peak efficiency from 12V to 60V/0.85A is 95.3% and the light load efficiency is 86% with only a 40°C temperature rise despite the small size of the eGaN FETs.

"In applications where light-load efficiency is critical, such as LED backlighting for laptops and monitors, the low switching losses of eGaN FETs provide high efficiency with very low temperature rise to prevent equipment overheating," says CEO Alex Lidow. "The synchronous boost topology is a simple, low-cost solution for power system designers."

The EPC9162 demonstration board is priced at $284.20 each and is available for immediate delivery from distributor Digi-Key Corp.

www.epc-co.com/epc/Products/DemoBoards/EPC9162.aspx
www.epc-co.com/epc/Products/eGaNFETsandICs/EPC2038.aspx

Efficient Power Conversion announces new textbook 'GaN Power Devices and Applications'

Book focuses on using GaN FETs and ICs in LiDAR, DC–DC conversion, motor drives and low-cost satellites

Efficient Power Conversion Corp (EPC) of El Segundo, CA, USA — which makes enhancement-mode gallium nitride on silicon (eGaN) power field-effect transistors (FETs) and integrated circuits for power management applications — has announced the publication of a learning resource for professional engineers, systems designers and electrical engineering students seeking the latest information on GaN technology and applications.

Since the 2019 release of the 3rd edition textbook, 'GaN Transistors for Efficient Power Conversion' (published by J. Wiley), there has been rapid adoption of GaN transistors and integrated circuits into a wide range of end-use applications such as robots, drones, artificial intelligence (AI) computers, AC adapters, autonomous vehicles (AVs), and even vacuum cleaners. The new book 'GaN Power Devices and Applications' (available for immediate delivery from both distributor Digi-Key Corp and Amazon) provides an update on gallium nitride technology and applications by leading experts.

With contributions from nearly 30 industry and academic experts, and edited by EPC's co-founder & CEO Alex Lidow, the book starts with two years of new information on technology developments, design techniques and reliability, beginning right after the publication of the 3rd edition textbook. In a practical sense, the book includes detailed discussion and analysis of the latest examples of actual GaN usage in power supplies, light detection & ranging (LiDAR), motor drives, and low-cost satellite applications.

"The information contained in this new textbook will help users fully understand, by examples, the incredible contribution that GaN devices can make to innovative power systems," comments Lidow. "In addition, QR codes have been inserted at the beginning of each chapter of the book so that readers can link to the very latest information on GaN as new it emerges," he adds.

www.epc-co.com/epc/Products/Publications/GaNPowerDevicesandApplications

Navitas China opens new office in Shenzhen

New facilities support growth in mobile fast-chargers, and spur GaN power IC adoption in data-center, solar and EV markets

Gallium nitride (GaN) power integrated circuit firm Navitas Semiconductor of El Segundo, CA, USA and Dublin, Ireland has opened a new office in Shenzhen, China (in the Baidu International Building, in the high-density Nanshan District), providing a 300% increase in capabilities to support what it describes as extraordinary revenue growth in that region.

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 control and protection circuits in a single SMT package. Since GaN is reckoned to run up to 20x faster than silicon, GaNFast power ICs are said to deliver up to 3x faster charging or 3x more power in half the size and weight, and with up to 40% energy savings compared with silicon chips. With over 130 patents issued or pending, and significant trade secrets including a proprietary process design kit (PDK), Navitas believes it has a multi-year lead in next-generation GaN power ICs.

The new Shenzhen facility offers significant engineering capacity for Navitas to co-develop GaN-based power systems with customers and design partners. The investment supports the rapid growth of GaN mobile fast chargers, as well as the firm's recently announced expansion plans to enable GaN-based data centers, solar installations and electric vehicles (EVs), which represent a multi-billion-dollar market opportunity for the company.

Data-center upgrades from legacy silicon to GaN are estimated to save almost $2bn/year in electricity costs, while GaN adoption in solar micro-inverters has been estimated by Enphase Energy to enable 10x faster switching and a significant reduction in costs. Per-vehicle, GaN content in passenger EVs is estimated to be $50 for on-board fast chargers, $15 for DC–DC converters, and then up to $200 for later adoption in traction drive.

"Alongside Hangzhou and Shanghai, the new state-of-the-art Shenzhen office is another, significant addition to Navitas China," says Charles (Jingjie) Zha, VP & general manager of Navitas China. "Chinese demand for next-generation power systems is growing exponentially and, with the world's only fully integrated GaN power ICs, Navitas is in a fantastic position to capitalize on that growth," he believes. "The new facilities demonstrate our commitment to support expanded customer demands in China."

www.navitassemi.com

Technology development partnership with BRUSA

Navitas and BRUSA HyPower AG (a provider of smart power electronic components and systems for motive and stationary applications) have announced a technology development partnership to speed adoption of Navitas' GaN power ICs to reduce the size and weight of power electronic components used in electric vehicle (EV) charging.

Dr Bernhard Budaker, vice president at BRUSA, recently introduced the firm's technology roadmap and how the company is planning to develop the next generation of on-board chargers (OBCs) and DC–DC converters adopting a new generation of GaN power semiconductor technology.

"BRUSA HyPower is convinced that gallium nitride will enable us to further improve our products," says Budaker. "The main advantages of Navitas GaN power ICs, are simplicity of driving high-speed switching performance, increased reliability and compact form factor. The technological insights provided by Navitas enable us to conduct advanced engineering projects," he adds.

"BRUSA's leading-edge insight and comprehensive review of next-generation technologies highlights how GaN power ICs help to overcome three obstacles to EV adoption: range anxiety, long charging time and cost," says Navitas' co-founder & CEO Gene Sheridan. "With up to 70% energy savings, we estimate up to 3x faster charging, and 5% longer range or a $500 saving on a typical EV battery. With a roadmap to address on-board chargers, DC–DC converters and traction drives, Navitas estimates a potential $250 of GaN revenue per EV in 2026."

Independent, international environmental research company DNV estimates that the adoption of EVs worldwide could be accelerated by up to three years by adopting GaN, saving 20% of road sector emissions each year by 2050 in the process.

www.brusa.biz

Navitas completes Live Oak II business combination

Value exceeds $1bn, after $320m raised for expansion to new markets of data-center, solar, energy storage and EV applications

Gallium nitride (GaN) power integrated circuit firm Navitas Semiconductor of El Segundo, CA, USA and Dublin, Ireland says that its common shares and warrants have begun trading on the Nasdaq Global Market (under the ticker symbols 'NVTS' and 'NVTSW'). CEO Gene Sheridan, accompanied by members of its leadership team, celebrated Navitas' first day of trading by ringing the bell at the Nasdaq MarketSite in New York.

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 control and protection circuits in a single SMT package. Since GaN is reckoned to run up to 20x faster than silicon, GaNFast power ICs are said to deliver up to 3x faster charging or 3x more power in half the size and weight, and with up to 40% energy savings compared with silicon chips. GaNFast power ICs are integrated in over 130 mobile chargers (more than all other GaN companies combined) and includes fast chargers from Xiaomi, Dell, Lenovo, LG, Amazon, OPPO, Anker, Belkin and dozens of other major OEMs. Over 30 million GaNFast power ICs have been shipped with zero reported field failures. With over 130 patents issued or pending, and significant trade secrets including a proprietary process design kit (PDK), Navitas believes it has a multi-year lead in next-generation GaN power ICs.

All of Navitas' co-founders are still with the company and celebrated at the Nasdaq podium, including CEO Gene Sheridan, COO/CTO Dan Kinzer, VP engineering Nick Fichtenbaum, and VP applications & technical marketing Jason Zhang. With over 130 patents issued or pending, and significant trade secrets including a proprietary process design kit (PDK), Navitas believes it has a multi-year lead in next-generation GaN power ICs, paving the way for expansion into consumer, solar, energy storage, data center and electric vehicle (EV) markets.

CEO Gene Sheridan rings the Nasdaq opening bell as NVTS begins trading after only seven years as a start-up.

The opening bell ceremony was broadcast live by TV networks including Fox, CNBC and Bloomberg, and live-streamed via Facebook to the entire Navitas team and investors worldwide, with local parties in Los Angeles, Shanghai, Shenzhen, Taipei, Manila as well as other Navitas locations.

"The first seven years have seen extreme growth in Navitas IP, revenues, customers… and we're looking forward to the next seven years, as we look to accelerate the transition to EVs, save billions in data center electricity costs and lower CO_2 emissions by up to 2.6Gtons/year by 2050," says Sheridan.

On 19 October, Navitas completed its business combination with Live Oak Acquisition Corp II — a publicly traded special-purpose acquisition company (SPAC) whose purpose was to effect a merger, capital stock exchange, asset acquisition, stock purchase, reorganization or similar business combination with one or more businesses. Live Oak II raised $253m in December 2020 and, prior to 20 October, its units, Class A common stock and warrants were listed on the NYSE under the tickers 'LOKB.U', 'LOKB' and 'LOKB WS', respectively.

The deal's 'PIPE' (private investment in public equity), originally oversubscribed and upsized at $145m on 7 May, had risen to $173m at closing, with all investments at the original terms. Additional capital from Live Oak II's cash-in-trust (net of redemptions) increased the gross proceeds raised in the transaction to more than $320m.

"The Navitas team comprehensively and confidently educated investors on the next-gen technology, the diverse markets and the detailed business model that makes GaN power ICs a great long-term story," comments Rick Hendrix, formerly Live Oak II's CEO and now a Navitas board member. "We're confidently locked-in with the Navitas senior management team for several years, which shows our commitment to this game-changing technology and our long-term investors," he adds.

Navitas expects that the additional capital will accelerate product development and expansion from an industry-leading position in GaN mobile fast chargers into consumer, enterprise, solar and electric vehicle (EV) markets, as well as providing funds for non-organic growth.

"From start-up to public company in just seven years, our goal at Navitas is to become the next-generation power semiconductor leader," says Sheridan.

www.navitassemi.com

EPowerlabs uses GaN Systems' 100V E-mode transistors to make DC/DC converter a third smaller and 50% lighter

GaN Systems Inc of Ottawa, Ontario, Canada (a fabless developer of gallium nitride-based power switching semiconductors for power conversion and control applications) and EPowerlabs of San Sebastián, Spain (an end-to-end engineering services firm helping OEMs and tier-1 firms to develop, test, validate and integrate power electronics in e-mobility applications) are collaborating to deliver a high-density DC/DC power converter (DDC48-1K) for a wide range of 48V mobility applications for consumer, industrial and automotive customers.

Using GaN solves space constraint challenges typical in electric mobility systems by providing more power in smaller form factors. The GaN converter is one-third smaller and 50% lighter than standard converters and has an overall efficiency of above 95%, it is reckoned.

"Creating a more sustainable world through e-mobility is at the heart of our mission, and leveraging technologies like GaN are vital in accelerating this move," says EPowerlabs' CEO Mikel Parel, "This is demonstrated by our GaN Systems-based converter, which reduces power losses by more than 50% compared to silicon-based designs in the market and is one-third the size of legacy converters."

With an input voltage range of 24–60VDC and rated at up to 1kW continuous power with an overall efficiency above 95%, the converter is said to offer a reliable and efficient solution for electric mopeds and scooters, electric vehicle (EV) systems and vehicles, and numerous transportation and robotics applications. Highlights are as follows:

- High efficiency of 97.5% at full load (a 4% improvement from similar types of converters currently available in the market);
- High power density of 28W/in^3 (compared with 10W/in^3 in converters using other topologies and switches);
- Lighter weight - the design without the case weighs only 345g, whereas an air-cooled DC/DC of the same power weighs around 750g.

EPowerlabs' GaN-based DC/DC converter uses GaN Systems 100V E-mode transistors (GS61008P), which leverage high-performance GaNPX embedded packaging and the high current, voltage breakdown and switching frequency of GaN. This combination allows high-power, low-loss performance, and thermal efficiencies in smaller, lighter power systems.

"It's wonderful to see customers like EPowerlabs using our GaN transistors to make vast power system improvements within the e-mobility space. These changes all play a part towards the goal of using less energy and creating a more sustainable future," says GaN Systems' CEO Jim Witham.

www.epowerlabs.com

GaN Systems' transistors used in HARMAN's InfinityLab 65W wall charger

GaN Systems' transistors are being used in Samsung Electronics subsidiary HARMAN's InfinityLab InstantCharger 65W.

HARMAN recently launched its line of InfinityLab small-sized and eco-friendly power accessories (which are made with 90% recycled plastic). Many of the power accessories feature GaN power semiconductors. HARMAN is used by brands including AKG, Bang & Olufsen, Crown, HARMAN Kardon, Infinity, JBL, Lexicon, Mark Levinson, and Revel.

Featuring two USB ports (one USB-C supporting 65W PD charging and one USB-A supporting 15W charging), the InstantCharger 65W can replace a laptop power adapter or multiple chargers. USB-C Power Delivery 3.0 ensures fast charging of USB-C laptops, smartphones and tablet devices. Performance tests show that charge times achieve 50% charge for the following devices: 30 minutes for an Apple iPhone 12, 40 minutes for a Samsung Galaxy S21, and 45 minutes for a MacBook Air.

The InstantCharger 65W is also lightweight and compact, and offers high efficiency, intelligent power distribution, and auto-protection features, meeting optimal charging needs. The charger comes in plastic-free, paper-based packaging that is fully recyclable.

"GaN is now the universal choice for chargers and adapters in the consumer market. And we see the same trajectory occurring in the data center, industrial, renewable, and electric vehicle markets," says GaN Systems' CEO Jim Witham. "This HARMAN GaN charger is another example where engineers have demonstrated their preference to GaN Systems' discrete transistors, which provide the best overall size and performance combination," he claims.

GaN transistor can deliver size, weight, efficiency and cost advantages for power electronics. To capture these benefits, designers can use GaN Systems' 65W QR Charger and 100W Dual USB-C Intelligent PD GaN Charger reference designs. These turnkey designs are said to provide a complete and simple-to-implement solution that shortens product development and time to market.

www.gansystems.com/evaluation-boards/gs-evm-chg-65wqr-gs1

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Imec and EUROPRACTICE announce winners of 2021 GaN-IC technology design contest

RWTH–Aachen wins, followed by ESAT-MICAS/KU Leuven and Leibniz University Hannover

Imec.IC-link (part of nanoelectronics research center imec of Leuven, Belgium) and the EUROPRACTICE consortium (which provides academic institutions and medium-sized companies with access to IC prototyping services, system integration solutions, training activities and small-volume production) have announced the winners of their 2021 GaN-IC design contest, which aims to encourage innovation in power electronics applications using imec's gallium nitride (GaN) technology for monolithic integration of power electronics circuits.

The prize-winning project 'High voltage half-bridge with integrated drivers and control circuits — all Gallium Nitride' was submitted by a team of researchers from the Chair of Integrated Analog Circuits and RF Systems of RWTH–Aachen University. Proposals submitted by ESAT-MICAS from KU Leuven and Leibniz University Hannover came second and third, respectively. The winning designs will be prototyped in imec's upcoming 650V GaN-IC multi-project wafer (MPW) run, starting in late October.

Monolithic integration of GaN-ICs unlocks full potential of GaN power electronics

The power electronics industry is looking for novel approaches to create higher-power, smaller and faster components that increase a device's power density. To do so, companies could resort to using GaN technology, yielding power devices that show a higher breakdown strength, faster switching speeds, and lower on-resistance. GaN technology allows power devices to significantly outperform silicon-based power chips in terms of system performance and efficiency, physical space specifications and packaging costs. Also, it works at higher temperatures. This has aroused interest from a wide range of industry sectors — from automotive and consumer electronics companies to providers of data-center solutions.

Today's GaN-based power chips have already pushed operating frequencies and efficiencies of switch-mode power supplies (SMPS) to record levels. Yet they are still mainly available as discrete components, while the key to unlocking the technology's full potential lies in reducing the parasitic inductances. Imec has responded to this challenge through the development of its GaN-on-SOI (silicon-on-insulator) technology, which allows the monolithic integration of logic and analog circuits with power components onto the same die. As such, parasitic inductances can be drastically reduced, resulting in a much improved switching speed.

Lowering access barrier to imec's GaN-IC technology

To make GaN-on-SOI devices and circuits more affordable and easily available to its customers, imec offers an MPW solution through EUROPRACTICE. In the MPW model, mask, processing and engineering costs are shared across multiple customer designs, typically delivering prototyping runs of 40 sample dies.

It is the same MPW solution that supported the GaN-IC contest launched recently by imec and EUROPRACTICE, targeting university teams that had never prototyped in imec's GaN-IC technology before.

The winning projects

The team from RWTH Aachen University proposed a circuit based on a high-voltage half-bridge output stage, featuring integrated drivers and a level-shifter. Potential applications include non-isolated buck converters supporting automotive electronics in lower-voltage systems for conventional or hybrid vehicles, or high-voltage circuits for fully electric vehicles.

Although multi-chip solutions combining GaN half-bridge ICs with integrated drivers and level-shifting are available from a limited number of suppliers, fully integrated GaN converters are not. The design proposed by the Aachen team features a very high level of integration for all GaN-ICs, integrating power- and control-circuitry, which eliminates the need for external controllers or drivers.

The design proposed by the KU Leuven team features an all-GaN direct AC/DC power converter IC, targeting large-volume products such as mobile appliance chargers and adapters, as well as integrated power converter regulators for automotive and consumer electronics.

Finally, the design from the University of Hannover takes advantage of GaN technology's higher switching frequencies to enhance the efficiency in off-line converters for home appliances and lighting in the 200W power range, which accounts for 60% of residential power consumption in the European Union (EU), helping to reduce power consumption.

Imec.IC-link is a complete ASIC solutions provider — serving companies as well as universities. Its services include design, chip manufacturing, assembly and test and qualification services. It realizes over 600 tape-outs per year across all of its supported technologies: CMOS, GaN-on-SOI, silicon and silicon nitride (SiN) photonics. Imec.IC-link is a TSMC Value Chain Aggregator, but also has long-standing relationships with other major semiconductor foundries. Imec.IC-link's services are available worldwide, via teams based in Europe, the USA, China, India, Japan, Brazil and Israel.

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Transphorm wins $1.4m DARPA contract

Project to develop N-polar GaN-on-sapphire for RF/mm-wave

Transphorm Inc of Goleta, near Santa Barbara, CA, USA — which designs and makes JEDEC- and AEC-Q101-qualified gallium nitride (GaN) field-effect transistors (FETs) for high-voltage power conversion applications — has been awarded a $0.9m contract with a $0.5m option by the US Defense Advanced Research Projects Agency (DARPA).

Contract W31P4Q-21-C-0009 commissions Transphorm to explore performance and cost boundaries for manufacturing an alternative nitrogen(N)-polar GaN solution for DoD and commercial radio frequency (RF)/millimeter-wave (mm-wave) applications. Transphorm will be responsible for delivering the epi-wafer technology, whereas sub-contractor University of California, Santa Barbara (UCSB) will fabricate the RF/mm-wave transistors.

The new project builds on Transphorm's history as well as ongoing work with the US Office of Naval Research (ONR) to establish a domestic resource and supply for RF GaN epiwafers, with emphasis on N-polar GaN, a technology that is proven to deliver greater benefits than today's more commonly used gallium-polar (Ga-polar) GaN for RF and mm-wave applications. Transphorm will explore the use of sapphire substrates to achieve greater cost efficiency for N-polar GaN solutions compared with conventional Ga-polar on silicon carbide (SiC) solutions. The work output is expected to yield a stable, high-quality thin-epi structure, with its capability established by the high-performance transistors.

Transphorm's team is targeted at meeting the following program objectives regarding N-polar GaN-on-sapphire:

- establish the overall value proposition;
- define the high-performance parameter space;
- define the viability of building the epiwafers.

"This project, coupled with our ongoing work to scale manufacturing with ONR support, is an incredible opportunity for Transphorm to grow its position as a premium RF epiwafer supplier, our second business vertical," says Dr Umesh Mishra, chief technology officer & co-founder. "The goal now is to take that foundation and enable our RF epi customers to achieve more efficient RF power for the dollar," he adds. "Sapphire is an attractive material choice for this purpose but has historically been dismissed as it has low heat conductance. We believe that, with innovative engineering, the program team can overcome that limitation."

The potential value of N-polar GaN in RF/mm-wave applications, and possibly for future power electronics, is appealing given its extraordinary efficiencies at frequencies as high as 94GHz, comments Transphorm. It is primed to directly benefit DoD systems along with applications for 5G, 6G and beyond, the firm adds.

Transphorm's board gains experienced general counsel

Transphorm's board has gained Cindi Moreland as an independent director.

Moreland has over 30 years of experience working as an attorney in the technical field. Having counseled public and private companies, both domestically and internationally, she is a recognized expert across the technology sector for her informed guidance on legal matters, such as SEC/SOX compliance, intellectual property and risk management, says Transphorm. She currently serves as the general counsel of Care.com, an online marketplace for care services and a subsidiary of IAC/InterActiveCorp. Previously, Moreland served as the VP, general counsel and chief compliance officer for Samsung Mobile USA. Prior roles include VP, general counsel, corporate secretary and chief compliance officer of Applied Micro, and general counsel of Motorola Inc's semiconductor unit. Moreland holds both a Bachelor of Arts and Juris Doctorate from the University of Mississippi.

"Cindi is well known in the industry for her legal expertise and corporate counsel," comments Transphorm's CEO Mario Rivas. "Having worked together previously while at Motorola Semiconductors, I have first-hand insight to the value of her guidance as well as the depth of her legal knowledge. She brings a wealth of complementary experience to Transphorm's existing board, which will play an important role as we continue to grow as a public company," he adds. "Together with the additions of Ms McFarland and Ms Smales earlier in the year, this appointment demonstrates our ongoing commitments to board diversification and further strengthening the breadth, talent, knowledge and background of our directors," Rivas says.

Concurrent with Moreland's appointment, Brittany Bagley has stepped down from Transphorm's board. The firm say that Bagley's resignation is not due to any disagreement relating to its operations, policies or practices, and primarily relates to a desire to dedicate more time to other existing full-time career commitments.

"I want to extend our utmost gratitude to Brittany for her loyal service and significant contributions over the past six years," comments Rivas.

www.transphormusa.com

Transphorm's strategic partner Yaskawa converts $15.6m of debt into common stock

Servo & industrial motor drive development partnership continues

Yaskawa Electric Corp of Kitakyushu, Japan (a manufacturer of low- and medium-voltage variable-frequency drives, servo motors, machine controllers and industrial robots with $3.7bn in annual revenues) has converted 100% of its $15.6m Transphorm convertible notes into common stock at $5 per share.

Transphorm and Yaskawa continue to work together in the previously announced multi-year partnership (expanded last December) for the development of GaN products for servo drives for robotics and motion control as well as a broader range of industrial and white-goods applications. Yaskawa intends to use Transphorm's GaN power device products for a variety of industrial power conversion applications, initially with servo motor and variable-frequency drive applications.

"We are pleased to become shareholders of Transphorm as we continue to collaborate in the development of highly reliable, higher-power GaN products, suitable for a variety of motion control applications," says Akira Kumagae, chief technology officer & managing executive officer of Yaskawa Electric. "The higher-frequency, highly efficient GaN power devices and modules that will be made possible with Transphorm's GaN FET solutions will also meet stringent system requirements like short-circuit protection ability," he adds.

"Transphorm greatly values its long-term relationship with Yaskawa and is delighted to add a worldwide leader in motion control and robotics such as Yaskawa as a strategic shareholder," comments Transphorm's co-founder & CTO Umesh Mishra. "Yaskawa continues to help shape key developments in Transphorm's GaN roadmap, resulting in high-performance power devices for industrial and motor control markets."

The conversion of the Transphorm debt also adds more than $17m of positive shareholder equity to the firm's balance sheet, based on fair market value estimates. Following this investment, Yaskawa will own about 3.1 million shares of Transphorm, representing an ownership stake of approximately 7%.

"The equity conversion significantly strengthens our balance sheet and is a key contributor toward the execution of the company's previously announced plans to uplist its shares of common stock to the NASDAQ," says co-founder & president Primit Parikh. "It also underlines the strength of Transphorm's leading high-voltage GaN platform with products ramping in applications ranging from 45W to 10kW with the highest levels of quality and reliability," he adds. "To date we have not seen any other competitive GaN platform cover this broad range of power levels or applications and that are actually in production, and many other existing offerings with GaN such as 'ICs' are typically limited to sub-500W."

www.transphormusa.com

IQE forms strategic partnership with GlobalFoundries

IQE's GaN-on-Si epi to be used in GF's Fab 9 in Burlington

Epiwafer and substrate maker IQE plc of Cardiff, UK has begun a long-term strategic collaboration with GlobalFoundries (GF) of Malta, NY, USA (which has operations in Singapore, Germany and the USA) to develop gallium nitride on silicon (GaN-on-Si) technologies for mobile and wireless infrastructure applications that should result in a GaN-on-Si offering at GF's Fab 9 facility in Burlington, Vermont, using wafers supplied by IQE.

Due to its unique material properties, gallium nitride is the material of choice for high-power, high-frequency applications, and the global deployment of 5G networks has relied heavily on its use. Future 5G systems, including mmWave, will address significant increases in data across mobile and digital ecosystems, supporting further growth for GaN-enabled solutions. Working together, GF and IQE aim to pool their expertise and facilitate the development of crucial building blocks for current and future communications systems.

"IQE's collaboration with GlobalFoundries marks a step change for us. It recognizes the quality of our market-leading GaN products and demonstrates how IQE's ever-closer customer relationships can bring more innovative products to market, at scale," says Dr Wayne Johnson, executive VP - Wireless & Emerging Products at IQE. "This is a unique opportunity to leverage the performance of GaN with the cost structure of high-volume silicon manufacturing. We look forward to working closely with GlobalFoundries over the coming years," he adds.

"GlobalFoundries continues to lead with innovative and feature-rich solutions for 5G," claims Dr Bami Bastani, senior VP & general manager, Mobile And Wireless Infrastructure at GlobalFoundries. "Our collaboration with IQE will enable us to deliver differentiated gallium nitride on silicon solutions that enable next-generation connectivity and user experiences that will help enable our customers' innovations."

www.globalfoundries.com
www.iqep.com

Cambridge GaN Devices named Tech Scale-Up of Year

CEO & CTO named Woman Entrepreneur and Academic Entrepreneur

Fabless semiconductor company Cambridge GaN Devices Ltd (CGD) — which was spun out of the University of Cambridge Department of Engineering's Electrical Power and Energy Conversion group in 2016 to develop power semiconductors using gallium nitride (GaN)-on-silicon substrates — has taken three titles at the Business Weekly Awards. The company's core business is to design, develop and commercialize power transistors and integrated circuits.

Following in the footsteps of former winners such as London Stock Exchange-listed cyber-defence company Darktrace (which was valued at about £2.5bn earlier this year upon its IPO), CGD has been named Technology Scale-up of the Year, with the founders also recognised in individual categories.

Chief executive officer Dr Giorgia Longobardi has been named Cambridge Judge Business School Woman Entrepreneur of the Year, which looks to recognize a female founder "who can demonstrate outstanding achievements in the last 12 months and who inspires and nurtures other women to excel".

Chief technology officer professor Florin Udrea has been named Cambridge Enterprise Academic Entrepreneur of the Year, which aims to identify "outstanding work by an academic as an innovator, founder or consultant in the past 12 months".

Operating in a market worth over $30bn, in March CGD completed its $9.5m Series A fundraising round, led by IQ Capital, Parkwalk Advisors and BGF. Using its proprietary ICeGaN technology, the firm is in the process of developing a range of energy-efficient GaN-based power devices to be deployed in key market segments such as consumer, switch-mode power supply (SMPS), lighting, data centers and automotive EV/HEV in 2022.

Since GaN-powered devices are significantly higher performing than state-of-the-art silicon-based device (enabling reductions in the size and weight of power converters, while producing energy efficiencies higher than 99%), CGD reckons that its transistors have the potential to transform the sustainability of everyday power devices, such as significantly reducing the energy losses and cooling requirements in data centers, slowing the drain of electric vehicles' batteries to increase distances travelled on a single charge, and harvesting more of the sun's energy to convert as much solar power into electricity as possible.

So far this year, CGD has been named 'DeepTech Investment of the Year' at the UKBAA Angel Investment Awards. The judges of the Business Weekly Awards this year included Dr Hermann Hauser (Amadeus Capital Partners co-founder), Hanadi Jabado (executive director of the Entrepreneurship Centre at Judge Business School), David Gill (managing director of St John's Innovation Centre), and Claire Ruskin (CEO of Cambridge Network), as well as judges from AstraZeneca, Mills & Reeve, Stansted Airport, PwC, and Barclays.

"The Business Weekly Awards wins are an enormous achievement and testament to the mission we are on to change the electronics market with innovative products that help to solve problems through world-class engineering," says Longobardi. "GaN-based power devices have an increasingly vital role to play in building a more energy-efficient world," she adds.

"By creating greener electronics, the drive towards net zero will be eminently more possible," says Udrea. "There is a more sustainable future in some of the most power-intensive industries and this has strengthened our belief and resolve that we're on the right track to realising it."

www.camgandevices.com

RF GaN firm Gallium Semi appoints VP of networks

Singapore-based Gallium Semiconductor — a supplier of RF gallium nitride (GaN) semiconductor solutions for 5G mobile communications, aerospace & defense and industrial, scientific & medical applications — has appointed Michael Guyonnet as VP of networks. He will be based in Toulouse, France, and oversee product teams across France, Netherlands and the USA.

"Michael brings a rare combination of technical and business expertise that will be critical in helping us deliver market-leading products for our 5G customers," reckons CEO Kin Tan. "Michael is highly experienced in the semiconductor and network communications industry, and we look forward to his contributions to our growth."

Guyonnet joins Gallium Semi from Renesas Electronics, a manufacturer of microcontrollers, analog, power and system-on-chip (SoC) products. He previously served in technical and marketing leadership roles at Ampleon, MACOM and NXP. He began his career as a design and modeling engineer at Freescale, and received his PhD and Master's degrees from Université de Limoges and a Bachelor's degree from Université d'Orléans.

"I look forward to working with Kin and the team in executing our technology and product strategy that addresses our customers' most challenging problems," says Guyonnet.

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Showa Denko agrees long-term silicon carbide epiwafer supply contract with Toshiba

Toshiba making SiC Schottky barrier diode & MOSFET power devices

Tokyo-based wafer manufacturer Showa Denko K.K. (SDK) has concluded a long-term supply contract with Japan's Toshiba Electronic Devices & Storage Corp, which makes silicon carbide (SiC)-based power semiconductor devices, to supply SiC epitaxial wafers for two and a half years (with an optional extension clause).

Toshiba has been developing and commercializing SiC-based power devices including inverters for railcars, while adopting SiC epiwafers made by SDK as the main material for SiC-based Schottky barrier diodes (SiC SBDs) and SiC-based metal-oxide-semiconductor field-effect transistors (SiC MOSFETs) .

SDK says that Toshiba concluded the long-term contract because it appreciates the homogeneity in properties (such as nitrogen doping) and the low surface defect density in SDK's SiC epiwafers. Based on improvement in performance of the SiC epiwafers, the long-term contract is expected to further strengthen technical cooperation between SDK and Toshiba. In addition, SDK expects that Toshiba's adoption of its SiC epiwafers will help it to expand its SiC epiwafer business further.

Claiming to be the largest independent manufacturer of SiC epiwafers, the Showa Denko Group says that it will continue to accommodate with rapid expansion of the SiC epiwafer market, contributing to the propagation of SiC power semiconductors that save energy through low power loss and less heat generation.

www.sdk.co.jp

Meister Abrasives introduces grinding wheel for SiC

Atomic-level step-terrace finishing precludes need for diamond

Meister Abrasives AG of Zürich, Switzerland — which designs and manufactures customized industrial superabrasive tools for high-precision grinding — has introduced the Ultra-Fine 6 grinding wheel, its latest technology for silicon carbide and other semiconductor processing solutions.

Having recognized the increasing need for grinding and polishing hard materials, Meister Abrasives developed the Ultra-Fine 6 (UF6) in the firm's own laboratory and honed in its test center. The new vitrified-bond ultra-fine grinding technology combines what is claimed to be unparalleled quality and exceptional performance to achieve results unseen until now. SiC wafers ground with Ultra-Fine 6 wheels are said to exhibit reduced crystal damage, a mirror-like surface and improved wafer geometry even on hard-to-cut materials, such as silicon carbide (SiC), gallium nitride (GaN), sapphire, LT (lithium tantalite)/LN (lithium niobate) and hard ceramics.

Meister Abrasives says that its Ultra-Fine 6 wheel achieves an atomic-level step-terrace finishing: the values obtained speak for a sub-nanometer average surface roughness and an incredibly low total thickness variation (Ra = 0.5nm and TTV <1µm). Surface qualities in the one-digit Angstrom range are achieved. The highly porous open structure of the wheel allows for an extremely low grinding force, causing the smallest subsurface damage and thus achieving ultra-smooth SiC surfaces and improved wafer geometry. Not only do the Ultra-Fine 6 grinding wheels achieve atomic-level step-terrace finishing but, due to their excellent self-dressing behavior combined with optimized grinding processing parameters, they also increase wafer throughput on any tool platform.

At the heart of that novel grinding technology is Meister Abrasives' proprietary bond-grit formulation, developed back in the 1980s, which allows for modifications not only of the grit but of the whole formula. Customizing the nanostructure allows Meister Abrasives to adapt to each surface condition, whether the start surface is saw, lasered, lapped or polished. The brand's expertise in varying the properties of the abrasive, the type of the bond and the engineering of the wheels allows it to make grinding wheels that suit any individual use.

By employing Ultra-Fine 6 technology, manufacturers of prime wafers and devices can minimize wafer processing steps and save a significant amount of processing time, claims Meister Abrasives. The achieved surface is so perfect that there is no need for diamond polishing, which is a slow and very costly process, says the firm. The technical impact of those novel wheels is that, rather than having lengthy processing times (as with lapping and diamond polishing), SiC wafers can be ground in less than ten minutes with fewer fabrication steps, completing the process in a minimum amount of time. The ultra-smooth surface profile allows manufacturers to fully cut diamond slurry costs, slash the cost of chemical mechanical polishing (CMP) and drastically increase throughput.

The long life and stable grinding current of Meister Abrasives' grinding wheels, combined with the achievable ultra-fine surface roughness, is a powerful fusion that is unique to the market, claims the firm.

www.meister-abrasives.com

Keysight and Taiwan's National Central University Optical Sciences Center establish wide-bandgap R&D and test lab

Joint effort to improve design and test validation efficiency of GaN and SiC applications in 5G and EV innovation

Keysight Technologies Inc of Santa Rosa, CA, USA and Taiwan's National Central University Optical Sciences Center (NCUOSC) have announced a collaboration to improve the design and test validation efficiency of gallium nitride (GaN) and silicon carbide (SiC) applications, accelerating the pace of 5G and electric vehicle (EV) innovation.

Since wide-bandgap (WBG) materials such as GaN and SiC offer rapid switching speeds, low loss and withstand high temperature and voltage characteristics, they are leveraged in consumer power products, fast charging, electric vehicles and rail transit, as well as 5G infrastructures and data-center servers. However, these advantages increase the complexity of design and testing.

NCUOSC successfully used Keysight's PD1500A Dynamic Power Device Analyzer/Double Pulse Tester (DPT) platform to establish a third-generation WBG semiconductor open laboratory to improve development and testing efficiency. As JEDEC (which develops open standards and publications for the microelectronics industry) continues to define the dynamic testing of WBG devices, standardized tests are starting to emerge. The PD1500A DPT determines the key performance parameters, which match all standards, such as turn-on/off and switching characteristics, dynamic on-resistance, dynamic current and voltage, as well as reverse recovery, gate charge and device output characteristics.

"Keysight is happy to work with NCUOSC to help engineering teams characterize, understand, integrate, deploy and drive innovations for next-generation semiconductor technologies," says Thomas Goetzl, VP & general manager of Keysight's Automotive and Energy Solutions business unit.

Reliable and repeatable measurements are critical to accelerating design and validation for new technologies, including wide-bandgap semiconductors, says Keysight. The PD1500A DPT intelligent functions - such as fully automatic parameter extraction software based on IEC and JEDEC standards, loop testing, voltage and current sweep testing, and automatic high-temperature testing - can help to drive future innovations, reckons the firm.

"Keysight's PD1500A DPT enables NCUOSC to reliably characterize wide-bandgap devices and effectively innovate GaN and SiC applications. Its safety protection, scalable and optional test fixtures deliver the flexibility we needed for future expansions," comments NCUOSC director professor Yue-Ming Hsin. "In addition to the PD1500A, we also set up the Keysight B1505A/N1265A Power Device Analyzer/Curve Tracer to serve the complete and crucial characterizations of WBG semiconductors. It's our pleasure to collaborate with Keysight and contribute to the ecosystem of 5G/6G and electric vehicles."

www.ncu.edu.tw/~osc
www.keysight.com

Axcelis ships full family of Purion SiC Power Series implanters to power device makers

Ion implantation system maker Axcelis Technologies Inc of Beverly, MA, USA says that in third-quarter 2021 it shipped its full family of Purion SiC Power Series ion implanters to several leading power device chipmakers in Asia and Europe.

The shipments include follow-on orders for the Purion H200 Power Series SiC high-current implanter and the Purion M Power Series SiC implanter, as well as a Purion XE Power Series SiC high-energy implanter, which is a new evaluation tool to a new customer.

The systems will be used in high-volume production of silicon carbide (SiC) power devices supporting automotive, mobile and Internet of Things (IoT) markets.

"The growing momentum in the electrification of the automotive industry is driving a strong demand for SiC power devices, and Axcelis is the only company with a complete family of ion implanters to support this transition," says executive VP of product development Bill Bintz. "Our leadership position in the power device market continues to grow due to the Purion SiC Power Series platform's common and flexible architecture, coupled with its highly differentiated silicon carbide process capabilities," he adds. "We look forward to supporting our customers' goals to improve power device performance and expand manufacturing capacity, by providing innovative, segment-focused Purion products that solve customers' high-value, high-impact emerging implant challenges."

www.axcelis.com

IQE selects Critical Manufacturing MES to integrate processes across global production sites

New manufacturing execution system part of IQE's core automation and digitalization strategy

Critical Manufacturing S.A. of Porto, Portugal (a subsidiary of ASM Pacific Technology) says that — following detailed technical discussions and evaluation based on its experience in the semiconductor industry, comprehensive functionality and extensive configurability — its manufacturing execution system (MES) has been selected by epiwafer foundry and substrate maker IQE plc of Cardiff, Wales, UK to replace legacy systems across its global business.

"The Critical Manufacturing MES has far-reaching capabilities to meet our production needs," comments IQE's chief operating officer Keith Anderson. "This strategic project will transform our production with enhanced integrated process control, real-time visibility of global operations, and improved production efficiency," he adds. "The system will support our goals for continuous process improvements, greater business agility, enriched quality assurance, and easier compliance."

IQE will be installing the new MES at all of its global production facilities. A core model will initially be deployed at its two facilities in South Wales, UK, and then the system will be rolled out to IQE's other global production sites in Massachusetts, North Carolina, and Taiwan. The configurability of the system means that IQE can use the same system model at all locations, providing it with standard processes and improved knowledge transfer across global sites.

"Our MES is specifically designed to handle highly complex processes and will enable IQE to continue to deliver world-leading quality with tight integration between applications and physical manufacturing equipment," says Critical Manufacturing's CEO Francisco Almada-Lobo.

IQE's epiwafer fabrication plant in Newport, South Wales, UK.

The MES gives IQE the capacity to readily reschedule production needs, taking into consideration all production factors such as equipment setup and throughput time, manpower and materials availability. With its ability to integrate processes and systems, IQE will be able to increase the level of automation throughout its facilities. This should lead to improved production speed, reduced errors, and less need for manual interventions, optimizing the utilization of IQE resources, it is reckoned.

"Our MES solution is highly modular to deliver all the capabilities IQE requires, integrated into a single, unified solution with user-configurable, intuitive graphical user interfaces (GUIs)," says Almada-Lobo. "Users will have access to support their daily process routines through a single application, ensuring they have the correct information to carry out tasks swiftly and correctly."

The MES will provide complete manufacturing traceability and visibility, ensuring that correct information reaches relevant users to enable informed, fast and error-free execution of processes. Advanced analytics and easy reporting tools will further support this digital backbone for IQE's business to reinforce strategic decision making and facilitate greater agility to respond to production or business disturbances.

The Critical Manufacturing MES supports smart manufacturing and is designed for connectivity to different protocols for legacy and new Internet of Things (IoT) devices and production systems. It is fully designed to adapt and evolve with IQE's future business demands.

"This is an exciting step for our business and part of our core automation and digitalization strategy," notes Anderson. "It gives us a platform to incorporate new technologies as they emerge and provides us with the capabilities to innovate cutting-edge products and deliver world-class service to our customers."

www.iqep.com
www.criticalmanufacturing.com

Veeco receives multi-system order for new dual-technology platform

Wafer dicing and wet cleaning combined into single platform for SiC-based power device making

Epitaxial deposition and process equipment maker Veeco Instruments Inc of Plainview, NY, USA has received a multi-system order from a leading semiconductor maker for its new ADS-800 SRD system.

Fully qualified for production in July, the new system combines wafer dicing and wet cleaning technologies into a small-footprint platform suitable for silicon carbide (SiC)-based power electronic devices. The systems will be used to accelerate production of power electronics used in vehicles.

"We are very excited about the adoption of our new ADS-800 SRD platform and the manufacturing challenges it solves for this key customer," says Adrian Devasahayam, senior VP, Product Management. "We were able to integrate our advanced dicing system and wet processing technologies to offer a truly unique solution that improves device performance, increases throughput and reduces cost of ownership. Our dicing capabilities and small footprint in particular enable a 25% cost of ownership benefit. We have received terrific feedback from this customer, and we are proud of the opportunity to solve difficult material challenges that will drive the future of electric vehicles."

A Veeco ADS-800 system

www.veeco.com

Oxford Instruments and Taiwan's ITRI cooperating

Compound semi collaboration targets development of supply chain for electric vehicles, 5G wireless and power converter technologies

On 24 September, witnessed by officials of Taiwan's Department of Industrial Technology (DoIT), Ministry of Economic Affairs (MOEA), HsinChu-based Industrial Technology Research Institute (ITRI) and the UK's Oxford Instruments plc signed an agreement for a cooperative research project on the development of next-generation compound semiconductors. The project is expected to complement the R&D capacities of both parties and help to develop a new industry supply chain for compound semiconductors in Taiwan to create new opportunities in the global market.

The MOEA has been active in assisting Taiwan's manufacturers in advancing core technologies associated with ultrahigh-frequency (UHF) components by providing key technology solutions and development platforms. It has also been dedicated to facilitating collaborations between Taiwan companies and global partners. For example, its International Industrial Innovative R&D Program and the Fast Track Program for clinical trials have attracted many cooperations and investments as well as the establishment of R&D centers in Taiwan. Up until the end of this April, a total of 18 applications have been received.

ITRI is an important stronghold of Oxford Instruments in the Asia–Pacific region, notes ITRI's executive VP Pei-Zen Chang. Both parties began cooperation on precision testing analysis 15 years ago and have achieved excellent results in multiple fields such as high-brightness light-emitting diodes (HB-LEDs), micro-electro-mechanical systems (MEMS), micro-LEDs, silicon photonics, and nano-analysis. "The collaboration with Oxford Instrument will enhance the growth of a next-gen semiconductor supply chain in Taiwan, allowing R&D to be implemented in system integration and multi-disciplinary innovation. This will further boost the industrial transformation and economy development of Taiwan," he reckons.

For both fundamental and applied research on compound semiconductors, many new technologies are coming through the UK's innovation-focused companies, remarks John Dennis, representative of the British Office in Taipei. Beyond this, the UK also has a number of key specialist companies providing equipment and services for semiconductor production, and Oxford Instruments is an example of this, providing high-tech products and services globally to industrial companies and scientific research communities including ITRI. The collaboration between Oxford Instruments and ITRI in compound semiconductors is expected to open the door to technologies including electric vehicles (EVs), 5G and other wireless technologies, as well as power converters in wind turbines.

Oxford Instruments' CEO Ian Barkshire points out that Oxford Instrument's R&D base established at ITRI in 2011 has allowed the firm to accelerate its technology program and better support its customers across Asia. With the new agreement, Oxford Instruments and ITRI aim to combine their innovation, technological and end-market knowledge to drive advances in semiconductors and power devices that will enable a greener, healthier, more connected, advanced and sustainable society.

ITRI VP & general director of its Electronic and Optoelectronic System Research Laboratories Chih-I Wu pointed out that ITRI has already developed gallium nitride (GaN) technology for application in high-frequency communications, and it has cooperated with universities on epitaxy technology and UHF communication components. "Based on Taiwan's key leading technology, its comprehensive industry chain in semiconductors, and ITRI's innovative R&D capabilities, the collaboration with Oxford Instruments on the development of compound semiconductors will help increase the yield rate of GaN's high-electron-mobility transistor (HEMT) component processing and improve the source charging power and transistor performance," he reckons.

www.itri.org.tw/eng
https://plasma.oxinst.com

Riber receives €1m order for MBE upgrade in Europe

Part of system to be replaced by new next-gen MBE412-based machine

Riber S.A. of Bezons, France — which manufactures molecular beam epitaxy (MBE) systems as well as evaporation sources and effusion cells — has received a major order (worth more than €1m) for MBE upgrade in Europe, involving the modernization of an MBE research and production machine.

To be delivered during first-half 2022, the order involves the replacement of a large part of an existing MBE system with a new next-generation MBE machine based on the MBE412 model.

The upgrade will enable the customer to modernize its semiconductor component R&D and production platform for photonics applications, especially in the field of telecommunications, says Riber.

www.riber.com

Montpellier's NanoMIR group orders Riber MBE system for antimonide research

Multi-chamber system to deposit III–V IR photonic materials on silicon

Riber S.A. of Bezons, France — which manufactures molecular beam epitaxy (MBE) systems as well as evaporation sources and effusion cells — says that it has received an order for a fully automatic, multi-chamber Compact 21 DZ research MBE system from the University of Montpellier's NanoMIR group, which specializes in antimonide-based (III-Sb) compound semiconductor materials.

NanoMIR is a research group of 'Institut d'Electronique et des Systèmes', which is a research laboratory of Université de Montpellier jointly operated by France's national center for scientific research CNRS (Centre national de la recherche scientifique). For the last ten years, nanoMIR has focused mainly on developing mid-infrared optoelectronic devices (lasers and photodetectors) based on gallium antimonide (GaSb), indium arsenide (InAs), aluminium antimonide (AlSb), indium antimonide (InSb), their alloys and their heterostructures.

The equipment order has been funded under the 'HYBAT' project (ANR-21 -ESRE-0026) by the Investments for the Future program (PIA), managed by the French National Research Agency (ANR).

The system comprises two chambers configured for the MBE growth of antimonide-containing compounds, and a third chamber for remote-plasma-assisted chemical vapor deposition (RP-CVD) of silicon germanium (SiGe). To optimize process control, the system will be equipped with Riber's new EZCURVE instrument, a metrology tool enabling real-time in-situ precision control and characterization of the MBE growth process. This multi-chamber system will be applied to the development of novel III-V infrared photonics materials deposited on silicon wafers and novel quantum structures (areas of strategic interest throughout Europe).

"The new Compact 21 DZ cluster will extend and reinforce our existing Riber MBE 412 and Compact 21 cluster capability to increase the range of possibilities we can explore in our research and development on mid- to long-wavelength infrared and quantum devices," says professor Eric Tournié, MBE group leader at the University of Montpellier. "Our existing Riber MBE installations have been exceptionally stable and reproducible over the short and long term; this is a pre-requisite to grow the complex III-Sb structures needed for our work. We are already familiar with the new EZ-CURVE tool, which we know is going to extend our reach in precision and perfection as we set out to grow ever more demanding device materials," he adds.

"This new order consolidates Riber's already unequivocal position as the global market leader in the supply of MBE equipment for optoelectronic materials containing antimonide," believes Riber's chairman Philippe Ley.

www.riber.com
www.nanomir.edu.

Picosun reports batch process results from Morpher ALD system acceptance runs

Uniformities of <1% (1σ) and single-digit particle levels reached for film materials including Al_2O_3 and SiO_2

Atomic layer deposition (ALD) thin-film coating technology provider Picosun Group of Espoo, Finland says that its PICOSUN Morpher ALD system has continued to demonstrate excellent batch process results in the latest acceptance runs performed for its customers in the global semiconductor industry. Uniformities of <1% (1σ) and single-digit particle levels have been reached in a number of acceptance runs with different film materials such as Al_2O_3 and SiO_2.

The Morpher system was launched in 2019 for up to the 200mm wafer markets. The tool's strength is the adaptability to the changing needs of different business verticals, from corporate R&D to production and foundry manufacturing. It enables fully automatic and high-throughput production of, for example, micro-electro-mechanical systems (MEMS), sensors, light-emitting diodes (LEDs), lasers, power electronics, optics and 5G components.

"The market showed great interest towards PICOSUN Morpher after the launch and it has now become a leading product for the sub-300mm production market," says Juhana Kostamo, VP, Industrial Business Area, at Picosun Group. "We have delivered PICOSUN Morpher to a variety type of customers, the latest including world-leading manufacturers that use the tool both for pilot and high-volume manufacturing of integrated circuits."

Earlier this year Picosun Group reported record-breaking batch film quality results with PICOSUN Sprinter, its new-generation tool for 300mm wafer markets.

www.picosun.com

5N Plus agrees long-term II-VI substrate supply deal with Samsung for next-gen medical imaging systems

Multi-year joint development program yields photon counting detector technology for CT imaging

Specialty semiconductor and performance materials producer 5N Plus Inc of Montreal, Québec, Canada has announced a long-term agreement with Samsung Electronics to supply engineered substrates based on II-VI semiconductor materials for the detector core of the next generation of medical imaging devices. The detector is based on photon counting detector (PCD) technology, and will be incorporated into computed tomography (CT) by Samsung's subsidiary NeuroLogica Corp of Danvers, MA, USA.

Market driver for PCD technology

The global market for medical imaging based on CT is estimated to over $5bn. The detector element comprises 5-10% of the cost associated with the device. Over 95% of the CT imaging devices produced today are non-PCD-based. The increased demand for enhanced diagnostics, radiation reduction and cost efficacy have made this market ripe for innovation, says 5N Plus. PCD technology is at the forefront of addressing the latent demands associated with this market. In recent years, the advances in product and process technologies have delivered PCD-based imaging systems with superior image quality and reduced radiation levels not achievable with the existing mainstream technology.

Collaborative innovation delivering breakthrough technology

Over the last several years, 5N Plus has been developing engineered substrates for high-performance detectors essential for applications in medical and security markets. These efforts have recently yielded a family of semiconductor substrates facilitating what is claimed to be unrivalled performance in both PCD-based CT imaging and various applications in the security market. Through its close collaboration with Samsung and NeuroLogica, 5N Plus has developed an engineered substrate product optimized to uniquely fulfill requirements for PCD-based CT medical imaging devices. The success of this program has prompted both parties to engage in a long-term supply relationship.

"5N Plus is uniquely positioned to become the leading global supplier of engineered substrates for PCD-based medical imaging applications," believes president & CEO Arjang Roshan. "We would like to thank Samsung and NeuroLogica for cultivating a collaborative ecosystem which not only fostered innovation but enabled its expedient implementation."

Expansion of specialty semiconductor value chain and product portfolio

Over the past several years, 5N Plus has expanded its value chain for specialty semiconductor materials through its site in St. George, Utah, utilizing these compounds to develop engineered substrates. These efforts have resulted in an array of engineered substrates facilitating what is claimed to be unsurpassed performance in customer applications ranging from PCD-based solutions in medical imaging to engineered substrates for infrared imaging and other applications within the security industry.

In early June, the firm announced that it is investing $8.5m in its Montreal campus to expand the development and manufacturing of critical and strategic materials (including those containing tellurium) for advanced II-VI semiconductor compounds and engineered powders. The investment is supported and has received funding from governmental agencies for about a third of the total investment.

Strategic alignment with AZUR acquisition

While 5N Plus has organically expanded its II-VI semiconductor value chain, its III-V semiconductor value chain has required a combination of organic growth initiatives and strategic investments. The firm is in the last stage of the regulatory approval process to acquire AZUR SPACE Solar Power GmbH. This acquisition is expected to be transformational for 5N Plus.

AZUR brings established businesses within III-V semiconductor materials which are complementary to 5N Plus' current activities. This, in combination with 5N Plus' expanding business in II-VI semiconductor materials, serves as a catalyst for future growth, reckons the firm. The synergies of AZUR and 5N Plus should result in a higher total addressable market beyond space and enable entry into larger markets such as high-power electronics, electrification, advanced communication and other areas in the security market.

www.5nplus.com
www.samsung.com

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Nitride Semiconductors granted micro-UV-LED related patents in Europe and USA

Efficiency boosted by using patterned sapphire substrate plus superlattice structure

Japan's Nitride Semiconductors Co Ltd (which was spun off from Tokushima University in 2000) says that patents regarding high-efficiency technology for micro UV(ultraviolet)-LEDs were granted to it in the UK, Germany and France on 8 September (European patent number 3644379) and in the USA on 5 October (US patent number: 11,139,342).

In collaboration with professor 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.

Regarding the latest patented technology, micro-LED displays are being actively developed by various companies (including Apple) as next-generation display technologies, superseding organic electro-luminescent (EL) displays (which have problems with durability). Since the light from conventional red, blue and green LEDs has different wavelengths, the compound semiconductor material differs depending on the color. Not only do the electrical characteristics differ but also the reaction speed and deterioration characteristics make it difficult to control the display. In addition, since the bandgap energy of the red LED is narrow, the electrical characteristics deteriorate due to micronization. Furthermore, since the material is brittle, it is difficult to reduce the size to 50μm or less, and each company is working on development.

The patented technology improves luminous efficiency in micro-LED chips with wavelengths of 385–400nm by reducing the chip size to 50μm or less, mainly by using a superlattice structure, and using a patterned sapphire substrate (PSS). Unlike LEDs of other colors whose luminous efficiency decreases due to micro-sizing, this patent suppresses the decrease in efficiency.

Micro-UV-LEDs can achieve full color by exciting red, blue and green phosphors. It is difficult and time-consuming to mount LED chips as small as wheat flour (20–30μm in size) on a TFT display board. By unifying the LED chips from three types (red, blue and green) to one type (UV-LED), not only mounting is easy but also current and voltage control is easy, says Nitride Semiconductors. Although it was said that the luminous efficiency of UV-LEDs is low, this high-efficiency technology can greatly improve the feasibility of micro-LED displays, reckons the firm.

www.nitride.co.jp

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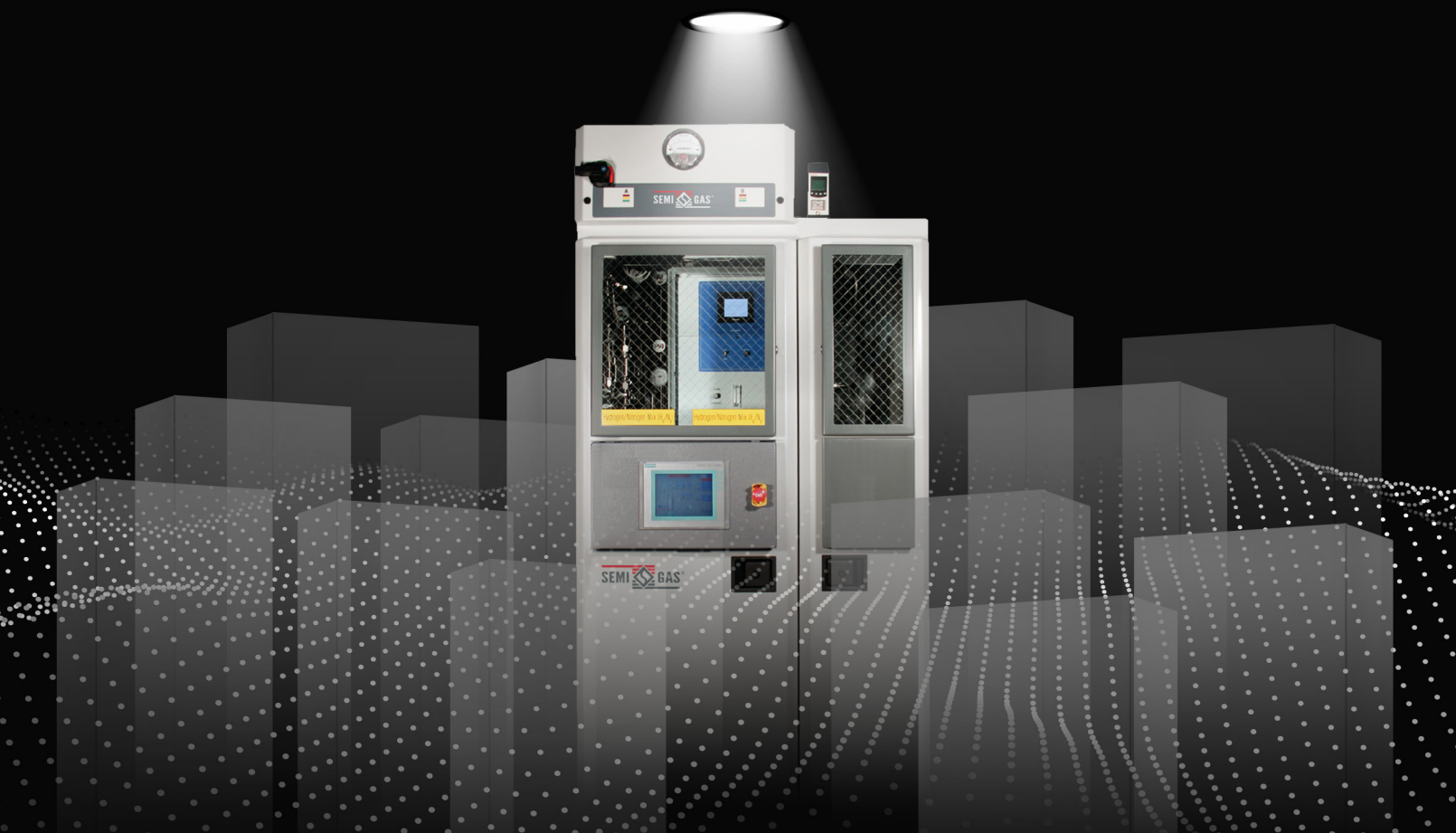

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Porotech creates first native-red InGaN micro-display

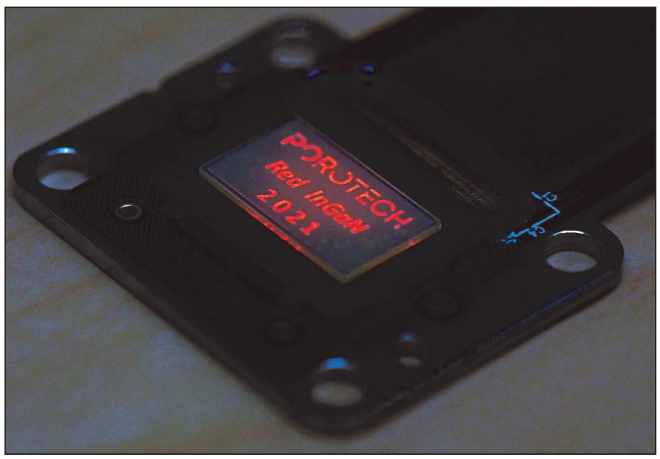
Development targeted at accelerating commercialization of AR glasses

Porotech (a spin-out from the Cambridge Centre for Gallium Nitride at the UK's University of Cambridge that has developed porous GaN material) has created what is reckoned to be the first micro-display based on native-red indium gallium nitride (InGaN) – with an active area of 0.55-inches diagonally and a resolution of 960x540.

In the past, it has only been possible to produce blue and green micro-displays using GaN-based light-emitting devices (LEDs) — with red emission relying on devices based on aluminum indium gallium phosphide (AlInGaP). But AlInGaP struggles at the small pixel sizes required by augmented reality (AR) glasses, so there is a drastic efficiency drop as the device size decreases. Also, to produce a full-color display, the light from different panels has had to be combined.

Porotech's native-red InGaN micro-LED means that, for the first time, all three light-emitting elements can be produced using a single toolchain, while removing the complexities of mixing devices based on different material structures.

"AR technology is set to be a game changer, and micro-LEDs are particularly vital for the advancement of AR interfaces," says CEO & co-founder Dr Tongtong Zhu. "In traditional liquid-crystal displays (LCDs) the image is a result of both modulating and filtering the light from a white back-lighting module. As such, most of the light created by the panel is wasted by the very working principle of the display. In addition to this inefficiency, the various filtering, diffusion and modulation stages of the LCD display impose limits on how lightweight the final display can be," he adds.



"Emissive display technologies, on the other hand, only produce the light that is required of them — allowing for the final devices to potentially achieve much higher efficiencies," Zhu continues. "Self-emitting displays based on inorganic semiconductors can also be produced in monolithic fashion, allowing them to be more easily scaled down than traditional LCD or organic semiconductor displays — allowing for smaller, lighter, brighter and reliable high-resolution displays to be made."

The stumbling block so far has been the need to combine light-emitting devices based on different material structures. One solution has been the use of prisms — but this is a relatively large and bulky approach. Stacking emitting layers on top of each other is another option but this results in the light emitted by each color coming from a different depth in the display — complicating the design of the optics and requiring very high precision in both the pitch of the LEDs in each display as well as the alignment of the various layers in the structure. Combining LEDs from different materials onto one panel horizontally is an alternative approach — but this requires very high precision in placing each individual LED element and other optical components.

"Porotech's new class of porous GaN semiconductor material is now redefining what is possible — enabling the creation of efficient and bright native-red InGaN micro-LEDs and micro-displays," says Zhu. "This has been the missing piece of the puzzle until now. As well as reducing costs, the bright native red can push the maximum achievable wavelength to 640nm and beyond — a first for micro-display visualization," he adds. "Our breakthrough is now set to accelerate the commercialization of AR glasses as well as heralding a new era of brighter, sharper, more vivid micro-displays for products such as smartphones and smartwatches."

www.porotech.co.uk

NCSU uses semi-bulk growth of InGaN templates to push emission wavelength into green gap

North Carolina State University (NCSU) has developed a process that makes use of existing industry-standard techniques for making III–nitride semiconductor materials but results in layered materials that can make LEDs and lasers more efficient.

A challenge for making LEDs and lasers has been that there was a limit to the number of holes that you can make in p-type III–nitride semiconductor materials created using metal-organic chemical vapor deposition (MOCVD). "We have developed a process that produces the highest concentration of holes in p-type material in any III–nitride semiconductor made using MOCVD," claims the paper's co-author Salah Bedair, a distinguished professor of electrical and computer engineering at NC State. "And this is high-quality material — very few defects — making it suitable for use in a variety of devices."

In practical terms, this means more of the energy input in LEDs is converted into light. For lasers, it means that less of the energy input will be wasted as heat by reducing the metal contact resistance.

To produce materials for use in LEDs or laser diodes, semi-bulk growth is used to produce indium gallium nitride (InGaN) templates, comprising dozens of layers of InGaN and GaN. These templates were used for the n-type region to reduce complications that arise with the growth of the quantum wells. The insertion of the GaN layer in between the InGaN layers in semi-bulk reduces defects due to the lattice mismatch between the semi-bulk template and the GaN substrate, as well as filling the pits that form on the surface.

In their new work, the researchers demonstrated that the semi-bulk growth approach can be used for the p-type layer in LEDs to increase the number of holes. This new approach is cost effective from a manufacturing standpoint, since III–nitride-based LED devices can be fabricated in one growth via MOCVD, without a lengthy processing time in between.

Using this technique, a hole density of $5x10^{19}cm^{-3}$ in the p-type material was achieved. Previously, the highest hole concentration in MOCVD-grown p-type III–nitride materials was about an order of magnitude lower.

The researchers also applied these InGaN templates as substrates for LED structures to address the long-running 'green gap' problem, where the LED's output deteriorates when emitting in the green and yellow part of the spectrum.

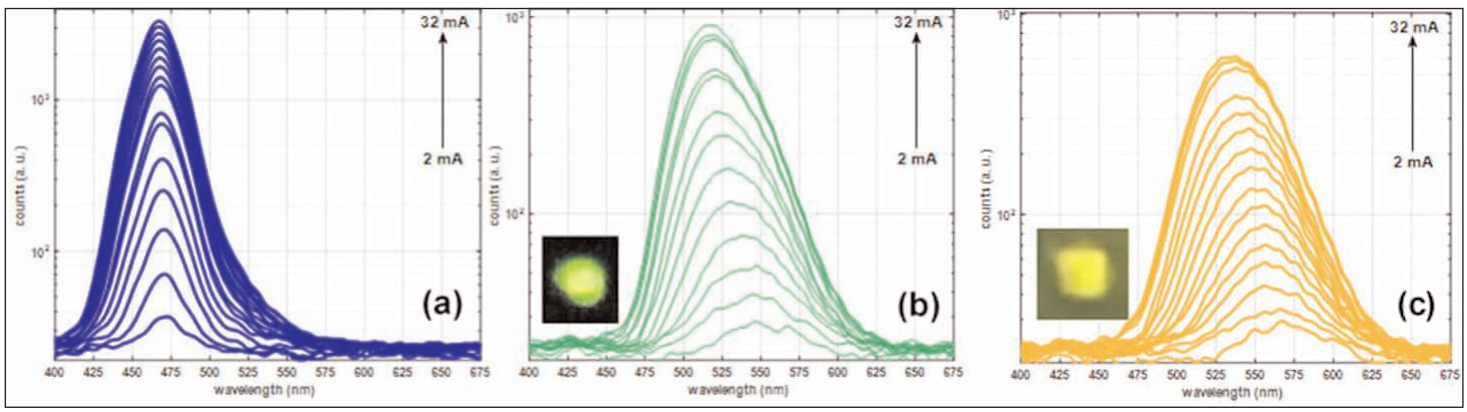
One of the main reasons for the green gap is the large lattice mismatch between the quantum well light-emitting part of the material when gallium nitride substrates are used. The researchers have demonstrated that replacing the gallium nitride substrates with InGaN templates results in improved LED performances.

The researchers compared the LED emission spectrum for the same quantum well emitting in blue when grown on GaN substrate and emitting either in green or yellow when grown on different InGaN templates. A 100nm shift in the emission wavelength was achieved due to the application of the InGaN templates.

The paper on improved efficiency, 'P-type $In_xGa_{1-x}N$ semibulk templates ($0.02<x\ 0.16$) with room temperature hole concentration of mid-$10^{19}cm^{-3}$ and device quality surface morphology', was published on 20 September in Applied Physics Letters. The first two authors are NC State Ph.D. students Evyn Routh and Mostafa Abdelhamid. Co-authors were postdoctoral researcher Peter Colter and Nadia El-Masry of both the US National Science Foundation (NSF) and NC State).

The paper addressing the green gap in LEDs, 'Shifting LED emission from blue to the green gap spectral range using $In_{0.12}Ga_{0.88}N$ relaxed templates', was published on 19 October in Superlattices and Microstructures. The first two authors are Abdelhamid and Routh. The paper was co-authored by Ahmed Shaker (a visiting scientist at NC State from EinShams University in Egypt).

www.ece.ncsu.edu



Electroluminescence measurements of (a) blue LED on GaN, (b) green LED on InGaN template, (c) near-yellow LED on InGaN template. The insets of (b) and (c) show the image of the emission at 1.5mA injection current.

Marktech launches first SWIR LEDs in chip-scale package

Marktech Optoelectronics Inc of Latham, NY, USA has introduced chip-scale packaged (CSP) short-wave infrared emitters (CSP SWIR LEDs, CSP short-wave IREDs, or CSP SWIR emitters).

The availability of SWIR LEDs or emitters in a chip-scale-packaged form factor is claimed to be an industry first. The compactness is such that a dozen or more of the CSP SWIR emitters would fit on the surface of a penny.

Compared with conventional short-wave IR emitters in surface-mount device (SMD) or transistor outline (TO) metal can packages, the next-generation CSP short-wave IR emitters have an extremely small footprint, consisting of a high-performance SWIR chip in a very compact 1.6mm x 1.6mm x 1.6mm cube-shaped SMD package with two lead pads. The flat lens design produces a wide or Lambertian radiation pattern with beam angles of 130°. The high-performance CSP short-wave infrared emitter products are available with wavelengths of 1040nm, 1070nm, 1200nm, 1300nm, 1460nm, 1550nm and 1650nm.

The 1020nm and 1720nm CSP short-wave IR emitters are available using conventional, lower-power-output SWIR chips. Marktech Optoelectronics can provide additional engineering and testing to deliver specific wavelengths and forward voltages as well as tighter power output bands through sorting or epi material customization. In machine vision and inspection, SWIR band-pass filters or longpass filters can be used in conjunction with SWIR light sources and SWIR cameras to adjust the bandwidth or pass only the SWIR light required for imaging — thereby increasing SWIR image contrast and resolution.

The major performance attributes of Marktech's chip-scale-packaged SWIR LED emitters include:

- up to double the power output versus older SWIR LED chips;
- compact CSP LED size that enables high stacking density on a printed circuit board (PCB);
- improved SWIR component reliability;
- increased SWIR component lifetime or mean time between failures (MTBF); and
- lower thermal resistance compared with plastic leaded chip frame (PLCC) SMD SWIR LEDs.

Multi-wavelength and multi-chip emitters and detectors

As well as SWIR LED emitters, Marktech Optoelectronics has additional infrared emitters within the near-IR (NIR) and mid-IR (MIR) bands. The firm has multi-chip packaging capabilities, which can combine various NIR and SWIR LEDs and detectors within the same package for multi-spectral applications such as LED LIDAR and optical ranging sensors. Marktech also provides complementary products such as short-wave IR InGaAs detectors for applications requiring both a SWIR light source combined with a SWIR sensor. A series of UV to SWIR emitters in a multi-chip package can provide a light source with a wide range of wavelengths for spectrometry and hyperspectral imaging. Marktech can bond from 2 to 144 die within the same package.

In summary, Marktech's multi-chip packaging processes can provide (within the same compact, surface-mount or hermetic package):

- multiple-wavelength emitters or LEDs with wavelengths of 255–1720nm;
- multiple spectral range detectors;
- combinations of multiple emitters and detectors.

Marktech Optoelectronics can also provide chip-on-board (COB) packaging where multiple chips populate a ceramic- or aluminium-cored metal-clad printed-circuit board (Al-cored MCPCB). Chip-on-board (COB) might be the best choice to maximize heat dissipation when a design requires very dense packaging of multiple emitters or LEDs. Aluminum-core COB boards are available in linear, ring and star-board formats.

ATLAS hermetic SMD packaging

Marktech's CSP SWIR LED joins a growing family of emitters and detectors in enhanced packaging such as the ATLAS-packaged line of LEDs, photodetectors and emitter-detectors. The ATLAS package combines the hermetic characteristics of a TO metal can packaged optoelectronic device with the great manufacturability associated with surface-mount devices (SMDs). ATLAS-packaged opto components are available in 3mm x 3mm and 5mm x 5mm sizes. The ATLAS hermetic SMD packaging is constructed using a glass-to-ceramic seam-welded process to provide water vapor and oxygen ingress protection.

Multi-wavelength LEDs or emitters and photodetectors can be packaged in the larger ATLAS package. ATLAS is a suitable package for applications requiring extreme sensitivity and high reliability because the seam-welded metal-to-ceramic seal prevents the ingress of water vapor and oxygen into the cavity holding the LED chips and photodetectors.

Using ATLAS package technology, Marktech can engineer hermetic SMD packages to hold and protect a wide range of SWIR LEDs, SWIR sensors and custom LED-sensor combinations to specific SWIR design application requirements in wavelengths ranging from 310nm to 2600nm. The firm has also begun to offer standard or catalog products in the hermetic ATLAS package, such as the MTSM1346SMF1-100 High-Speed InGaAs PIN Photodiode, which delivers IR to SWIR (600–1750nm) photodetection.

In summary, Marktech says that the compactness and high power output of its new CSP infrared LEDs, multi-chip packages and ATLAS hermetic SMDs can enable engineers to shrink and enhance their optoelectronic design projects. Their adoption in product development projects is expected to lead to breakthrough designs in many industrial applications.

www.marktechopto.com

Kaadas leverages ams OSRAM dToF sensor to deliver intelligent e-locks

High ranging accuracy prevent false triggering

ams OSRAM of Premstaetten/Graz, Austria and Munich, Germany is partnering with e-lock provider Kaadas of Shenzhen, China to introduce the latest intelligent e-locks. Providing distance information as an input to the facial recognition system, ams OSRAM's TMF8801 direct time-of-flight (dToF) sensor is incorporated into Kaadas' series of new e-locks (including the K20 and K20 Max).

As an entry-level product for smart homes and as a core element of future smart home security systems, the e-lock has become an indispensable component of the smart home ecosystem, says ams OSRAM. Following the early development of smart locks and their introduction to the market, today factors such as performance, safety, multi-functionality and intelligence have become critical attributes for e-lock products, the firm adds.

With an integrated vertical-cavity surface-emitting laser (VCSEL) infrared emitter, multiple SPAD (single-photon avalanche photodiode) light detectors, time-to-digital converter, and on-chip microcontroller for histogram processing, the direct ToF time measurement methodology used in the TMF8801 delivers higher accuracy and true-distance measurements, compared with distance averaging employed with an indirect ToF system, says ams OSRAM.

The TMF8801 has a sunlight rejection filter that as a result provides what is claimed to be excellent sunlight immunity capability with accurate ranging even in full sunlight. Meanwhile, it provides a high dynamic range with a measurement range of 20mm to 2500mm, which outperforms its ToF peers, it is reckoned. Either indoors or outdoors, the TMF8801 recognizes the presence of a person in diverse lighting conditions.

Leveraging the TMF8801's high ranging accuracy characteristics, ams OSRAM and Kaadas developed optimized algorithms to prevent the false triggering of the sensor in the e-lock caused by the detection of a person passing by the front of the door.

"The TMF8801 provides more accurate distance measurements to help Kaadas achieve more reliable, effective and energy-efficient e-lock solutions," says ams OSRAM's marketing manager Barry Guo. "It can be used for user presence detection to automatically wake up or put the system into a low-power sleep mode based on the presence or absence of a user," he adds.

"ams OSRAM TMF8801's precise ranging and excellent sunlight immunity capability make our e-lock work well in a variety of application scenarios," says Xian Li, executive VP at Kaadas.

www.kaadasgroup.com
www.ams.com/tmf8801

Princeton Infrared announces Phase II SBIR award to develop high-resolution SWIR electro-optical seeker

Imager using InGaAs/GaAsSb on InP substrate to span SWIR range

Princeton Infrared Technologies Inc (PIRT) of Monmouth Junction, NJ, USA – which designs and manufactures indium gallium arsenide (InGaAs)-based shortwave-infrared (SWIR) line-scan cameras, visible-SWIR science cameras, and 1D and 2D imaging arrays — has received a Phase II Small Business Innovation Research (SBIR) award from the Office of The Secretary of Defense to fund the development of a Megapixel high-resolution seeker with extended wavelength detection capability covering the entire SWIR range.

The camera will have a high pixel operability with a digital output at greater than industry standard frame rate at full resolution. The imager will be manufactured on indium phosphide (InP) substrates using the InGaAs/GaAsSb system, allowing for low cost and the ability to utilize modern III-V semiconductor processing. Additionally, the imager will be manufactured and hybridized at wafer scale to minimize cost.

"This research has huge benefits for both the defense and commercial markets," states president Martin H. Ettenberg Ph.D. "This research will lead to wide-spectral-width imagers in the SWIR which will provide for various hyperspectral imaging opportunities," he adds. "We are also excited to be leveraging new technology to bring much lower-cost imagers to the market through wafer-scale hybridization. These new imagers will require significantly less cooling, allowing reduced system size, weight, power and cost, which is important to both our military and commercial customers."

www.princetonirtech.com

NSF awards Michigan $1.8m to develop room-temperature, controllable quantum nanomaterials

Project could pave way for compact quantum computing, communications and efficient UV lamps for sterilization, air purification

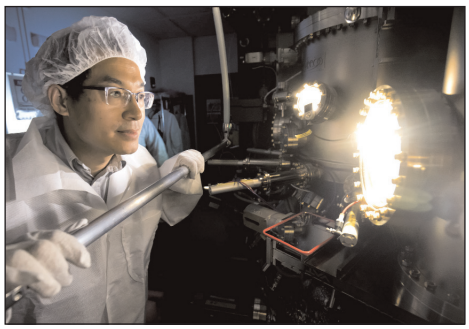
A team at the University of Michigan has been awarded $1.8m by the US National Science Foundation (NSF) for the project 'III–nitride Monolayers and Extreme Quantum Dots' to create quantum semiconductors that operate at room temperature. These could lead to the integration of quantum information and communications technologies with conventional computers — as well as advances in high-precision sensing and more sustainable ultraviolet (UV) lamps for sterilization and air purification.

"By demonstrating the controlled synthesis of such quantum nanomaterials, utilizing industry-standard processing tools, we hope to establish the material platform for scalable, next-generation quantum technology," says Zetian Mi, professor of electrical engineering and computer science and principal investigator for the project.

The properties of gallium nitride (GaN) can be tuned by replacing some of the gallium with fellow group-III elements boron, aluminium and indium to create 'extreme' quantum-dot arrays which, because they are perfectly ordered and emit light identically, could offer new levels of control over quantum light emission and interactions between quantum dots used quantum bits (qubits).

So far, researchers haven't been able to build perfectly ordered materials, controlling the location and size of each dot (necessary for controlling how the quantum dots interact when used as qubits). Mi believes that his team can overcome this through ultrahigh-temperature molecular beam epitaxy (MBE).

Because quantum nanomaterials differ from both classical semiconductors and conventional quantum materials, co-principal investigator Mackillo Kira (professor of electrical engineering and computer science) is leading the arm of the project developing a systematic quantum theory that will predict their behavior. This theory will enable researchers to figure out the available quantum states in the nanostructures, their light emission properties, and their capacity for quantum entanglement.



Zetian Mi produces a sample in the MBE machine. (Image credit: Joseph Xu, Michigan Engineering.)

The light emission is useful for reading and writing quantum information, but it can also be used directly for efficiently producing UV light. At present, UV sterilization and air-purification technology typically relies on mercury lamps, which contain toxic materials and produce a lot of waste heat. Mi believes quantum nanomaterials could make UV-C lamps safer and 100 times more efficient than what is currently available.

"This material is ideally suited for UV optoelectronics, including UV LEDs for disinfectant applications," Mi says. "Broadly speaking, 200–280nm is very important for disinfection purification applications. But there is no viable way to do that efficiently using conventional semiconductor technology."

Beyond UV lamps, Kira is particularly interested in quantum computing and communications. "We're talking about controlling the energy of light, and then what type of light is emitted which is also critical for quantum information applications, such as moving information long distances, quantum processing, information security, or highly sensitive sensing and detection."

Mi's group will use the theory to inform how they build the semiconductors to get the desired quantum properties. Then, researchers specializing in materials characterization will test the new materials to confirm their reliability and, by extension, the underlying theory.

"If we can make a few entanglement-based demonstrations, based on the new materials, that's a big step forward," says Kira. "That would be a founding moment of making semiconductors quantum-ready."

In addition to Mi and Kira, key members of the team include co-principal investigators Theodore Norris (the Gerard A. Mourou Professor of Electrical Engineering and Computer Science) and Parag Deotare (assistant professor of electrical engineering and computer science), who will test and evaluate the materials. In addition, Manos Kiopakis (associate professor of materials science and engineering) will help with the design and modeling of GaN structures. Industrial partners Sandia National Lab and the Air Force Research Lab bring extensive experience in materials characterization.

The project is part of the Materials Genome Initiative, a federal multi-agency initiative for discovering, manufacturing and deploying advanced materials twice as fast and at a fraction of the cost compared with traditional methods.

Some IP related to this work was licensed to NS Nanotech Inc., which was co-founded by Mi. The University of Michigan has a financial interest in NS Nanotech.

https://qstl.engin.umich.edu

FBH presents new diode laser and UV LED developments at Photonics Days 2021

Diode laser stack optimized for high output; UVC LED irradiation system for medical studies

Ferdinand-Braun-Institut, Leibniz-Institut für Höchstfrequenztechnik (FBH) of Berlin, Germany participated at the Photonics Days Berlin Brandenburg 2021 event (4–7 October), which involved a four-day conference (gathering experts from photonics, optics, microsystems technology and quantum technology) and a two-day exhibition (6–7 October) at the WISTA Science and Technology Park in Berlin-Adlershof.

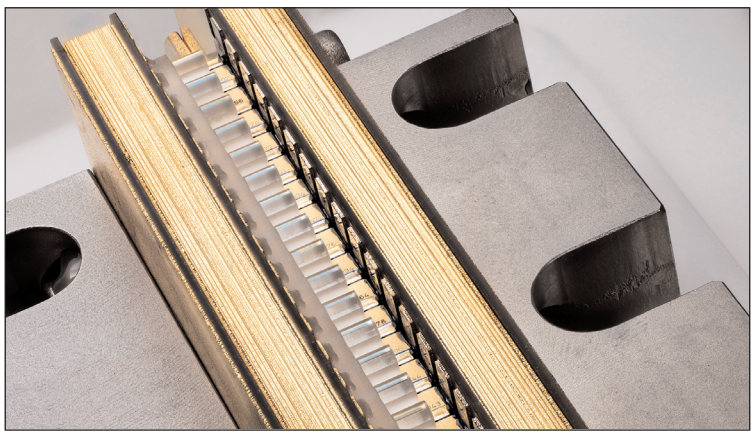
In Session 7.10 ('Advanced UV technologies & applications'), scientists from FBH presented the latest results on high-power diode lasers, UV LEDs (including corresponding irradiation systems for medical applications) and quantum technologies.

At its booth, FBH showcased a diode laser stack optimized for high output powers and a UVC LED irradiation system for medical studies. Moreover, an exhibit exemplifying the application of yellow-green laser modules in ophthalmology was displayed for the first time. FBH is developing the directly tunable laser sources in the wavelength range from 532nm to 561nm to 590nm with up to 2W output power in continuous wave operation. The compact laser sources have the potential to replace significantly larger dye and copper bromide lasers.

LED irradiation systems to fight multidrug-resistant pathogens and coronaviruses

FBH has developed UV LED-based irradiation systems, which are already being tested at the Charité, Universitätsmedizin Berlin and at the Greifswald University Hospital. In the future, this irradiation concept will be used to inactivate multidrug-resistant pathogens such as MRSA and coronaviruses including SARS-CoV-2 directly on humans in a way that does not harm the skin. Each system is equipped with 120 LEDs that emit at 233nm wavelength, developed jointly with TU Berlin. Due to optimized semiconductor epitaxy and chip process technology, these latest-generation LEDs can be operated with twice the current than previously — they deliver more than 3mW output power at a drive current of 200mA.

Furthermore, FBH has developed new silicon-based LED packages in collaboration with the CiS Forschungsinstitut für Mikrosensorik.



A diode laser stack with lenses, for use as a pump laser in industrial applications.

UV-LED irradiaition system comprising 120 233nm-wavelength LEDs, for inactiviating pathogens or coronaviruses without damaging the skin.

In addition to efficient heat dissipation, aluminium reflectors and a plano-convex lens ensure a beam angle of only 60º. This, in turn, increases the transmission (i.e. the light that the integrated spectral filter allows to pass through). The systems can irradiate an area of 70mm diameter with a homogeneity of more than 90%. The UVC light is free of skin-damaging wavelengths above 240nm and has an irradiance of 0.4mW/cm^2 — ten times more than that achieved by previous systems.

Record values for diode lasers — optimized for high output powers

FBH also presented its advances in high-repetition-rate pump lasers for future high-energy-class solid-state laser systems. The institute was able to increase the peak output power of its diode laser bars in quasi-continuous operation by up to four times while maintaining excellent efficiency. This reduces the cost in euros per watt — a key parameter for industry.

FBH builds the optimized diode lasers into stack modules, with improvements in packaging and optics. For example, a fiber-coupled pulsed pump laser source with 1kW output power at 780nm wavelength was demonstrated for the first time in a 1mm core fiber (previously 1.9mm). The passively cooled module was able to increase the duty cycle from 20% to up to 50% (10ms, 10–50Hz).

www.fbh-berlin.com

ROHM launches 75W high-optical-output laser diode for LiDAR, AGVs, robots

Japan-based ROHM has launched a 75W high-optical-output laser diode, the RLD90QZW3, for applications such as automated guided vehicles (AGVs) and service robots in the industrial equipment sector and robot vacuums in the consumer field that incorporate LiDAR (light detection & ranging) for distance measurement and spatial recognition.

In recent years, LiDAR has been adopted increasingly in a wide range of applications that need to be automated to precisely measure distance and for spatial recognition. For such market trends, there is a need to improve the performance of laser diodes when used as light sources to increase detection distance and accuracy while reducing power consumption.

ROHM says that it has met this market requirement by establishing original patented technology to achieve narrower emission width. This contributes to longer range and higher accuracy in LiDAR applications. In 2019, ROHM released the RLD90QZW5 25W laser diode, which has been adopted primarily in the consumer electronics sector. The latest product expands applicability in the industrial sector by providing higher optical output.

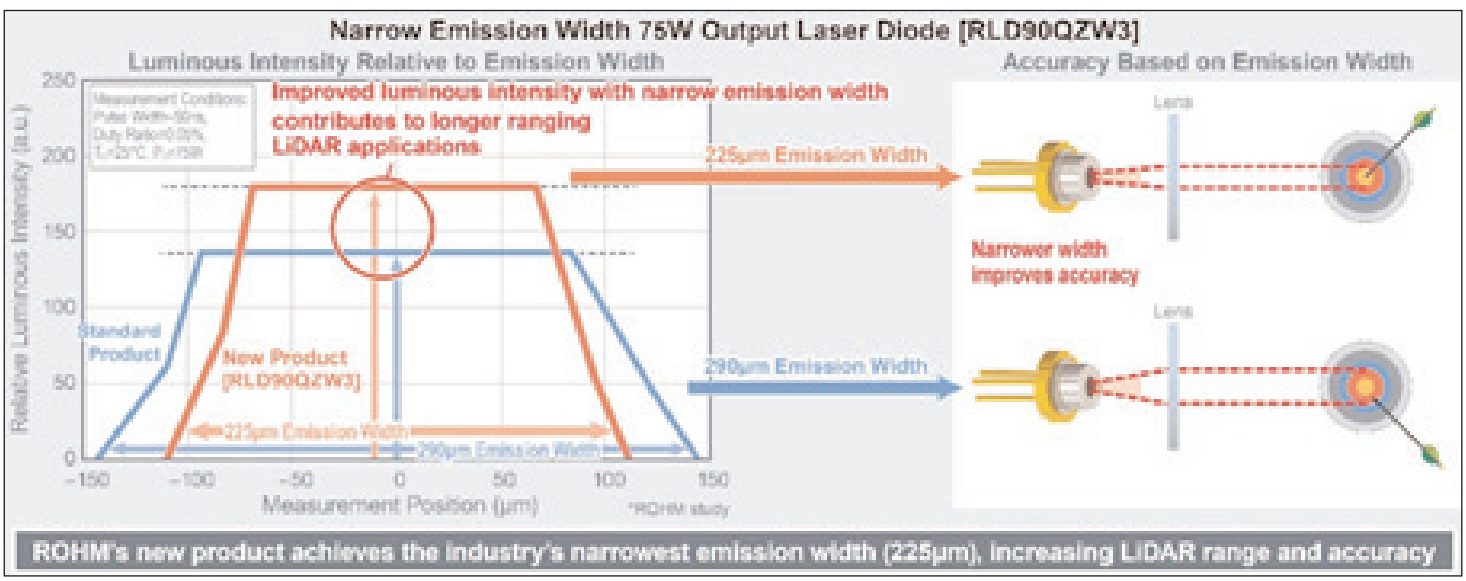
The new RLD90QZW3 is a 75W infrared high-optical-output laser diode designed for LiDAR used in distance measurement and spatial recognition in 3D ToF (time-of-flight) systems. Leveraging original device development technology allows ROHM to achieve an unprecedented emission width of 225µm at equivalent optical output. This is 22% narrower than conventional products, improving beam characteristics. At the same time, uniform emission intensity — together with low temperature dependence of the laser wavelength — ensure stable performance, contributing to higher accuracy and extended distances in various LiDAR applications. Moreover, a power conversion efficiency (which is a trade-off with narrow emission width) of 21% — the same as standard products (at a forward current of 24A and 75W output) — enables use without increased power consumption.

A broad range of design support data is also available on ROHM's website free of charge, including optical circuit simulation models and application notes on drive circuit design. This is necessary for integration and evaluation that supports quick market introduction.

ROHM is currently developing even higher-output 120W laser diodes for the automotive sector (AEC-Q102 qualified). Going forward, ROHM aims to continue contributing to achieving safer, more convenient LiDAR-equipped applications.

Online distributors for the RLD90QZW3-00A are Digi-Key, Mouser and Farnell, but the product is also scheduled to be released at other online distributors too.

www.rohm.com/opto-solutions



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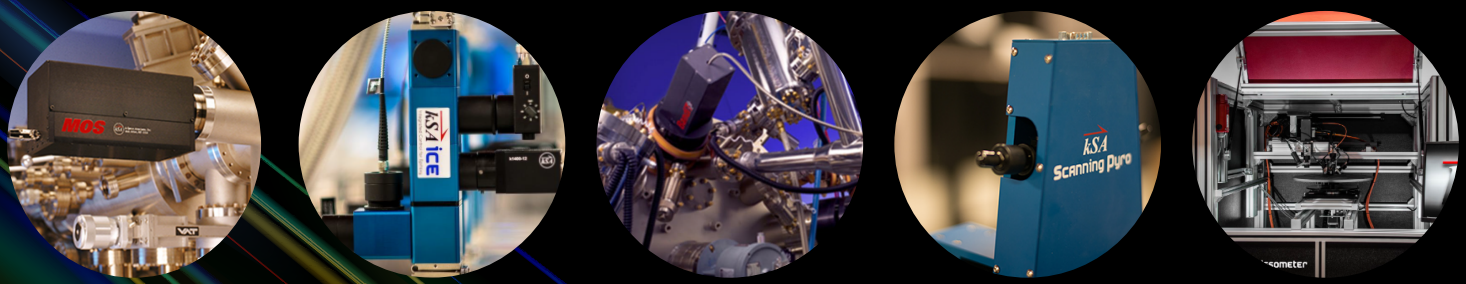

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Lumentum launches first 10W flood illuminator modules for next-generation 3D sensing

Industry-standard package with multiple fields of illumination, flexible peak power and integrated monitoring for closed-loop control and eye-safety functionality

Lumentum has announced what it claims is an industry-first 10W flood illuminator module that incorporates a high-performance three-junction vertical-cavity surface-emitting laser (VCSEL) array for consumer and industrial 3D sensing applications.

VCSEL illuminators are increasingly being used in high-performance 3D sensing applications ranging from biometric security in mobile phones to emerging industrial and consumer AIoT (artificial intelligence of things). AIoT, the convergence of artificial intelligence and the Internet of Things, benefits from 3D sensing since it is dependent on capturing vast amounts of high-quality data to enable efficient artificial intelligence processing.

To meet the needs of these growing numbers of applications, Lumentum's new 10W flood illuminator provides a high-power, high-efficiency integrated solution in easy-to-incorporate industry-standard packages that can be paired with time-of-flight sensors and infrared cameras.

"Lumentum's three-junction VCSEL arrays provide customers with highly differentiated performance in an embeddable flood illuminator module," says Ken Huang, director of product line management, 3D Sensing. "Compared to single-junction array modules currently in the market, Lumentum's multi-junction design achieves high peak optical powers and densities with increased efficiency and eye-safety functionality, all of which are critical for many emerging 3D sensing applications," he adds.

Lumentum's 10W consumer-grade flood illuminator modules leverage the firm's decades of experience in providing high-performance and field-proven VCSELs to the market in high volumes, including shipping over 1 billion VCSEL arrays into 3D sensing applications. The flood illuminator is available in a compact standard surface-mount package with a built-in eye-safety function. It integrates a three-junction VCSEL array, an optical diffuser, a ceramic substrate, and a photodiode, which enables closed-loop control. Customers can select three different fields of illumination, including 60°x45°, 72°x58°, and a wider 110°x85° to attain more depth of information.

Lumentum partners with driver integrated circuit providers to offer illumination solutions for different sensing applications. The firm also provides reference designs for custom driver circuits for its VCSEL arrays for special applications that may require higher powers and narrower pulse widths.

Lumentum chief information officer receives Leadership honor at 2021 Bay Area CIO of the Year ORBIE awards

Lumentum Holdings Inc of San Jose, CA, USA says that its senior VP of IT & chief information officer (CIO) Ralph Loura has been recognized as the recipient of the Bay Area CIO of the Year ORBIE award for Leadership.

"His reimagining of IT excellence and innovative approach have had a positive impact on transforming our business and culture, especially during the global pandemic where our IT systems and tools are critical enablers of success," comments president & CEO Alan Lowe.

Hosted by InspireCIO, the preeminent executive peer leadership network of CIOs, the annual Bay Area CIO of the Year ORBIE awards program honors CIOs who have demonstrated excellence in technology leadership. The global organization InspireCIO recognizes inspiring and transformational CIOs who have implemented products, developed solutions, and created business value for their organizations.

"Ralph is an intuitive connector and nurtures relationships and creates community with other leading CIOs," comments InspireCIO's founder Frank Bell. "Ralph understands that sharing ideas and best practices, what's working, and what to avoid, is a long-term winning strategy," he adds.

"I want to personally thank my amazing team at Lumentum who have been exceedingly agile and resilient in keeping the company connected and thriving during these unprecedented times," says Loura.

Led by an advisory board of CIOs from prominent organizations in the Bay Area, including Loura as an acting south chair member, the BayAreaCIO chapter sets the direction for the organization's events, membership and annual awards program. Recipients of the Leadership ORBIE award are nominated and selected by prior ORBIE winners based on their impressive career of successful technology leadership as a CIO, significant contributions to the business and technology community, and on inspiring personal, professional, and civic accomplishments.

www.lumentum.com

TRUMPF Photonic Components ships its 2 billionth VCSEL/photodiode product

Demand driven by smartphones and data centers; quantum computer chips to be fabricated next

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, has shipped its two billionth product. The firm says that the cumulative milestone has been enabled through significant growth in demand for VCSEL technology, driven by trends such as proximity sensing and 3D facial recognition technology in consumer smartphones, as well as rising demand in optical data communication in data centers.

In the last two years (since TRUMPF Group acquired the business from Philips), the company has invested more than €20m into the headquarters in Ulm. Production capacity has been expanded to support further business growth, both in existing markets as well as in new segments like quantum computing. TRUMPF says that it continues to drive the technology know-how that has been established for over 20 years to implement a Photonic Hub in Ulm.

"Reaching the milestone of two billion products confirms our strategy to build on strong partnerships with our customers. Next to standardized solutions, we are also developing customized solutions to address the application needs in its best way," Berthold Schmidt, CEO at TRUMPF Photonic Components. "Therefore, we are continuously investing into high-tech equipment and human resources to meet the rapidly growing global demand and to guarantee best-in-class infrastructure, as German leader in supplying VCSELs and photodiodes," he adds. Recently the firm said that, in future, quantum computer chips of TRUMPF Group subsidiary Q.ANT will also be fabricated in Ulm. To manufacture these quantum computer chips, further expansion of the existing cleanroom fabrication facilities in Ulm is planned.

Growing application areas

Consumer electronics comprise one of the main business fields for TRUMPF Photonic Components. The VCSEL products are a fundamental component of sensors that feature prominently in modern smartphones. They enable, for example, the functionality of face recognition, to switch off the display automatically, or to improve the camera autofocus.

Trumpf's 56G VCSEL arrays (top) andphotodiode arrays (bottom).

On the other hand, optical data communication is becoming increasingly relevant as the amount of data to be handled is increasing. That's why TRUMPF has recently been developing 100G solutions.

In addition, TRUMPF offers industrial heating systems, while VCSELs are used, for example, in e-mobility within the battery process chain (another growing business field).

The latest potential application field is quantum computing. With VCSELs becoming part of quantum technology there is huge potential for the laser diode technology, the firm reckons. These chips will be capable of creating, controlling and manipulating quanta.

"I am convinced that VCSEL technology drives the future not only of consumer electronics, industrial sensing or optical data communication, but also for autonomous driving and quantum technology," says Berthold Schmidt. "So VCSEL laser diodes will be in every home, every mobile device, every car and within industrial production," he reckons.

www.trumpf.com/VCSEL-solutions

Vector Photonics' CTO runner up at IET Achievement Awards for outstanding contribution to engineering

Richard Taylor honoured for pioneering work in developing PCSELs

Photonic-crystal surface-emitting laser (PCSEL) firm Vector Photonics Ltd of Glasgow, Scotland, UK says that, at the annual IET (Institution of Engineering and Technology) Achievement Awards, its chief technology officer Dr Richard Taylor was runner up for the Mike Sargeant Medal (won by Dr Adeayo Sotayo CEng, PhD).

The IET Achievement Awards were introduced to inspire and reward engineering excellence. As one of two 'Early Career Professional Medals' awarded by the IET to young engineers, the Mike Sargeant Medal is awarded for outstanding contribution to engineering, with candidates from all over the world, nominated by their peers. The medal recognizes world-class engineers at the start of their careers, for their exceptional impact on society and contribution to the advancement of engineering and technology.

Vector's CTO Richard Taylor.

Along with four other international candidates shortlisted for the award, Taylor was shortlisted for his pioneering work in developing PCSEL technologies. This led him in 2020 to found Vector Photonics, focused on commercializing the technology for fast-growing data communications, metal and plastic printing, light detection & ranging (LiDAR) and optical sensing markets.

www.vectorphotonics.co.uk

Vector's CEO is guest 'Opening up Photonics' panellist

Photonic-crystal surface-emitting laser (PCSEL) firm Vector Photonics Ltd (which was spun off from Scotland's University of Glasgow in March 2020) says that its CEO Neil Martin was a guest panellist for the inaugural 'Opening up Photonics' initiative at the SPIE Photonex Exhibition and Conference (29–30 September) at Glasgow's Scottish Event Campus (SEC).

The 'Opening up Photonics' initiative was a special event in the exhibition's conference program, set up to discuss the challenges and barriers faced by minority groups in the photonics industry. It was chaired by Alison McLure, head of the Institute of Physics (IoP) in Scotland, responsible for the advancement of physics education, research and application.

"As CEO of Vector Photonics, and previously CST Global, I have seen first-hand that attracting and keeping the best talent is critical to success as a business and an industry," comments Martin. "Driving accessibility and championing diversity will remove barriers and contribute to accelerating growth and developing new talent."

www.vectorphotonics.co.uk

III-V Epi supplying epi structures to Vector Photonics

Fast-turnaround, low-volume service aiding commercialization of hyperscale, data-center PCSELs

III-V Epi Ltd of Glasgow, Scotland, UK says that its fast-turnaround, low-volume supply service for molecular beam epitaxy (MBE) and metal-organic chemical vapor deposition (MOCVD) epitaxial structures has helped Vector Photonics Ltd to expedite the commercialization of its hyperscale, data-center photonic-crystal surface-emitting lasers (PCSELs). Spun off from the University of Glasgow in March 2020, Vector is focused on developing low-cost, high-performance lasers.

"III-V Epi's specialist, fast-turnaround, low-to-medium-volume compound semiconductor epitaxy production service has been needed in the photonics industry for some time," comments Vector's sales & marketing director Euan Livingston. "Major house-hold brands, with huge volume requirements, have been taking almost all available capacity. Fabless start-ups like Vector Photonics, which only require prototype and small-volume production runs, have been left struggling to secure supply and attain short lead times," he adds. "III-V Epi solves this problem, making it an ideal partner as we commercialize our PCSELs."

As well as Vector Photonics, others using III-V Epi's low-volume, fast-turnaround service include universities, the Ministry of Defence (MoD) and lower-volume telecoms, datacoms, additive manufacturing, light detection & ranging (LiDAR) and optical sensing manufacturers. III-V Epi says that they can also benefit from its wrap-around wafer design, product development, process optimization and complete range of test, metrology and characterization services.

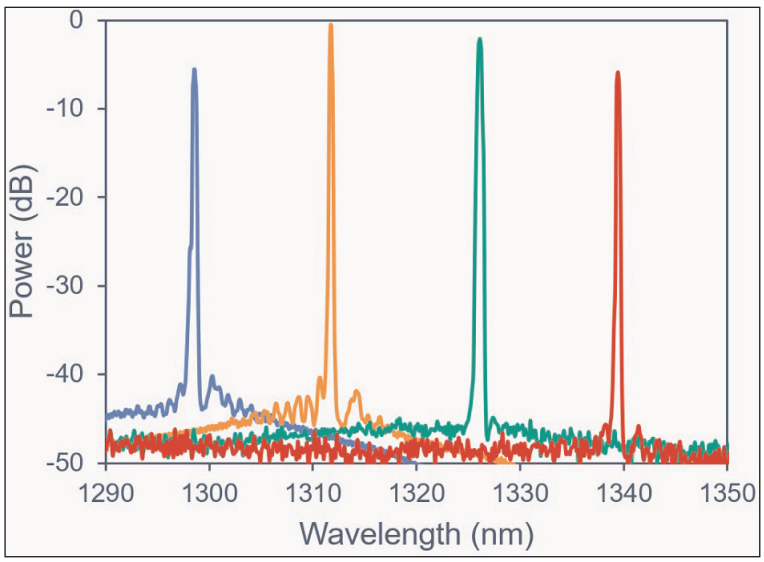
www.iii-vepi.com

Vector Photonics demonstrates four wavelengths on monolithic 1.3µm data-center PCSEL chip

Senior development engineer gives post-deadline presentation at ISLC

Vector Photonics Ltd says that senior development engineer Dr Calum Hill delivered a post-deadline presentation of the firm's latest paper 'Monolithic all-semiconductor PCSELs emitting at 1.3µm' at the 27th International Semiconductor Laser Conference (ISLC 2021) in Potsdam, Germany (10–14 October).

"Vector Photonics can demonstrate how a simple pitch change on a PCSEL [photonic-crystal surface-emitting laser] will allow multiple wavelengths on a single, monolithic chip," says Hill. "We have demonstrated the lasing of four neighbouring PCSELs, between 1298nm and 1340nm on the same wafer. Each channel is suitable for CWDM (coarse wavelength division multiplexing) datacoms applications and has a SMSR (side-mode suppression ratio) measurement greater than 35dB," he adds.



"The results validate Vector Photonics compound semiconductor technology and opens up new levels of flexibility in commercial laser design," Hill continues. "PCSELs already deliver the essential datacoms parameters of high speed and high power, combined with the low-cost packaging benefits a surface-emission-based device brings. This latest development offers even more flexibility and cost savings, as fewer lasers are required for equivalent results."

www.islc2021.org

Vector Photonics wins Royal Academy of Engineering award for outstanding contribution to engineering

Vector Photonics Ltd of Glasgow, Scotland, UK has won the Royal Academy of Engineering Colin Campbell Mitchell award for 'the greatest contribution to the advancement of any field of engineering in the past four years'. Previous winners of the UK-based award include the team that developed Ford's 1.0 litre EcoBoost engine; Oxehealth, non-contact health monitoring; and Optical Networks Group for advancements in optical communications.

Colin Campbell Mitchell OBE FRSE (1904-69) was one of Scotland's most accomplished marine engineers, credited for the development of the aircraft carrier steam catapult.

The Vector Photonics winning team, comprising Dr Richard Taylor, Dr David Childs and professor Richard Hogg, received the award for the Photonic-crystal surface-emitting laser (PCSEL), a low-cost, high-speed, high-power surface-emitting laser. "It's the biggest development in semiconductor lasers in 30 years," comments professor Steve Beaumont OBE, vice-principal for Research and Enterprise at the University of Glasgow, who nominated them for the award. "The engineering accomplishments of the team look set to revolutionize the field of photonics – an achievement deserving of this award alone — and, thanks to their varied, multi-disciplinary and complementary skillset, they have also managed to accelerate through the 'technology readiness levels' and create a rapidly expanding company."

Left to right: professor Richard Hogg, Dr David Childs and Dr Richard Taylor.

The team invented and is now commercializing the technology, which was initially focused on datacoms but is beneficial to multiple semiconductor applications. Vector Photonics was spun out of the University of Glasgow in March 2020. Within a year, the firm has secured private investment and innovation grants worth over £4m.

www.vectorphotonics.co.uk

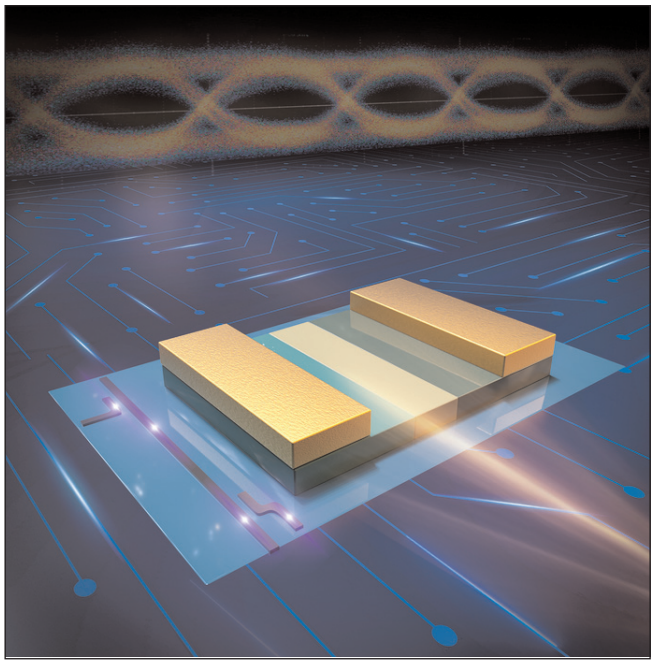
HKUST demonstrates high-performance photodetector grown on SOI for silicon photonics

Lateral ART precludes need for thick buffers

A team led by professor Kei-May Lau of the Department of Electronic and Computer Engineering at Hong Kong University of Science and Technology (HKUST) has developed a novel semiconductor deposition scheme and demonstrated high-performance photodetectors (PDs) grown on silicon-on-insulators (SOI) for silicon photonics (Ying Xue et al, 'High-performance III–V photodetectors on a monolithic InP/SOI platform', Optica, volume 8 (2021), issue 9 , p1204). The III–V photodetectors are qualified candidates for high-speed data communications in silicon photonics. The results point to a practical solution for the monolithic integration of III–V active devices and silicon-based passive devices on the SOI platform in the future.

With ever-growing communication traffic pushing the conventional electronic interconnection to the limit, silicon photonics is regarded as an enabling solution due to its high-speed and large bandwidth capability, as well as scalable and high-throughput manufacturing. High-performance photodetectors are crucial optical building blocks in silicon photonic integrated circuits (Si-PICs). In addition to characteristics such as high responsivity, low dark current, large bandwidth, operation over a wide wavelength band, efficient light coupling with silicon waveguides and CMOS compatibility are also needed for the photodetectors.

III–V photodetectors have long been deployed in indium phosphide (InP)-based photonic integrated circuits (PICs) because of their superior device performance. Recently, interest in III–V photodetectors grown on silicon began to flourish, complementing the research on integrating III–V lasers on silicon and the eventual goal of having high-performance III–V photonics integrated on the silicon photonics platform. For the III–V photodetectors on silicon realized using the traditional blanket hetero-epitaxy method, the thick buffer layers used for defect reduction make it challenging for light coupling with silicon waveguides, and the reported 3dB bandwidths of these photodetectors often fall in the range of sub-10GHz.



Fabricated high-performance III-V photodetector on a monolithic InP/SOI platform for application in silicon photonics (courtesy of Hong Kong University of Science and Technology)

HKUST developed the lateral aspect ratio trapping (ART) method to grow III–V materials on SOI without the need for thick buffers. III–V photodetectors grown on SOI using this method feature an in-plane configuration with the silicon device layer, which allows easy integration of the photodetectors and silicon waveguides. The team designed and fabricated III–V photodetectors with a variety of dimensions on a monolithic InP/SOI platform, also developed by the team.

The photodetectors feature a large 3dB bandwidth exceeding 40GHz, a high responsivity of 0.3A/W at 1550nm and 0.8A/W at 1310nm, a wide operation wavelength span over 400nm, and a low dark current of 0.55nA. The photocurrent is adjustable for various applications by varying the length of the photodetectors. Design of interfacing these photodetectors with silicon waveguides can be flexible and simple.

For the first time, the team has demonstrated III–V photodetectors grown on the monolithic InP/SOI platform (paper to appear in Light: Science and Application) to fulfill the stringent criteria for photodetectors in silicon photonics.

"This was made possible by our latest development of a monolithic InP/SOI platform with both submicron InP bars and large-dimension InP membranes," says Lau. "Our team's combined expertise and insights into both device physics and growth mechanisms allow us to accomplish the challenging task of cross-correlated analysis of epitaxial growth, material characteristics and device performance."

The work is a collaboration with a research team led by professor Hon-Ki Tsang of the Department of Electronic Engineering at Chinese University of Hong Kong (CUHK).

The device fabrication technology was developed at HKUST's Nanosystem Fabrication Facility (NFF) on Clear Water Bay campus. The work is supported by Research Grants Council of Hong Kong and Innovation Technology Fund of Hong Kong.

http://dx.doi.org/10.1364/OPTICA.431357

https://ece.hkust.edu.hk

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Windstream partners with II-VI Inc

Windstream Wholesale of Little Rock, AK, USA has partnered with II–VI Inc of Saxonburg, PA, USA to co-develop next-generation transceivers that will streamline deployment of 400 gigabit services while significantly reducing costs, power consumption and network complexity.

"This game-changing partnership is a vital step toward making 400G wavelengths the default deployment service for large wholesale and hyperscale customers," says Windstream's chief network officer Buddy Bayer. "II-VI's high-transmit-power 0dBm 400G QSFP-DD DCO [digital coherent optics] transceivers will enable Windstream to deploy greatly simplified network architectures, by optically connecting routers directly to access, metro and regional transport networks without additional intermediary interfaces, eliminating an entire layer of optical equipment," he adds. "This revolution in IP-over-DWDM network architecture achieves significant savings in upfront costs and ongoing expenses, affording Windstream a highly competitive operational model."

Windstream Wholesale said in February it had deployed 400Gb/s single-wavelength transmission across its long-haul network using compact, low-power, industry-compliant pluggable modules. These modules represent the next major step in network evolution while driving high-capacity optical connections to the network edge to deliver ultra-fast speeds to more end-users than before.

Windstream Wholesale says that the announcement bolsters its position leveraging a multi-layer open architecture that enables a fast and flexible solution along with interoperability through the fundamental design principles of disaggregation, promoting speed, flexibility and interoperability standards.

"Our partnership with Windstream will fast-track the development of a disruptive 400G transmission technology that builds on our award-winning integrated coherent transmitter and receiver optical subassembly, or IC-TROSA, which itself is based on our advanced and proprietary indium phosphide technology along with our industry-leading optoelectronic integration platform," says Matthias Berger, VP, coherent technology, II-VI Inc. "Indium phosphide is the intrinsic enabler of the 400G transceiver's high 0dBm output power yet with low enough power consumption to be uniquely suitable for QSFP-DD."

Windstream says that the new technology will:

- deliver what is claimed to be the world's first high-performance 0dBm, 400G QSFP-DD coherent pluggable module — making these transceivers compatible with existing and emerging modern ROADM-based photonic layers supporting multi-service, multi-layer architectures;
- significantly increase 400G transceiver density by drastically reducing the size and power demands of 400G pluggables relative to sled-based and even CFP2-based solutions;
- reduce CapEx and OpEx by allowing for direct insertion of high-performance coherent optics into current 400G-enabled routers, based on the smaller form factor; and
- open up a direct technical path for the further evolution of IP-over-DWDM with ROADM-based photonic layers, extending the application space beyond simple point-to-point DCI-style networks.

On 19 October, Art Nichols, Windstream's VP of architecture and technology, participated with industry experts in a webinar panel 'Beyond 400ZR-Expanding the Reach of Pluggable Coherent'.

Windstream's Intelligent Converged Optical Network provides open and disaggregated networking infrastructure, enabling wholesale and enterprise technology customers to select unique custom routes, maintain operational insights with Windstream's Network Intelligence functions, and place their networks closer to the edge to better serve end-users.

www.windstreamwholesale.com
www.ii-vi.com

II-VI's European sites go 100% renewable electricity

Engineered materials and optoelectronic component maker II-VI says it is powering all its European facilities with 100% renewable electricity sources.

The renewable electricity is supplied to II-VI's manufacturing operations, R&D sites and sales offices throughout six European countries (Belgium, Germany, Italy, Sweden, Switzerland, and the UK), encompassing 615,000ft^2 (57,000m^2) of facility space across 12 sites.

To power its footprint across Europe, II-VI is purchasing about 38 million kilowatt-hours (kWh) per year of renewable electricity, eliminating about 5800 metric tons of CO_2 emissions each year.

"II-VI has made it a top priority to reduce its carbon footprint across its global operations," says Dr Karlheinz Gulden, senior VP, Laser Devices and Systems business unit.

Globally, II-VI has entered into renewable-electricity contracts for 24 sites, including 14 of them now covering 100% of their annual electricity usage from renewable sources. Over 20% of II-VI's global electricity needs are now supplied by renewable sources across the USA and Europe. The percentage of renewable electricity powering II-VI's operations is expected to grow annually and, in the future, include the company's major manufacturing sites in Asia.

II-VI wins ECOC's Most Innovative Product/Optical Integration award for 400G integrated coherent transceiver technology

II-VI Inc says that its Optical Internetworking Forum (OIF) Type (2) integrated coherent transmitter & receiver optical subassembly (IC-TROSA) for 400G transmission has won the 2021 Industry Award at the European Conference on Optical Communications (ECOC 2021) in the category of Most Innovative Product/Optical Integration.

Communications service providers are planning to deploy new network architectures that will considerably reduce capital expenditures and operating expenses by leveraging next-generation transmission technology. II-VI's IC-TROSA is 400G transmission technology with a combination of high output power, small size, and low power consumption that enables the elimination of an entire layer of optical equipment, dramatically reducing capital outlays and greatly simplifying network operation.

"The IC-TROSA is based on advanced proprietary indium phosphide technology," says Patrik Evaldsson, VP & general manager, II-VI Järfälla. "Indium phosphide is an intrinsic enabler of 0dBm output power in 400G digital coherent optics transceivers, yet with low enough power consumption to be suitable for the small QSFP-DD form factor."

"The availability of 400G with such high output power in a QSFP-DD form factor is a game-changer due to its compatibility with router interfaces," says Dr Sanjai Parthasarathi chief marketing officer. "Now, service providers can connect routers directly to access, metro and regional optical transport networks without client interfaces. This type of network architecture, such as IP-over-DWDM, achieves huge savings in upfront costs and ongoing expenses."

Launched in early 2020 and now in volume production, II-VI's IC-TROSA integrates all the optical functions of a coherent transceiver into one digitally controlled subassembly that customers can interface to the DSP of their choice. It is said to be the first of its kind to conform to the Type-2 form factor specified in the OIF IC-TROSA implementation agreement (IA) and to support optical performance compatible with both 400ZR+ and the OpenROADM multi-source agreement (MSA).

www.ii-vi.com

Sivers to develop CW-WDM MSA-compliant InP DFB laser arrays supporting Ayar's SiPho optical I/Os

Sivers Semiconductors AB of Kista, Sweden says that its subsidiary Sivers Photonics of Glasgow, Scotland, UK will develop CW-WDM MSA-compliant laser arrays that support the optical I/O solution of Ayar Labs of Santa Clara, CA, USA, whose integrated optical I/Os are targeted at artificial intelligence (AI), cloud, high-performance computing (HPC), 5G, and light detection & ranging (LIDAR).

This comes after Ayar demonstrated the "first Terabit per second wavelength division multiplexing (WDM) optical link" with its TeraPHY optical I/O chiplet and SuperNova multi-wavelength optical source, supporting high-data-rate advanced optical communication and computing applications.

Sivers Photonics reckons its new InP100 platform will form a crucial part of the supply chain for the CW-WDM MSA (continuous-wave wavelength division multiplexing multi-source agreement), designing and manufacturing bespoke high-power distributed feedback (DFB) laser arrays that will support the ongoing development of Ayar Labs' multi-wavelength optical sources.

The SuperNova multi-wavelength optical source is reckoned to be the first product compliant with the optical source specifications of the CW-WDM MSA, for which Sivers Photonics is also a promoter member. The CW-WDM MSA was formed to standardize CW-WDM sources in the O-band for emerging advanced silicon photonics (SiPh)-based optics applications that are expected to move to 8, 16 and 32 wavelengths, to support high-volume datacom optics in application areas including artificial intelligence, high-performance computing, and cloud data services.

"We have worked very hard creating this platform to support DFB array technology for CW-WDM MSA applications," says Sivers Photonics' managing director Billy McLaughlin. "Our InP100 platform is accelerating time to market for many silicon photonics applications. Our bespoke high-power DFB laser arrays are the perfect fit to serve Ayar Labs' SiPh integration requirements for development in this high-volume market," he adds.

"Ayar Labs was designated one of three companies in the 2021 Gartner 'Cool Vendors in Silicon Photonics' report," notes Anders Storm, group CEO of Sivers Semiconductors. "Ayar Labs optical device technology will transform next-generation computing and Sivers Photonics is excited to be engaged in this new technology," he adds.

"A strong ecosystem of partners and suppliers who deliver products based on the CW-WDM MSA standard is essential for the optical I/O market to meet the ever-growing bandwidth needs of data-intensive applications," comments Ayar Labs' CEO Charles Wuischpard. "Sivers Photonics' bespoke DFB laser arrays based on the CW-WDM MSA spec are a critical component for our solution and move us one step closer to delivering optical I/O at scale."

www.ayarlabs.com
www.sivers-semiconductors.com

POET launches Optical Interposer platform in China

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 — says that its participation in the two opto-electronics conferences/exhibitions in China in mid-September generated numerous customer engagements in both its announced Optical Engine products and its Optical Interposer platform. Notably, transceiver module supplier Shenzhen Fibertop Technology Co Ltd committed to incorporate POET Optical Engines in its line of optical modules as soon as production Optical Engines are available.

Live demos of six different applications of the Optical Interposer encompassing both standard and custom products developed by POET were conducted over five full days (14–18 September) in Shenzhen in conjunction with the 23rd China International Optoelectronics Exhibition (CIOE 2021) and the concurrent ICCSZ Conference. The live demos were held in meeting rooms located at both of the conference venues and in POET's lab in Shenzhen. In addition, Dr Mo Jinyu, POET's senior VP – Asia, gave an invited presentation during the ICCSZ Conference that was attended by nearly 1000 industry participants.

POET says that among the attendees of the live demonstrations were more than 60 C-level and senior R&D executives representing over 20 companies, including major China-based network equipment suppliers, tier-1 transceiver module companies, leading optical module and fiber-optic companies (several of which are publicly traded), data-center operators, and major multi-billion-dollar public enterprise companies aiming to expand into the optical transceiver business. Interest was shown in engaging with POET on both a strategic level and in evaluating and subsequently sourcing the Optical Engine products outlined in its roadmap, says the firm.

Attracting the most attention was POET's demonstration of a 400G FR4 transmit engine performed as a two-chip demo in connection with SiluxTek's high-performance silicon photonics-based modulator. Over the next several months, POET plans to transform the two-chip pre-Alpha prototype into a fully integrated transmit and receive Beta product for sampling to interested customers.

The firm also demonstrated its standard products, soon to be in Beta form, featuring a 100G CWDM4 transmit engine, a 200G FR4 receive engine, and three versions of its LightBar products, including a 4-channel transmit engine with continuous wave (CW) lasers and arrayed waveguide (AWG) multiplexer, a dual two-channel version with low-loss Mach-Zehnder Interferometer (MZI) multiplexers, and (the firm's newest advanced development) a LightBar designed to connect four separate channels into a single multi-core fiber (MCF), which has the potential to solve key challenges in 800G and co-packaging applications.

"Participation in these conferences and especially the live demonstrations made a tremendous impact on the optical ecosystem in China," reckons president & general manager Vivek Rajgarhia. "We were already engaged with a few customers, such as Fibertop, and their commitment to adopt POET optical engines in their optical modules is a breakthrough for us," he adds. "Other companies requested samples of our demonstrated products, and several more want to either engage in development contracts that would incorporate POET Optical Engines in their products or have POET incorporate their components into POET's Optical Engines. Numerous opportunities for increased customer engagement in China, including with some of the largest players, resulted from this effort. I would like to commend and thank Dr Mo Jinyu and her team in our Shenzhen office, as well as the team from our Super Photonics JV, for an outstanding debut of POET Technologies into the optoelectronics market in China."

www.cioe.cn/en
www.poet-technologies.com

POET announces design win and purchase order for 100G CWDM4 and 100G LR4 optical engines

POET Technologies Inc of Toronto, Ontario, Canada has secured a commitment from a leading network systems company for a unique multi-engine design for 100G CWDM4 and 100G LR4 optical engines based on its POET Optical Interposer. The combined value of the NRE (non-recurring engineering) and the purchase order for initial units exceeds US$1.2m.

"We have been engaged with this customer for several months on a breakthrough design to incorporate multiple optical engines in a single industry-standard transceiver module, something that only a POET Optical Interposer-based engine can enable," says president & general manager Vivek Rajgarhia. "The LR4 product is directed at the client side of major telecom networks, using rigorous standards for data communication between a transport network backbone to data centers and customer locations globally," he adds. "Our customer is already selling into the well-established telecom equipment market and, with the POET Optical Engines, will be able to offer a solution to its customers that delivers superior performance at a price that cannot be matched today by competing solutions."

In September 2020, forecasting firm LightCounting noted increased demand for 100G LR4 transceiver modules with a 10km reach, reversing its previous revenue forecast of a flat $300m annually to one that increased in the 2020–2025 period to over $700m annually.

"Modules based on the POET Optical Engine can deliver the equivalent of 200–400G speeds using the established 100G technology that has met standards preferred by major telcos," Rajgarhia says. "Our small form factor, including monolithically integrated mux and demux, are unique to POET. In CWDM4, and especially in a LR4 optical engine, our full integration and small form factor yield strong performance and cost advantages," he adds. "We believe that this customer engagement represents a major market opportunity and demonstrates all of the key benefits of the POET Optical Interposer platform."

The commitment from a tier-1 customer and the numerous other recent customer engagements show that a market is building for the Optical Interposer's hybrid integration approach, and multiple product designs can benefit from POET's unique platform solution, says the firm.

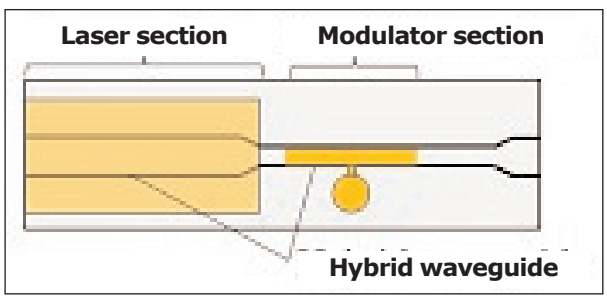
POET also reported that its unaudited cash balance at 30 September stood at about US$20m. Additionally, it reported that the majority of the C$0.52 warrants, expiring on 2 November, had been exercised during their five-year lifetime. About 11 million warrants with a value of US$4.5m remain outstanding and unexercised.

www.poet-technologies.com

Mitsubishi to ship samples of wider-temperature-range CWDM 100G (53Gbaud PAM4) EML chip for data centers

Tokyo-based Mitsubishi Electric Corp says that on 1 November it will begin shipping samples of its ML7CP70 100Gbps (53Gbaud) four-level pulse-amplitude modulation (PAM4) electro-absorption modulator (EML) laser diode chip for coarse wavelength division multiplexing (CWDM), which is expected to be applied in sets of four EML chips (emitting at wavelengths of 1271nm, 1291nm, 1311nm and 1331nm) as a light source in optical transceivers for 400Gbps optical fiber communication in data centers.

Mobile data traffic volume is increasing rapidly in parallel with increasing optical fiber communication transmission rates and capacity in data centers. The high-density deployment of servers and routers in data centers, however, is creating major problems in terms of increasing power consumption.



Mitsubishi Electric says that its new ML7CP70 has a unique hybrid waveguide structure (pictured) that combines a buried hetero-structure laser diode (for high optical output power) and a high-mesa waveguide electro-absorption modulator (EAM) to enable a high extinction ratio and wide frequency range.

In addition, due to optimized design parameters for the laser diode and modulator sections, 53Gbaud PAM4 operation is available at temperatures ranging from 5°C to 85°C.

Operability over a wider temperature range eliminates the need for chip temperature control units in optical transceivers, reducing both power consumption and costs.

By enabling low-power optical transceivers, the new CWDM 100Gbps (53Gbaud PAM4) EML chip hence helps to reduce power consumption in data centers, Mitsubishi Electric concludes.

www.mitsubishielectric.com

Freedom launches aura product line with 2.5W diffraction-limited 1550nm lasers and SOAs

Order-of-magnitude increase in power on single-spatial-mode lasers and amplifiers

Component, module and subsystem maker Freedom Photonics LLC of Santa Barbara, CA, USA has launched its new high-power diffraction-limited semiconductor laser and semiconductor optical amplifier (SOA) product line aura. The first commercial offerings are 1550nm semiconductor lasers and SOAs that achieve 2.5W continuous wave optical power with >25% E/O efficiency and nearly diffraction-limited beam quality (M2 about 1.3)

"Conventional broad-area edge-emitting diode lasers offer excellent power conversion efficiency but poor beam quality, and for the past 30 years the technology has not fundamentally changed; improvements in brightness and efficiency have been steady, but incremental," says Dr Paul Leisher, VP of research. "Our proprietary aura design solves the beam-quality problem, thus delivering powers and efficiencies comparable to broad-area lasers with nearly-diffraction-limited output," he claims. "This highly disruptive technology delivers a full order-of-magnitude increase in power compared to existing single-spatial-mode semiconductor lasers and amplifiers in this wavelength band."

Freedom Photonics is beginning to deploy this chip technology into consumer, industrial and defense markets. Applications of the 2.5W aura 1550nm laser include next-generation high-brightness laser pump sources and illumination. The aura SOA offers (for the first time, it is reckoned) an alternative to bulky erbium-doped fiber amplifiers (EDFAs) critical to optical communication, sensing and automotive light detection & ranging (LIDAR) at substantially reduced cost.

Customization of aura lasers and amplifiers and extension to other wavelengths between 1300nm and 2100nm is possible, notes the firm.

The performance and advances enabled by aura were presented by Dr Jenna Campbell, director of High Power Laser Engineering, at the 27th IEEE International Semiconductor Laser Conference (ISLC 2021) in Potsdam, Germany on 13 October.

www.islc2021.org
www.freedomphotonics.com

MACOM demonstrates latest products for 5G and data-center applications at CIOE

At the China International Optoelectronic Exposition (CIOE 2021) in Shenzhen (16–18 September), MACOM Technology Solutions Inc of Lowell, MA, USA showcased its optoelectronic and photonic components with demonstrations featuring new product additions to its broad portfolio. These include the following:

112Gbps TIA family for DR and FR single-mode applications

MACOM demonstrated a Gold Box evaluation board that included its 4x100Gbps MATA-03819 trans-impedance amplifier (TIA) and its BSP56 photodetector (PD). The display highlighted the MATA-03819 TIA's bit-error-performance.

10Gbps components for PON applications

MACOM is demonstrating its latest 10Gbps passive optical network (PON) component solution for XGPON and XGSPON spanning its portfolio of TIAs, drivers, photodiodes and lasers. The firm is highlighting the MALD-02186 multi-PON combo chip (OLT), MALD-02188 XGPON combo chip (OLT), MALD-02183 XGPON combo chip (ONU), MALD-02181 XGSPON combo chip (ONU), MATA-02239 10Gbps BM TIA (OLT), MATA-02240 10Gbps TIA (ONU), MAOD-127D02IL1T0 – XGPON laser, MAOD-127D10I-LCT0 – XGSPON laser, MARP-FSAPD10A PD (ONU) and MARP-FSAPD10B/32445-02 PD (OLT).

200Gbps and 400Gbps chip-set for SR multimode applications

MACOM demonstrated a two-chip analog solution for short-reach 200Gbps QSFP and 400Gbps OSFP, as well as QSFP-DD modules and AOC data-center applications. The first chip is a 4x53Gbps PAM-4 CDR and TIA, and the second chip is a 4x53 Gbps PAM-4 CDR and VCSEL driver. The chip-set demonstrates IEEE standard compliant bit-error rate (BER) performance and Open Eye MSA transmit eye compliance, while displaying interoperability with an Ethernet switch.

50Gbps reference design for 5G wireless mid-haul applications

MACOM demonstrated its 50Gbps reference design for 5G wireless mid-haul applications, featuring a complete 50Gbps PAM-4 QSFP28 reference design, using all-MACOM components. The demonstration platform was a 20km optical link with single-mode fiber using a 1310nm wavelength. The reference design showcased MACOM's new PRISM-50D DSP with integrated DML driver, a 26GBaud 1310 I-temp laser, a 26GBaud PIN photodiode, and a 26GBaud PAM-4 TIA.

www.cioe.cn/en
www.macom.com/opto

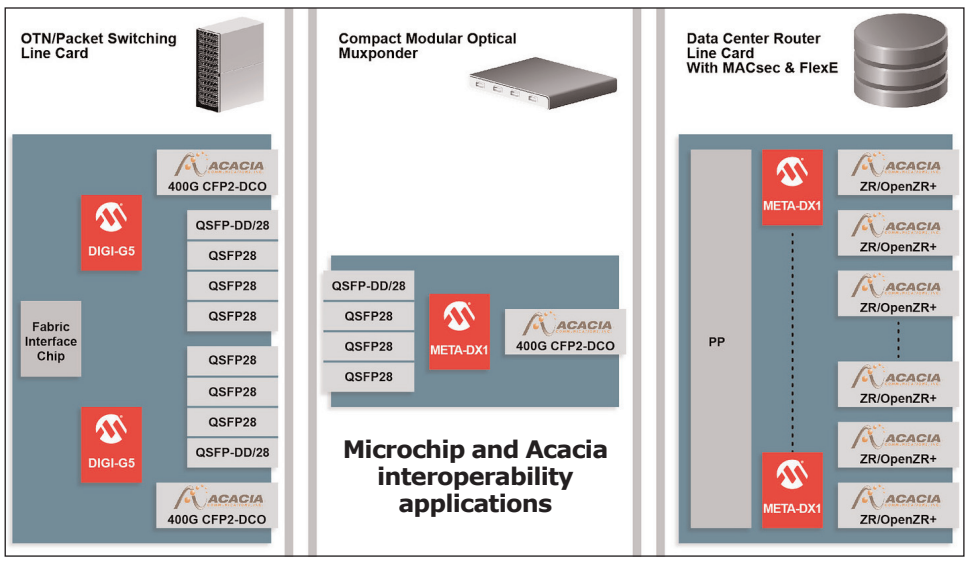
Microchip and Acacia collaborate on 400G pluggable coherent optics for data-center routing, switching and metro OTN platforms

Solutions enable encrypted 100/400 GbE, FlexE and Flexible OTN interfaces for 400ZR, OpenZR+ and Open ROADM applications

Bandwidth growth, driven by the expansion of data centers and 5G network build-outs, is expected to drive the need for faster coherent dense wavelength division multiplexing (DWDM) pluggable optics. Consequently, data-center interconnect (DCI) and metro optical transport network (OTN) platforms are transitioning from 100/200G to 400G pluggable coherent optical modules to support these hyper-connected architectures. Microchip Technology Inc of Chandler, AZ, USA and Acacia Communications Inc of Maynard, MA, USA (now part of Cisco) — which develops and manufactures high-speed coherent optical interconnect products — are supporting this transition by bringing to market interoperable solution sets consisting of Microchip's DIGI-G5 OTN processor and META-DX1 terabit secured-Ethernet PHY and Acacia's 400G pluggable coherent optics. The purpose of the collaboration is to establish an ecosystem to support 400G CFP2-DCO, QSFP-DD and OSFP modules for the 400ZR specification as well as the OpenZR+ and Open ROADM multi-source agreement (MSA) applications.

The collaboration between Microchip and Acacia helps to enable the use of 400G coherent pluggables in OTN and Ethernet systems as follows:

- For converged packet/OTN optical platforms, Microchip's DIGI-G5 and Acacia's 400G CFP2-DCO module are designed to enable terabit-class OTN switching line-cards, muxponders, and switchponders. The DIGI-G5 interoperates with Acacia's 400G CFP2-DCO module using a Flexible OTN (FlexO) or NxOTU4 interface to efficiently support OTN traffic, including Open ROADM MSA interface modes and 200G/400G ITU-T standards currently being drafted.
- For compact modular optical systems, Microchip's META-DX1 and Acacia's 400ZR and OpenZR+ modules are designed to enable 400G flexible line-rate muxponders/transponders with support for multiple client optics types including QSFP28, QSFP-DD and OSFP modules, helping service providers to transition from 100 GbE to 400 GbE using the same hardware.
- For data-center routing and switching platforms, Microchip's META-DX1 and Acacia's 400ZR and OpenZR+ modules are designed to enable dense 400GbE or FlexE with per port MACsec encryption coherent line-cards. This helps customers to leverage IP routers/switches over DWDM (IPoDWDM) infrastructure in DCI deployments.



"DIGI-G5 and META-DX1 have enabled our optical transport, IP routing and Ethernet switching customers to implement a new class of multi-terabit OTN switching and high-density 100/400 GbE and FlexE line-cards that deliver on stringent packet timing and integrated security capabilities for the build out of cloud and carrier 5G-ready optical networks," says Babak Samimi, VP for Microchip's Communications business unit. "Our interoperability efforts with Acacia help to demonstrate that an ecosystem for volume deployment of these new line-cards with pluggable 400G coherent optics exists," he adds.

"With Acacia's 400G coherent modules verified to interoperate with Microchip's DIGI-G5 and META-DX1 devices, we see it as a robust solution designed to address network capacity growth and improved efficiency," says Markus Weber, senior director DSP, product line management, at Acacia. "The compact size and power efficiency of our 400G OpenZR+ CFP2-DCO modules were designed to help network operators deploy and scale capacity of high-bandwidth DWDM connectivity between data centers and in metro networks."

www.acacia-inc.com/products
www.microchip.com/

Phononic announces full customer and manufacturing qualification at Fabrinet

Partnership in Asia–Pacific expands global production of high-performance thermoelectrics

Phononic Inc of Durham, NC, USA (which provides solid-state thermoelectric cooling and heating technology) has announced full customer qualification of manufacturing operations at Thailand-based Fabrinet Co Ltd (which provides OEMs with optical packaging and precision optical, electro-mechanical and electronic manufacturing services). The partnership dramatically ramps up Phononic's global manufacturing capability, allowing for increased growth and revenue despite global supply chain bottlenecks that have impacted numerous industries worldwide.

Despite COVID-related travel restrictions between US-based Phononic and Fabrinet's manufacturing facilities in Thailand, the firms succeeded in gaining full customer qualification in just over a year. Phononic's highly automated and readily transferable chip manufacturing process, coupled with Fabrinet's manufacturing capabilities and speed-to-market, enabled them to scale with customers in an exceedingly stressed global manufacturing environment.

The expansion allows Phononic to continue delivering sustainable cooling solutions for its key target sectors: optical communications and light detection & ranging (LiDAR); cold chain fulfillment; retail merchandizing in grocery; and product licensing initiatives in life sciences, healthcare and climate control.

"The world is demanding the sustainable cooling solutions that we provide," says chief revenue officer Kevin Granucci. "Fabrinet gives us that critical, predictable global access to state-of-the art manufacturing while stateside we can continue to focus on our innovation pipeline. Early on in 2020, we forecast strong and robust global demand for our solid-state solutions. By aligning just a year later with one of the most respected manufacturing partners in the world, the message is clear: we're open and ready for business," he adds.

"Fabrinet excels in the production of high-complexity semiconductor products," claims Edward Archer, executive VP, sales & marketing, at Fabrinet. "Our advanced optical and electronic packaging and precision manufacturing capabilities were a natural fit for Phononic's exacting specifications, and we are proud of our ability to operate at speed under such extraordinary conditions in which most of the work was handled virtually across continents."

As a result of the partnership, Phononic says that it can also meet demand and strengthen its commercial position in the Asia-Pacific (APAC). Optical communications components companies based in the region will be able to leverage the firm's in-continent expansion for thermoelectric devices in optical components for data centers, high-speed coherent applications, as well as 5G mobile and access networks (FTTx). Phononic R&D, product development and production will continue at the firm's headquarters and manufacturing facility in Durham, NC, USA.

www.phononic.com/optoelectronics

Precision OT's Advanced Engineering Group gains nine US patents

New technologies in integrated photonics, electronics and software simplify, improve and reduce cost of communications systems

The Advanced Engineering Group at Precision OT of Rochester, NY, USA (a provider of optical transceivers and related active/passive optical components) has gained nine patents from the United States Patent and Trademark Office (USPTO) in the areas of optical networking, integrated photonics and photonic radio systems, with many more pending. The group of in-house engineers develops solutions that help network providers to reduce costs while future-proofing their networks. The firm's first proprietary design by this team - the PAM4 Access Reach (P4AR) transceiver - will be available for demo and pre-order in first-quarter 2022.

Precision OT's Advanced Engineering Group offers extensive experience in embedded systems, communications theory, signal processing, integrated photonics (both silicon photonics and indium phosphide), high-speed electro-optical integration, and integrated circuit manufacturing.

Due to increasing consumer and enterprise adoption of the Internet of Things (IoT), 5G, HD streaming, artificial intelligence (AI) and other cloud-based applications, the optical networking industry is in a 'golden age' of innovation and expansion, notes the firm. Accommodating such bandwidth-intensive technologies within existing or new networks places significant strain on the budgets of today's network providers.

"The Advanced Engineering Group's objective is to develop new technology that can assist network operators in handling higher data rates across longer distances and generating crucial efficiencies that can positively impact their bottom lines," says Chris Page, Precision OT's chief technology officer. "To that end, we're proud to have recently earned nine patents by the federal government that have the potential to shape global optical networks for years to come," he adds. "With many optical component providers on the market simply white-labeling products, our Advanced Engineering Group is a key differentiator for Precision OT. And we not only develop new solutions, but we share our engineering expertise with our partners to help them build the networks that will work for them now and into the future."

Precision OT's P4AR solution is a prime example of the Advanced Engineering Group's function. The existing QSFP28 DWDM DCI solution currently on the market requires external components such as erbium-doped fiber amplifiers (EDFAs), dispersion compensation modules, specialized filters and other transport equipment. In contrast, P4AR is the only commercial 100G DWDM QSFP28 switch pluggable product that does not require DCM (or other equipment) for transmission up to 40km, it is claimed. As a result, it enables network providers to achieve high capacity with high speed at the edge while reducing costs. With 4TB maximum capacity and a 40km reach without external equipment, P4AR yields upwards of 76% of CapEx savings, more than 8.5kW of power savings and 10RU of rack savings, it is reckoned.

www.precisionot.com/advanced-engineering-group

Zephyr Solar sets HAPS altitude record of 76,100ft

18 day stratospheric flights demonstrated with multiple payload integrations

Airbus says that the solar-powered Zephyr S High Altitude Platform System (HAPS) has completed a successful 2021 test flight campaign in the USA. The final flight touched down on 13 September in Arizona, USA, ending the most ambitious and successful Zephyr flight campaign to date, which achieved record absolute altitude of 76,100ft for this class of unmanned aerial system (UAS).

The flight campaign had a customer focus — to demonstrate how Zephyr could be used for future operations, flying outside of restricted airspace and over airspace shared with commercial air traffic. Carrying an Optical Advanced Earth Observation system for Zephyr (OPAZ) payload, Zephyr proved its operational value to provide instant, persistent and improved situational awareness, streaming Earth observation data.

"Working with Airbus and the Zephyr team during the 2021 flight campaign, significant progress has been made towards demonstrating HAPS as a capability. This summer's activities represent an important step towards operationalising the stratosphere," says James Gavin, Future Capability Group Head at Defence Equipment & Support, the procurement arm of the UK Ministry of Defence.

"Defence investment in cutting-edge technology is key to the development of world-leading military capabilities," says Major General Rob Anderton-Brown, director Capability and MDI Change Programme at Strategic Command. "Zephyr is an important program within UK Strategic Command, and the recent successful flight has required many innovative technical solutions," he adds. "This represents a significant milestone for Zephyr which is informing the development of new concepts and ways of enabling military operations, particularly in the context of Multi-Domain Integration."

Take off for the 2021 test flight campaign of the Zephyr S High Altitude Platform System.

The campaign consisted of six flights in total: four low-level test flights and two stratospheric flights. The stratospheric flights flew for around 18 days each, totaling more than 36 days of stratospheric flight in the campaign. This adds a further 887 flight hours to the 2435 stratospheric flight hours for Zephyr to date, marks significant progress for fixed-wing HAPS, and is a step towards making the stratosphere an operational reality for customers, Airbus says.

"Credible and proven ultra-persistence, stratospheric agility and payload interoperability underscore why Zephyr is the leader in its sector," says Jana Rosenmann, head of Unmanned Aerial Systems at Airbus. "It is a sustainable, solar-powered ISR [intelligence, surveillance and reconnaissance] and network-extending solution that can provide vital future connectivity and earth observation to where it is needed."

The flight campaign had a customer focus — to demonstrate how Zephyr could be used for future operations

Airbus says that such an innovative capability is part of its ambition to rapidly move towards operationalizing the stratosphere. 'Carbon neutral' Zephyr uses sunlight to fly and recharge its batteries, using no fuel and producing no carbon emissions.

The firm adds that, with its ability to remain in the stratosphere for months at a time, Zephyr will bring new 'see, sense and connect' capabilities to both commercial and military customers, providing the potential to revolutionize disaster management, including monitoring the spread of wildfires or oil spills. It also provides persistent surveillance, tracing the world's changing environmental landscape and will be able to provide communications to the most unconnected parts of the world.

www.airbus.com

University of Oklahoma challenges Shockley–Queisser limit to solar cell efficiency

Three-year, $310,000 NSF grant to investigate harnessing excess energy before it is lost to heat generation

One of the greatest challenges of solar cells is the Shockley–Queisser limit - the assumption that there is a fundamental limit to the amount of energy that a solar cell can absorb and convert into usable energy. University of Oklahoma physicist Ian Sellers is showing that the widely held assumption is false.

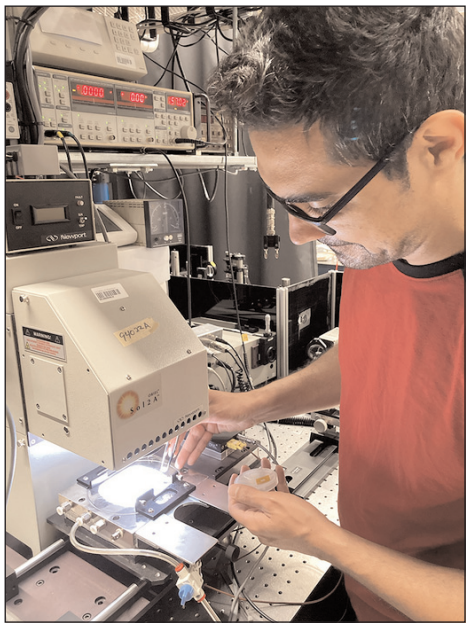
Sellers, an associate professor in the Homer L. Dodge Department of Physics and Astronomy in the Dodge Family College of Arts and Sciences, has received a $310,000 grant from the US National Science Foundation (NSF) to demonstrate the utility of some commonly used semiconductors to significantly increase the efficiency of solar cells.

"It was always assumed a semiconductor could only convert so much energy from the sun because it would either lose energy as heat or that sunlight would be too low-energy to be captured," Sellers says. "It was considered that this single gap limit could not be overcome," he adds.

"What we found was a physical effect that exists in conventional optoelectronic materials already used in space solar cells," he adds. "This is a natural effect, not related to exotic quantum structures or processes, and we realized we could make quite simple solar cells based on conventional materials already used in optoelectronics for lasers, LEDs and all kinds of things that has the potential for us to realize a very high-efficiency solar cell."

The potential efficiency that could be realized through this process increases what until now has been considered the industry-standard limit of about 30%, to a breakthrough maximum efficiency of greater than 60%.

"One of the major problems with solar cells is that, currently, most commercial solar cells can only harness about 20% of the sun's energy," Sellers notes. "These solar cells absorb very high-energy light from the sun and any excess energy turns into heat. It warms up the material and that's a loss — it's not something a conventional solar cell converts to electricity."



University of Oklahoma graduate student Hadi Afshari measuring next-generation solar cells on the solar simulator in the Sellers Lab.

I started working with a theorist at Arizona who was working on high-mobility transistors where the effect we're using is a problem for high-mobility transistors. What we've found is the ability to store excess energy in the material prior to heat generation, and we can store it there for long enough that our charge carriers can potentially be extracted before the energy is lost as heat

III-V semiconductors (which Sellers calls the 'workhorse' systems of optoelectronics) generate and conduct this unwanted heat very efficiently, making this a big problem for conventional solar cells. A conversation with a colleague at Arizona State University brought to light a potential new approach to harness this lost energy and more effectively convert sunlight to electricity before the generation of heat occurs.

"I started working with a theorist at Arizona who was working on high-mobility transistors where the effect we're using is a problem for high-mobility transistors," Sellers says. "What we've found is the ability to store excess energy in the material prior to heat generation, and we can store it there for long enough that our charge carriers — the electrons created by light absorption — can potentially be extracted before the energy is lost as heat," he adds. "There isn't anything exotic — it's always existed," he added. "It's a natural process that is a problem in certain transistors, but for solar it could be extremely beneficial."

The three-year grant will also support graduate and undergraduate students in Sellers' lab to gain practical skills in fundamental device physics and technology transfer.

"What students learn here is a strong understanding of how a device works and the mechanisms that inhibit improved performance, as well as the importance of finding a niche in an area that can be improved or used in a new way," Sellers says. "They get a very unique perspective of how academic research relates to real technology."

https://ou.edu/research-norman/news-events/2021/ou-physicist-

Ascent Solar's custom-designed CIGS PV retains 92% of original power during NASA space flight experiment

MISSE-X set stage for involvement with LISA-T and Solar Cruiser

Ascent Solar Technologies Inc of Thornton, CO, USA — which makes lightweight, flexible copper indium gallium diselenide (CIGS) thin-film photovoltaic (PV) modules that can be integrated into consumer products, off-grid applications and aerospace applications — says that its PV solution specially designed for a flight experiment conducted by NASA's Materials International Space Station Experiment (MISSE-X) has exceeded performance and power retention expectations; validating Ascent's ability to create solar power solutions custom-designed for the extreme conditions unique to the space industry. The results of the experiment were announced by NASA at its 26th Space Photovoltaic Research and Technology (SPRAT) conference held virtually on 20 October from Cleveland, OH.

At the conference, Dr John Carr, deputy center chief technologist for NASA MSFC (Marshall Space Flight Center), presented data that validated the performance of Ascent Solar's flexible CIGS PV in ground-based space environmental testing with appropriate space protective coatings. The NASA MSFC data results correlated with the performance of the International Space Station (ISS) in relation to the MISSE-X flight experiment. This flight experiment resulted in Ascent's PV retaining 92% of its beginning of life (BOL) power, exceeding the NASA MSFC ground data predictions for about one year in orbit. This data was summarized as part of the ongoing investigations, conducted by the NASA MSFC, into the viability of lower-cost PV technologies and solutions, and the significant advantages they may have over existing 'space power' technologies.

Ascent's flexible, ultra-lightweight, monolithically integrated PVs are based on CIGS chemistry and will benefit various future missions, ranging from CubeSats, solar sails and, potentially, missions to the moon and Mars, says the firm. As with other space programs, NASA MSFC began investigating the firm's flexible monolithically integrated CIGS several years ago for a wide range of applications. This includes its use in both the upcoming LISA-T demonstration, which is part of NASA's Pathfinder Technology Demonstrator 4 CubeSat (slated for launch in 2022), and the upcoming Solar Cruiser.

"We are extremely pleased with both the reported ground test results, as well as how the predictions from these results were exceeded by the actual MISSE-X flight experimental results," says Dr Joseph Armstrong, founding team member, chief technology officer & chief operating officer of Ascent. "The inherent radiation resilience of our lightweight, flexible PV technology, coupled with the robustness of the monolithic integration process, has shown itself as a unique, robust solution for space. In fact, the only true but positive surprise from the MISSE-X was that the bare control sample of our CIGS module actually retained nearly 76.1% of its BOL power, despite having no protective cover and visible damage from ultraviolet light and atomic oxygen. Data presented at the conference indicate that we are ready for more challenging assignments, such as LISA-T and Solar Cruiser, and also reinforce the choice from other customers who are developing future applications using our PV material," he adds.

"I want to congratulate and commend our team, along with those at NASA and our industry partner NeXolve, who have worked diligently on this project for many years," says Ascent's president & CEO Victor Lee. "These test results certainly set the stage for the potential of Ascent's future involvement with LISA-T and Solar Cruiser, as well as some internal projects, that are designed for Ascent to advance to TRL (Technology Readiness Level) 7 and eventually Level 8 (Space Qualified) in the near future," he adds. "The space community is extremely prudent and takes no chances for failures, hence these early flight opportunities that would establish higher TRL will encourage the industry to adopt our flexible, robust, very high specific-power PV product in the near future," he believes.

www.AscentSolar.com

5N Plus' acquisition of AZUR gains regulatory approval

Specialty semiconductor and performance materials producer 5N Plus Inc of Montreal, Québec, Canada has received the necessary approval from relevant regulatory agencies for its acquisition (announced in late March) of AZUR SPACE Solar Power GmbH of Heilbronn, Germany, which develops and manufactures multi-junction solar cells based on III-V compound semiconductor materials. The firm expects the deal to close within the next few weeks.

5N Plus provides purified metals such as bismuth, gallium, germanium, indium, selenium and tellurium, and also produces related II-VI semiconducting compounds such as cadmium telluride (CdTe), cadmium sulphide (CdS) and indium antimonide (InSb) as precursors for the growth of crystals for solar, LED and eco-friendly materials applications. Operating R&D, manufacturing and commercial centers in several locations in North America, Asia and Europe (including three in Germany and one in Belgium), the firm supplies to the thin-film PV renewable energy industry and is a supplier within the US satellite supply chain.

"AZUR's acquisition is a key element of 5N Plus's strategic transformation toward critical material technology," says 5N Plus' president & CEO Arjang Roshan. "AZUR's cutting-edge space technology and exceptional talent firmly and uniquely positions our company as a leader in the field of specialty semiconductors and engineered substrates at a time when these technologies are of paramount importance," he believes. With nearly 60 years of experience in space solar cell manufacturing, AZUR is backed by nearly 120 patent families.

"The long-standing trust and mutual respect between our businesses will ensure a successful integration, the results of which will unlock a well of untapped potential to serve rapidly scaling and essential markets," believes says AZUR's managing director Jürgen Heizmann, who will join 5N Plus's Executive Committee pending closure of the acquisition.

As well as developing and manufacturing II-VI compound semiconductor materials, 5N Plus has expanded its value chain to include the growth and manufacturing of a variety of semiconductor crystals and engineered compound semiconductor wafers. The vertical integration of AZUR into 5N Plus creates a global enterprise with what is reckoned to be a unique ecosystem across the specialty semiconductor value-chain, spanning from the procurement and processing of critical materials to the manufacturing of finished epitaxy engineered substrates.

Spanning three sites in Canada, Germany and the USA, this ecosystem — dubbed the Specialty Semiconductor Triad — enables 5N Plus to provide competitive and customized solutions to a number of essential industries. The acquisition is expected to benefit the firm's current business within the renewable energy, security and space industries, while also enabling 5N Plus to enter new markets such as high-power electronics, electric mobility, wireless charging and advanced communications.

"AZUR's addition to the 5N Plus family will make a material contribution to our electronic materials business," says 5N Plus' chief financial officer Richard Perron. "AZUR is an established business supported by sustainable operating activities and relatively low integration complexity. The solid backlog of future business supported by a pool of best-in-class talent and a strong platform of technologies will elevate the combined capabilities of our two companies and enable future growth," he concludes.

www.5nplus.com

MOCVD tunnel junctions beat ITO for blue micro-LEDs

Chemical treatment enables significantly higher external quantum efficiency and wall-plug efficiency.

University of California Santa Barbara has demonstrated micro-scale blue light-emitting diodes (μLEDs) with metal-organic chemical vapor deposition (MOCVD) tunnel junction (TJ) contacts with peak external quantum efficiency (EQE) and wall-plug efficiency (WPE) significantly higher than devices using indium tin oxide (ITO) [Matthew S. Wong et al, Appl. Phys. Express, vol14, p086502, 2021].

UCSB has been developing MOCVD GaN TJs for some time. In July, we reported on UCSB's work in using MOCVD TJs to stack blue and green LEDs [www.semiconductor-today.com/news_items/2021/jul/ucsb-220721.shtml].

A key problem with TJ contacts in indium gallium nitride (InGaN) LEDs is that the p-side of the device becomes buried under n-GaN material. This makes it difficult to activate the magnesium doping that provides acceptor levels that grab electrons out of the valence band, creating mobile positively-charged holes in the p-GaN layers.

The activation of p-GaN is mainly designed to drive out hydrogen, which passivates the magnesium acceptor states, blocking the desired generation of holes. This is normally achieved with thermal annealing. However, if the p-GaN is buried, it becomes much more difficult to activate the doping.

With μLEDs there is a potential escape route for the hydrogen through the sidewalls of the device but, as we will see, this route can be blocked by damage from the etch used to create the device mesa. The UCSB team implemented a chemical treatment to open up this hydrogen escape path.

An alternative technique to achieve TJs is to use molecular beam epitaxy (MBE), where the presence of

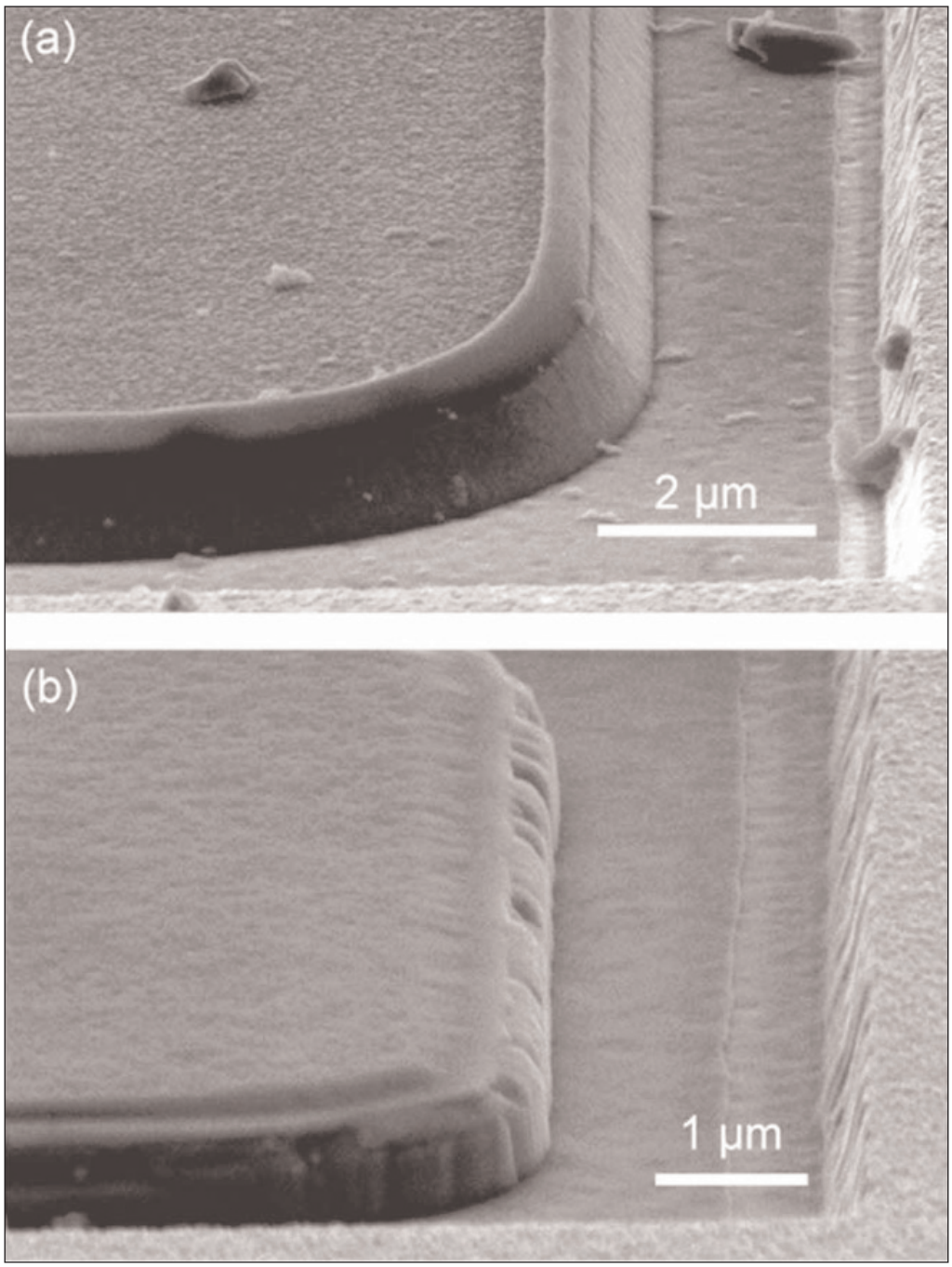


Figure 1. SEM images of μLED sidewall profiles (a) without and (b) with chemical treatments.

hydrogen can be avoided. However, MBE is generally slower than MOCVD so, in industrial contexts, the latter process is preferred.

However, μLEDs are not just a useful way to allow the use of more transparent n-GaN as a current-spreading contact on p-GaN instead of ITO. Such devices are being explored for deployment in next-generation display and visible-light communication systems. The UCSB researchers comment: "Monolithic III–nitride-based μLEDs are particularly interesting for near-eye display applications, since this approach will simplify the mass transfer process with high pixel-per-inch standards."

The UCSB team used commercial blue LED wafers grown on sapphire through MOCVD. The peak wavelength was designed to be 465nm at 20A/cm^2 current density.

The TJ was created using three added n-type layers: 10nm n^{++}-GaN, 100nm n-GaN, and 10nm n$^+$-GaN. The MOCVD growth temperatures were 825°C for the first layer, and 900°C for the others. The commercial wafers were prepared for the TJ growth step with a 5-minute buffered hydrofluoric acid (BHF) dip.

The μLEDs were fabricated with the mesas formed using reactive-ion plasma etch. The mesa areas ranged from 5μmx5μm to 100μmx100μm.

A chemical treatment was performed before activation of the buried p-GaN, consisting of a series of cycles of 5-minute treatments: 60° phosphoric acid treatment, ultraviolet-ozone, and BHF dip. The p-GaN activation was 30 minutes 700°C annealing in a nitrogen/oxygen environment.

The researchers see the chemical treatment as reducing the sidewall damage from the mesa plasma etch. The damage creates band-bending effects, which can result in mid-level defects and regions of n-type material near the sidewall surface of the p-GaN.

The surface damage creates a barrier to the diffusion of hydrogen out of the p-GaN sidewalls during thermal annealing. For example, the preferred states of hydrogen is H$^+$ in p-GaN, and H$^-$ in n-GaN. The H$^+$ ions are therefore blocked from entering n-GaN regions.

Scanning electron microscope (SEM) studies showed that, without chemical treatment, the sidewalls appeared to be smooth (Figure 1). The chemical treatment made for rougher, but more vertical sidewalls.

A dielectric isolation layer of 3x silicon dioxide/tantalum pentoxide pairs, capped with aluminium oxide, also served as an omnidirectional reflector (ODR). Further silicon dioxide deposition provided mesa sidewall passivation.

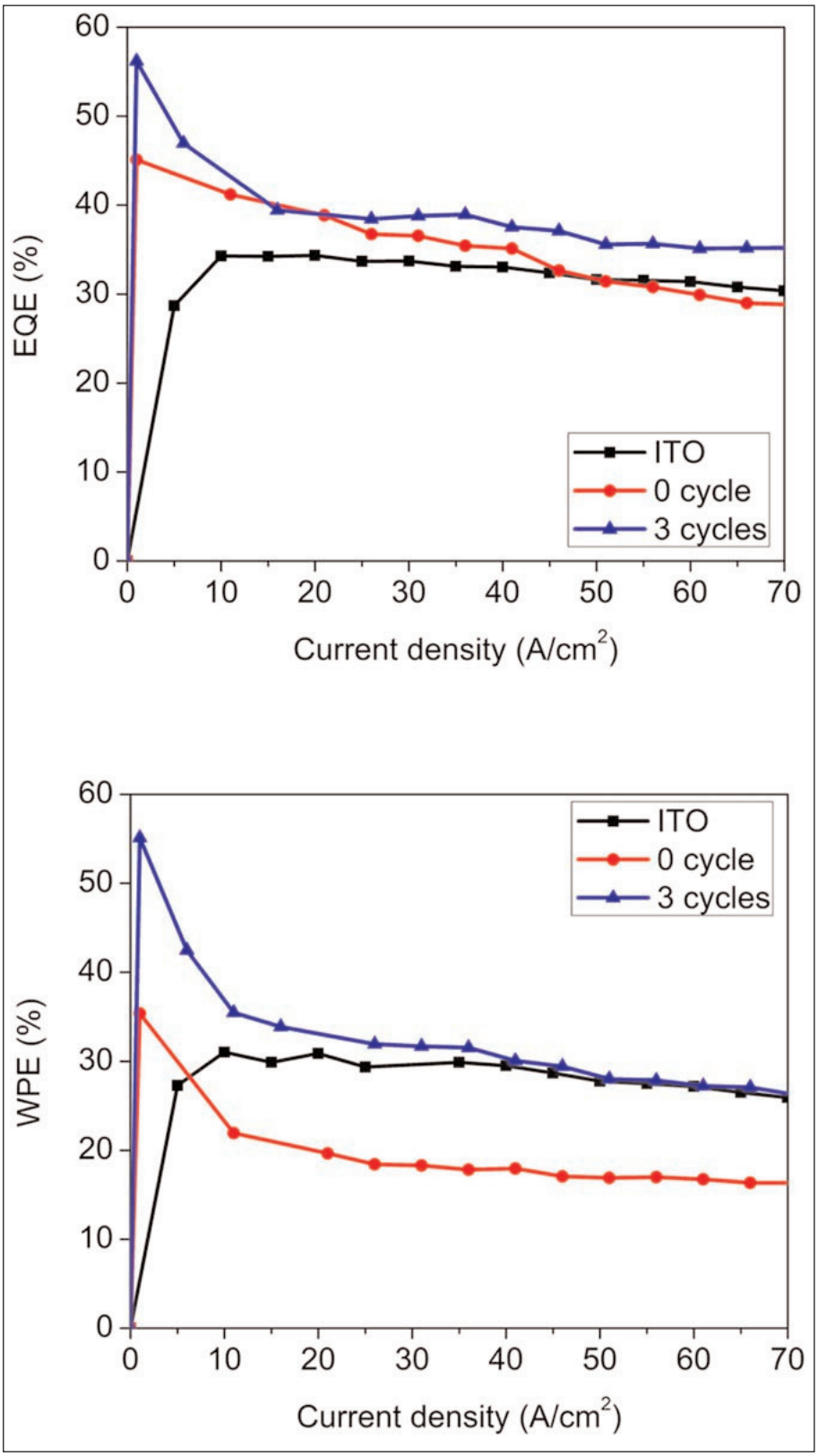


Figure 2. (top) EQE and (bottom) WPE of 20μmx20μm devices with ITO or TJ contacts.

The devices were completed with opening contact windows in the dielectric with BHF etch, followed by deposition of the aluminium/nickel/gold electrodes. Reference devices were also produced with 110nm ITO on the p-GaN rather than a tunnel junction.

Electrically the chemical treatments reduced the forward voltage needed to generate a given current injection. The greatest improvement was achieved in one cycle. The optimal voltage reduction was given by three cycles. The increased resistance from further cycles was attributed to formation of an n-type diffusion barrier due to oxidation.

The team explains: "The additional number of chemical treatment cycles provides oxygen at the sidewalls, where oxygen acts as a donor in the p-GaN and converts to n-type, and hence immoderate use of chemical treatments would result in more resistive characteristic than the optimal condition."

There was also a size penalty with larger devices being more resistant to current flow, suggesting incomplete p-GaN activation. The team writes: "Because this proposed method relies on sidewall activation, this method is effective to device dimensions less than 40μm, yet additional activation is needed to utilize this method on devices with larger area."

The forward voltage on a 20μmx20μm device at 20A/cm^2 was 5.3V without chemical treatment, and 3.05V with a 3-cycle treatment. A reference device with ITO transparent current-spreading layer on the p-GaN had a 2.85V forward voltage at 20A/cm^2. The 0.2V penalty between the 3-cycle TJ and ITO is lower than that achieved with MBE for TJs.

The benefit of the TJ over ITO is that it is more transparent to the emitted blue light. The light output power was greater in both TJ devices relative to ITO for a given current injection.

At 20A/cm^2 injection, the light output power was 42% and 46% greater than the ITO device, for the TJ without and with chemical treatment, respectively. The corresponding improvements were 15% and 30% at 60A/cm^2 injection. The faster fall off in performance of the TJ device at higher currents was attributed to increased Joule heating from the higher voltages needed.

The balance between energy loss, as expressed through higher forward voltage, and light output power was determined through external quantum efficiency (EQE) and wall-plug efficiency (WPE) — see Figure 2. The device with ITO contact achieved peak EQE and WPE of 34% and 31%, respectively. The corresponding figures for the chemically treated TJ μLED were 56% and 55%. As the current increased, the TJ μLED demonstrated ~10% higher EQE over the ITO-contact device. For the WPE, the TJ value descended to the ITO level at higher current injection.

The researchers comment: "The higher WPE performance at low current density was attributed to the greater light output power (LOP), where the voltage penalty was relatively low and the enhancement in LOP was significant, and the increase in WPE diminished with current density." ■

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Red InGaN micro-LEDs for displays

Researchers find more stable external quantum efficiency at smaller sizes relative to the AlInGaP alternative.

University of California Santa Barbara (UCSB) in the USA suggests that indium gallium nitride (InGaN) red micro-sized light-emitting diodes (μLEDs) could provide a solution for displays [Panpan Li et al, Appl. Phys. Lett., v119, p081102, 2021].

Although the high indium content leads to relatively low external quantum efficiency (EQE) compared with commercial aluminium indium gallium phosphide (AlInGaP) regular-size LEDs, which can reach 20–30%, the UCSB research shows that the InGaN devices maintain their ~2.5% EQE as the dimensions scale down to the tens of microns level.

By contrast, AlInGaP μLEDs suffer from severe degradation of the EQE as the size decreases. This suggests a sidewall surface effect, since the mesa perimeter becomes increasingly important relative to the bulk in smaller devices.

μLED-based displays should enable higher resolution, high contrast ratio, longer lifetime, and lower power consumption in comparison with traditional technologies such as liquid-crystal displays (LCDs). Other potentials include wearable devices, ultra-large and very small display screens, augmented reality (AR), virtual reality (VR), and visible light communication.

The UCSB μLED material (Figure 1) was grown on patterned sapphire using atmospheric-pressure metal-organic chemical vapor deposition (MOCVD). The 3μm GaN buffer was unintentionally doped (UID).

The light-emitting multiple quantum well structure consisted of six periods of red-emitting indium gallium nitride (InGaN), an aluminium gallium nitride (AlGaN) cap, and GaN quantum barrier. For red light with wavelengths longer than 600nm, the indium content should be more than 35%.

The purpose of the AlGaN cap was to increase the peak EQE. Previous research suggests that the cap could prevent desorption of indium from the well during growth, and partially compensate for the compressive strain of InGaN relative to the GaN lattice.

The fabricated square μLEDs ranged from sides measuring 100μm down to 20μm. Transparent indium tin oxide (ITO) was used as the top p-contact. The devices included an omni-directional reflector (ODR) layer constructed from silicon dioxide and tantalum pentoxide layers. Atomic layer deposited (ALD) SiO_2 was also used to passivate the mesa sidewalls of the μLED, to reduce surface recombination from the reactive ion etch damage. The contact electrodes consisted of aluminium/nickel/gold (Al/Ni/Au).

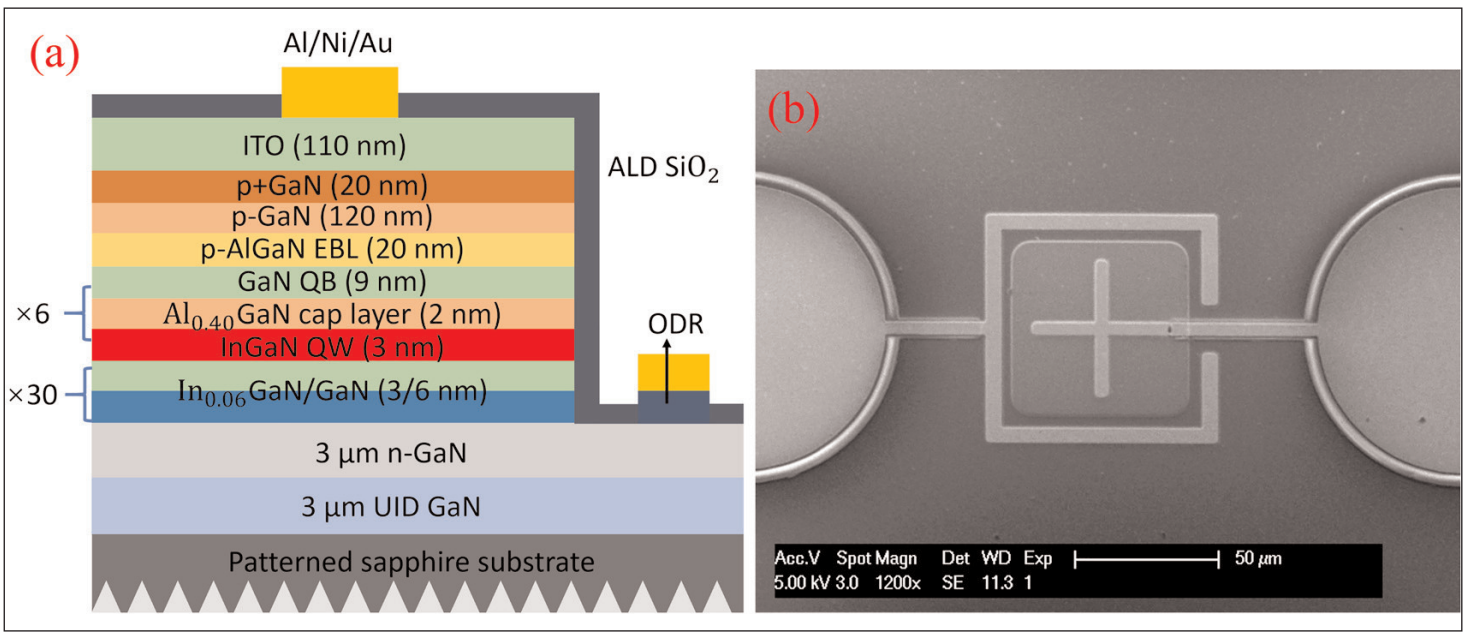

Figure 1. (a) Schematic epitaxial structure of InGaN red μLEDs; (b) Scanning electron micrograph of fabricated 60μmx60μm μLED.

The forward voltage for 20A/cm^2 current density was 3.7V for devices with sides from 40μm to 100μm. The smallest 20μm device had an even lower forward voltage of 3.5V, which the team suggests resulted from more effective current spreading in the ITO of the smaller device.

The light output power (LOP) increased approximately linearly with current injection, with the curves from the different size devices overlapping over their respective current domains. The LOP for the 100μm device reached 0.83mW at 20mA.

The spectrum of the red light peaked at 611nm with 48nm full-width at half-maximum (FWHM) at 3A/cm^2. The researchers report that there was no short-wavelength peak from the 30-period InGaN/GaN superlattice on the n-GaN layer, suggesting electron–hole injection was restricted to the red-emitting quantum wells.

At higher injection the peak blue-shifted to 588nm at 200A/cm^2. The shift was attributed to higher localized states filling up at higher current, increasing the effective bandgap, along with screening of the charge-polarization electric fields of the epitaxial structures. This large blue-shift would not be welcome in color display applications.

The peak EQE for 80μm and 100μm LEDs was around 2.6%, with the peak coming for injection in the range 10–20A/cm^2. The 20μm device had a slightly reduced value of 2.4%. The EQE range at 100A/cm^2 was 2.3–2.5% for the 20μm to 100μm devices.

The researchers also compared the size dependence of the peak EQE with that of aluminium indium gallium phosphide (AlGaInP) devices produced by UCSB and Seoul Viosys Co Ltd of South Korea (Figure 2). The AlGaInP structure showed a 57% reduction in EQE in going from sides of 100μm down to 20μm, while the InGaN μLEDs showed relatively stable performance.

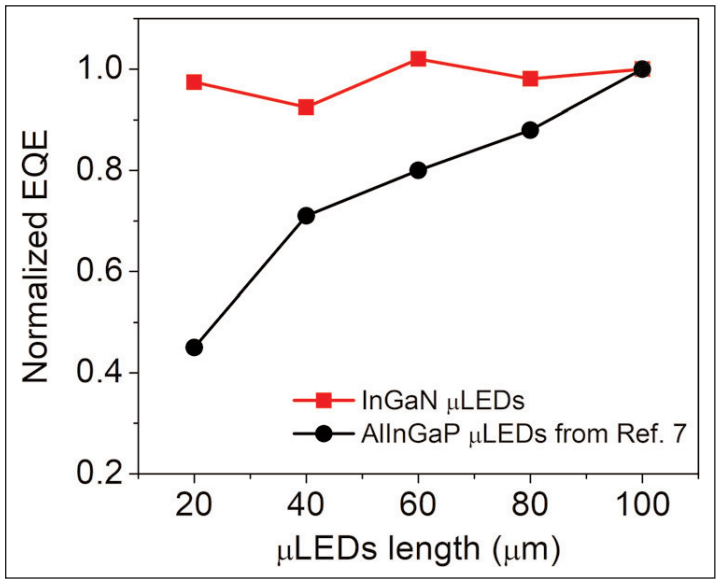

Figure 2. Comparison of normalized peak EQE for square InGaN and AlInGaP red μLEDs with different side lengths.

The researchers comment on the AlGaInP μLED EQE: "This is caused by the SRH [Shockley–Read–Hall] carrier injection loss due to a higher surface recombination velocity of AlInGaP, which is related to the fundamental property of the materials and difficult to overcome." The Shockley–Read–Hall mechanism is the major non-radiative recombination route at low current density.

The team also points out that μLED display proposals suggest the need for 5μmx5μm red-emitters with 5% EQE, adding "we believe that InGaN red μLEDs would have large potentials for such efficiencies." ■

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Author: Mike Cooke

Increased current for red InGaN micro-LEDs

Researchers have achieved power density comparable to AlGaInP devices targeting display applications.

King Abdullah University of Science and Technology (KAUST) in Saudi Arabia has reported indium gallium nitride (InGaN) red micro-sized light-emitting diodes (μLEDs) aimed at meeting the color and power requirements of LED-based displays [Zhe Zhuang et al, Photonics Research, v9, p1796, 2021]. In particular, the researchers compared the color performance of red, green and blue (RGB) InGaN μLED arrays with that required by the International Telecommunication Union Radiocommunication Sector (ITU-R) Recommendation BT.2020 (Rec.2020), 'Parameter values for ultra-high definition television systems for production and international programme exchange'.

Although blue and green InGaN LEDs are reaching commercialization, the red sector is still very much "in development" with red InGaN LEDs generally suffering from very low efficiency and output power, compared with devices based on aluminium gallium indium phosphide (AlGaInP) technology. However, the AlGaInP LED performance does not scale well to the micro-level. This is attributed to material problems, in particular high surface recombination velocities and longer carrier diffusion lengths. As devices become smaller, surface effects come to dominate. Surface carrier recombination tends to be non-radiative, sapping output power. By contrast, the performance of InGaN red μLEDs has been found to be only slightly impacted by scaling to the micro-level.

Displays based on mixing RGB light from μLEDs is desired from the perspectives of fast response, long lifetime, high brightness level, and low energy consumption.

The KAUST red InGaN structure was grown by metal-organic vapor phase epitaxy (MOVPE) on patterned sapphire at 100kPa pressure. The active region consisted of two red-emitting quantum wells (QWs) and one blue-emitting quantum well. The 24nm barriers between the wells used a multi-layer AlN/GaN/AlGaN/GaN structure in an effort to compensate for strain imbalances. The presence of

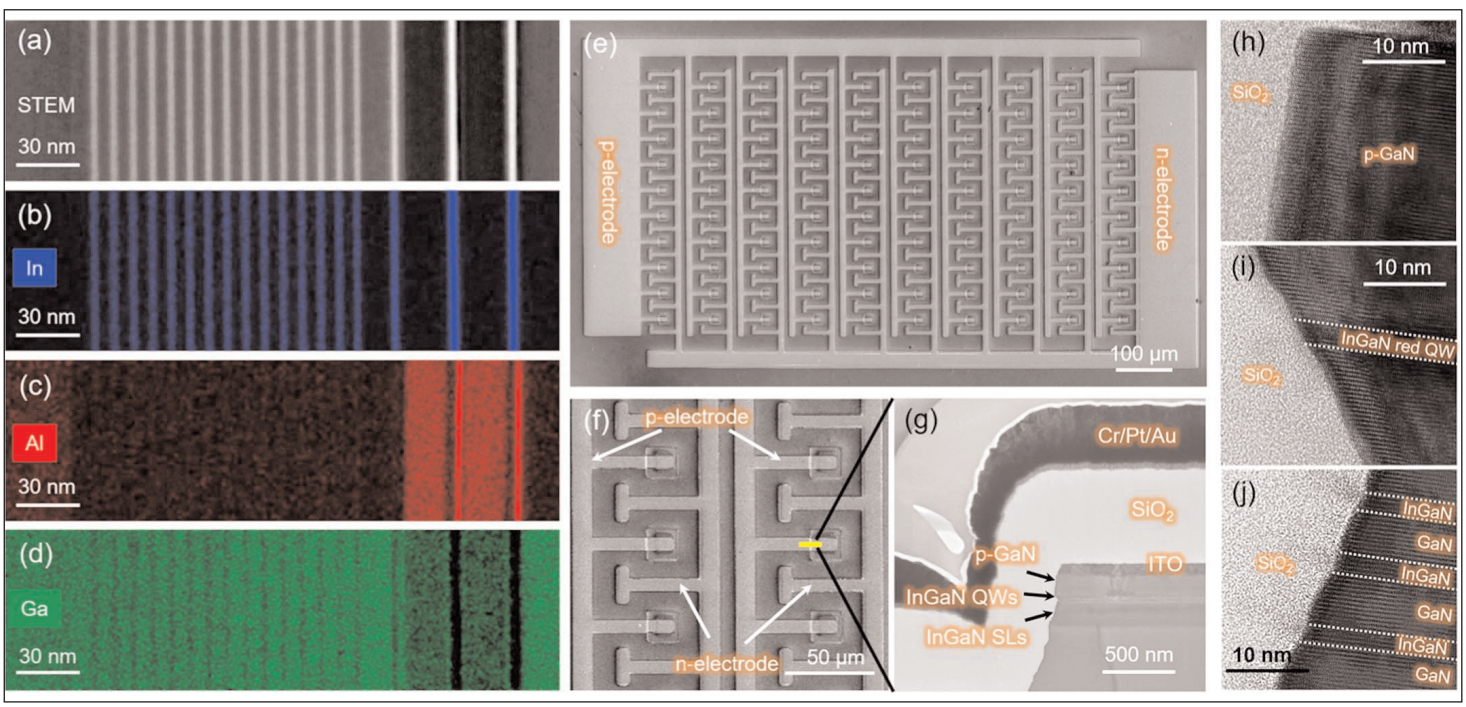

Figure 1. (a) Cross-sectional scanning transmission electron microscopy (STEM) image of red InGaN LED structures. (b)–(d) Energy-dispersive x-ray spectroscopy (EDS) elemental mappings of In, Al and Ga atoms in InGaN QWs and SLs. (e) Top-view and (f) high-resolution scanning electron microscopy (SEM) images for red μLED array. (g) Cross-sectional TEM image of single μLED. (h)–(j) Cross-sectional high-resolution TEM (HRTEM) images of interfaces between nitride materials and SiO_2.

aluminium (Al) in the barrier also inhibited indium evaporation from wells during high-temperature growth. A 15-period InGaN/GaN superlattice (SL) was placed under the active region.

The µLEDs were fabricated with indium tin oxide (ITO) as a transparent conductor on the p-side on the device (Figure 1). The ITO layer was annealed in a two-step process. Then the 17µmx17µm device mesa was plasma etched using plasma-enhanced chemical vapor deposition (PECVD) silicon dioxide (SiO_2) as a hard mask. The mesa sidewalls were treated with tetramethylammonium hydroxide (TMAH) wet-etching to remove surface damage from the plasma etch process.

The SiO_2 hard mask residue was removed with buffered oxide etch and replaced with a new layer of PECVD SiO_2 as a sidewall passivation layer and electrical isolation. The n- and p-electrodes consisted of chromium/platinum/gold connected through the SiO_2. The devices were connected in 10x10 arrays, using the same metal combination as for the electrodes. Green and blue 10x10 structures were also fabricated using commercial LED wafers.

The turn-on voltage was around 2V, while there was quite a high current leakage under reverse bias: 7.8µA or 0.27mA/cm^2 at –4V. The leakage was blamed on the "many defects/dislocations generated in high-indium-content QWs", as needed for red emission.

At 50A/cm^2 injection, the electroluminescence spectra showed a single red peak at 630nm with 62.9nm full-width at half-maximum (FWHM). At lower 10A/cm^2 injection, the peak exhibited a shoulder, which the researchers attribute tentatively to "localized states, which originated from the indium phase separation in high-indium-content QWs." The 630nm wavelength meets the Rec.2020 requirement for red primary color emission.

Between the two current levels there was a large 32nm blue-shift with the increased injection, mainly due to "strong quantum-confined Stark effect (QCSE) and band-filling effect in red InGaN QWs." Other research on red InGaN tends to see similar shifts. The width of the peak also reduced with increased current due to the emission from localized states saturating. The localized states have more varied emission wavelengths, relative to band-to-band recombination.

The 50A/cm^2 emission at 630nm was at a much higher injection level compared with other attempts at red InGaN µLEDs reported in the literature (Figure 2), which suffer from blue-shift into orange or amber wavelengths.

The external quantum efficiency (EQE) increased up to 40A/cm^2, when the increase flattened off, reaching about 0.18% on-wafer at 50A/cm^2. The researchers expect that if the measurements had been performed in an integrating sphere, the value would have come in the

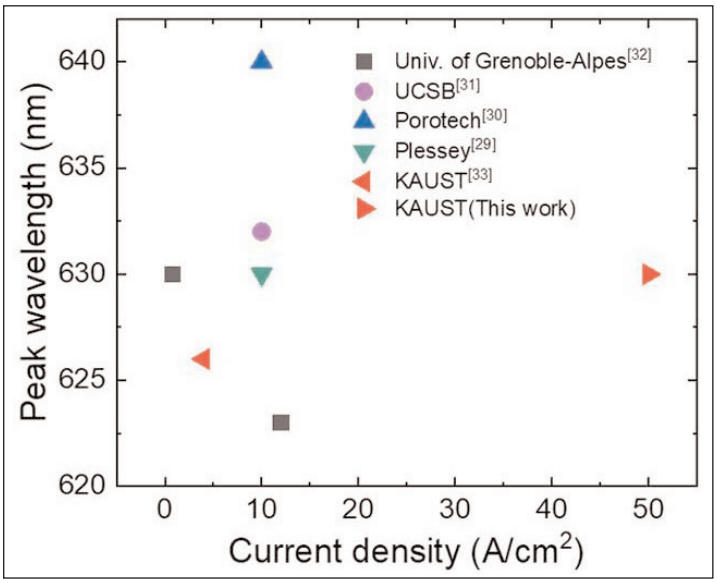

Figure 2. Peak wavelength comparison with other works.

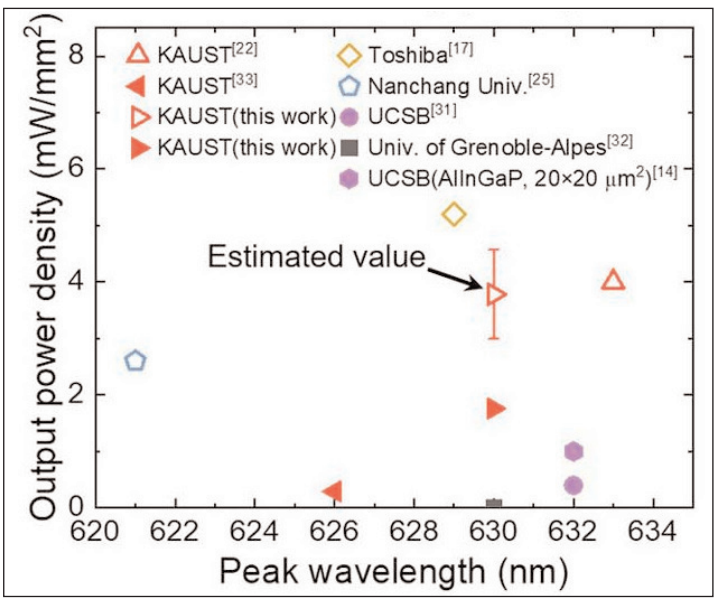

Figure 3. Output power density comparison with other works. Solid dots on-wafer testing; hollow dots large-sized LEDs in integrating sphere. Also shown, estimate of KAUST value in integrating sphere.

range 0.3–0.5%. These values are still way below that presently achieved by blue or even green InGaN LEDs.

The on-wafer light output power reached 51µW at 50A/cm^2. The corresponding output power density was 1.76mW/mm^2. The researchers report: "The output power density in this work was the highest compared with other red InGaN µLEDs." The team also says that their red µLEDs had similar performance to normal-sized red InGaN LEDs.

The researchers also compared their work with the output power density achieved in 20µmx20µm AlGaInP LED reports by University of California Santa Barbara (UCSB), along with other reports (Figure 3). The AlGaInP device achieved a 1W/mm^2 power density.

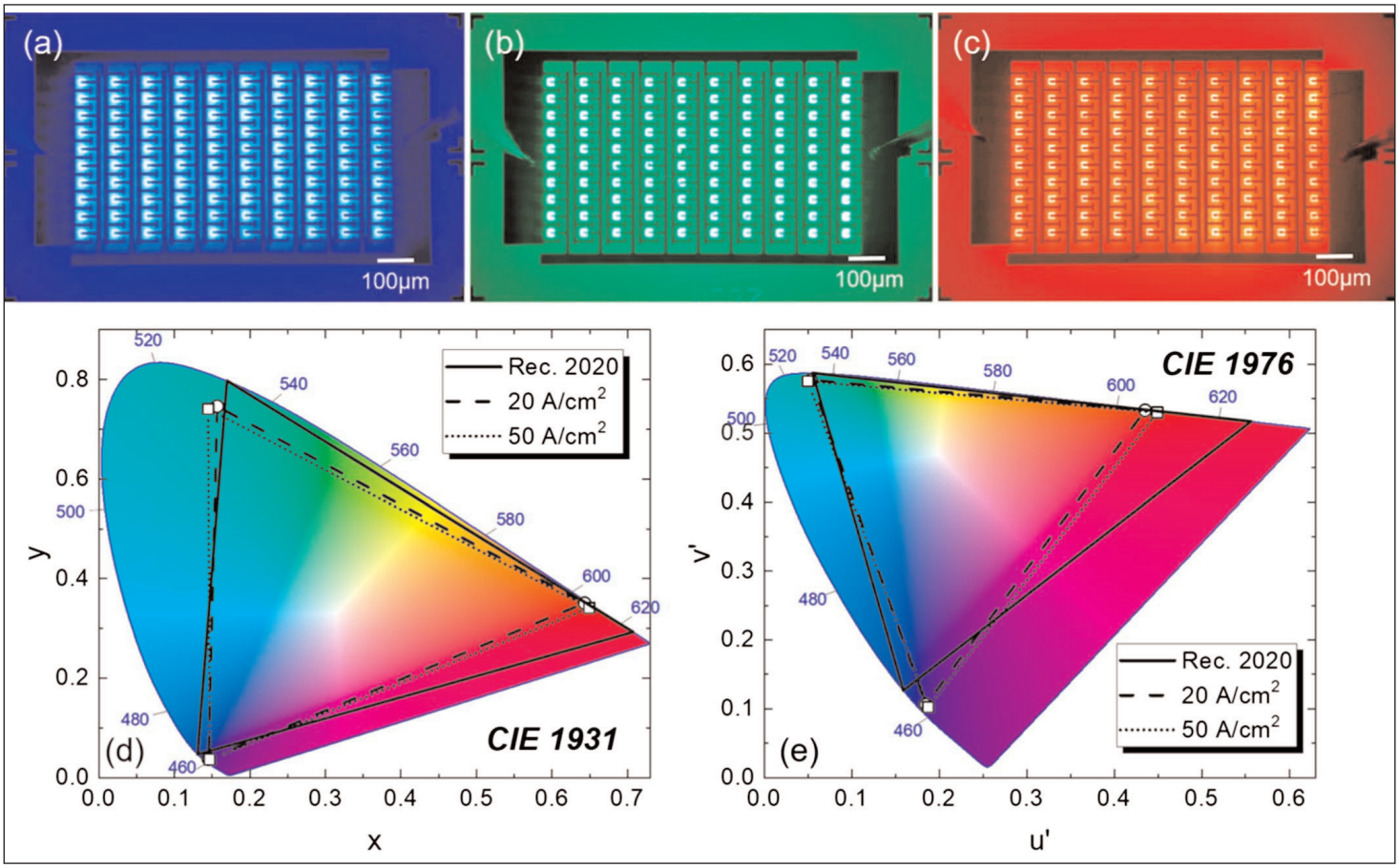

Figure 4. (a)–(c) Electroluminescence images of blue, green and red 10x10 μLED arrays at 20A/cm^2. (d) CIE 1931 and (e) CIE 1976 diagrams blue, green and red 10x10 arrays at 20 and 50A/cm^2, along with Rec.2020.

The UCSB team suggested that this could be increased up to 50% at most by separating the device from the growth wafer.

The researchers plotted their RGB device performances on CIE 1931 and 1976 diagrams (Figure 4). At 20A/cm^2, the KAUST devices covered 81.5% and 76.2% of the Rec.2020 color space in the CIE 1931 and 1976 diagrams. At 50A/cm^2, the corresponding figures were 81.3% and 79.1%. These figures could be improved by using a blue μLED with a wavelength closer to that of the Rec.2020 specification. Such material has already been commercialized. ■

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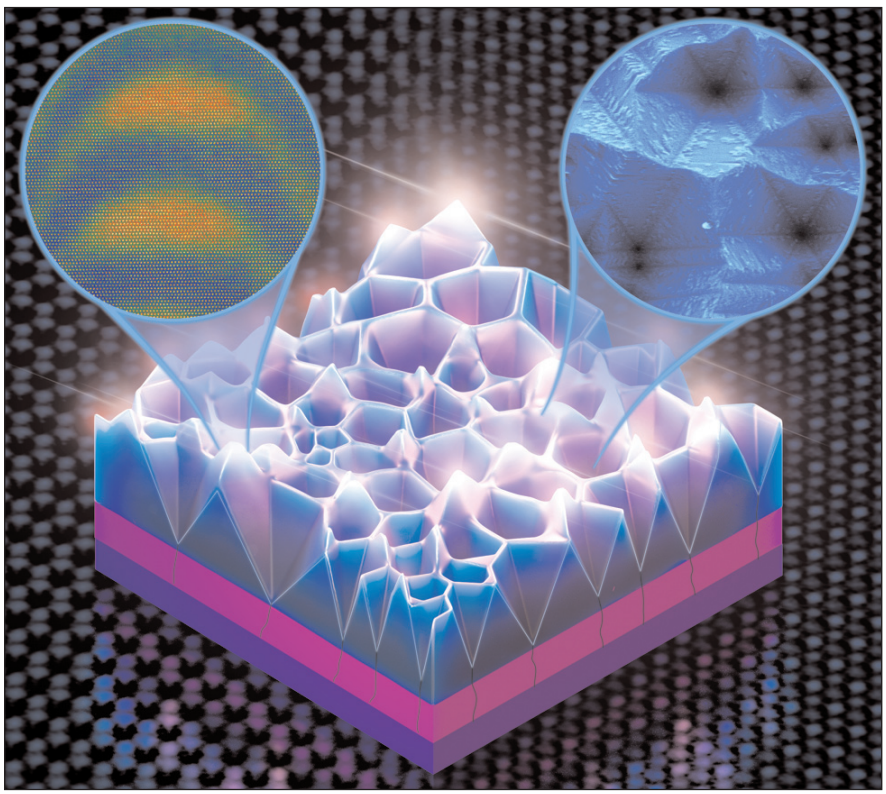
SMART uses intrinsic defects to form indium-rich quantum dots yielding long-wavelength InGaN LEDs

V-pit-induced pyramids could provide the basis for the future development of monolithic RGB micro-LED arrays on silicon.

Together with collaborators at the Massachusetts Institute of Technology (MIT), National University of Singapore (NUS) and Nanyang Technological University (NTU), researchers at the Low Energy Electronic Systems (LEES) Interdisciplinary Research Group (IRG) at Singapore–MIT Alliance for Research and Technology (SMART, a partnership between the Massachusetts Institute of Technology and the National Research Foundation of Singapore) have discovered a new method of generating long-wavelength (red, orange and yellow) light through the use of intrinsic defects in semiconducting materials, with potential applications as direct light emitters in commercial light sources and displays. This technology would be an improvement on existing methods (which use phosphors, for example) to convert one color of light to another.



A new method of quantum dot fabrication has been demonstrated by making use of intrinsic defects in LED materials. Through the formation of pyramids, localized bright luminescence emanates from the pyramid apexes containing indium-rich quantum dots. Credits: Singapore-MIT Alliance for Research and Technology (SMART).

Since first being fabricated over two decades ago in the 1990s, indium gallium nitride (InGaN) LEDs have evolved to become ever smaller while growing increasingly powerful, efficient and durable. InGaN LEDs are currently found across a myriad of industrial and consumer use cases (including signals & optical communication and data storage) and are critical in high-demand consumer applications such as solid-state lighting, television sets, laptops, mobile devices, augmented reality (AR) and virtual reality (VR) solutions.

Ever-growing demand for such electronic devices has driven over two decades of research into achieving higher optical output, reliability, longevity and versatility from semiconductors — leading to the need for LEDs that can emit different colours of light. Traditionally, InGaN material has been used in modern LEDs to generate purple and blue light, with aluminium gallium indium phosphide (AlGaInP) used to generate red, orange and yellow light. This is due to InGaN's poor performance in the red and amber spectrum caused by a reduction in efficiency as a result of the higher levels of indium required.

In addition, such InGaN LEDs with considerably high indium concentrations remain difficult to manufacture using conventional semiconductor structures. As such, the realization of fully solid-state white-light-

emitting devices — which require all three primary colors of light — remains an unattained goal.

Addressing the above challenges, in the paper 'Light-Emitting V-Pits: An Alternative Approach toward Luminescent Indium-Rich InGaN Quantum Dots' (ACS Photonics, 2021 (8), issue 10, p2853), the SMART researchers describe a practical method to fabricate InGaN quantum dots with significantly higher indium concentration by making use of pre-existing defects in InGaN materials.

In this process, the coalescence of V-pits, which result from naturally existing dislocations in the material, directly forms indium-rich quantum dots, small islands of material that emit longer-wavelength light. By growing these structures on conventional silicon substrates, the need for patterning or unconventional substrates is further eliminated. The researchers also conducted high spatially resolved compositional mapping of the InGaN quantum dots, providing the first visual confirmation of their morphology.

In addition to the formation of quantum dots, the nucleation of stacking faults — another intrinsic crystal defect — further contributes to emissions of longer wavelengths.

"For years, researchers in the field have attempted to tackle the various challenges presented by inherent defects in InGaN quantum well structures," notes the lead author, SMART graduate student Jing-Yang Chung. "In a novel approach, we instead engineered a nano-pit defect to achieve a platform for direct InGaN quantum dot growth. As a result, our work demonstrates the viability of using silicon substrates for new indium-rich structures which, along with addressing current challenges in the low efficiencies of long-wavelength InGaN light emitters, also alleviate the issue of expensive substrates."

SMART says that, in this way, its discovery represents a step forward in overcoming InGaN's reduced efficiency when producing red, orange and yellow light. In turn, this work could be instrumental in the future development of micro-LED arrays consisting of a single material.

"Our discovery also has implications for the environment," says co-author Dr Silvija Gradecak, principal investigator at LEES. "For instance, this breakthrough could lead to a more rapid phasing out of non-solid-state lighting sources — such as incandescent bulbs — and even the current phosphor-coated blue InGaN LEDs with a fully solid-state color-mixing solution, in turn leading to a significant reduction in global energy consumption," she adds.

"Our work could also have broader implications for the semiconductor and electronics industry, as the new method described here follows standard industry manufacturing procedures and can be widely adopted and implemented at scale," says SMART CEO and LEES lead principal investigator Eugene Fitzgerald. "On a more macro level, apart from the potential ecological benefits that could result from InGaN-driven energy savings, our discovery will also contribute to the field's continued research into and development of new efficient InGaN structures."

The research was carried out by SMART and supported by the National Research Foundation (NRF) Singapore under its Campus for Research Excellence and Technological Enterprise (CREATE) program. For this paper, the LED structures were grown using SMART's unique facilities , structural studies were conducted at NUS using atomically resolved electron microscopes, while nanoscale optical studies were conducted at MIT and NTU. ■

https://pubs.acs.org/doi/10.1021/acsphotonics.1c01009
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Stacking three III–nitride light-emitting diodes

First triple-junction monolithic cascade structure enabled with improved MOCVD tunnel junctions.

Ohio State University and Sandia National Laboratories in the USA claim the first demonstration of triple-junction cascaded III–nitride light-emitting diodes (LEDs) grown by metal-organic chemical vapor deposition (MOCVD) [Zane Jamal-Eddine et al, Appl. Phys. Express, v14, p092003, 2021].

Stacking LEDs is one way to overcome the limitations in output power density imposed by the effects of efficiency droop at large current density. Tunnel-junction (TJ) structures are used to connect LEDs since they enable electron majority carriers to be transformed to holes for injection into the next stage of the cascade. Producing TJs with a low voltage drop for a given current is a challenge, particularly in an MOCVD growth scheme relative to molecular beam epitaxy (MBE). By contrast, MOCVD is preferred for mass production, and also tends to produce higher-quality active regions.

The epitaxial structures (Figure 1) were grown in one run. Three identical layer sequences were grown on top of each other, consisting of active light-emitting multiple quantum wells (MQWs), followed by a tunnel-junction (TJ) structure, which included a very low-indium-content indium gallium nitride (InGaN) layer, graded from a peak of 6% to 0%. The low content ensured that the layer was transparent to the light generated from the higher-indium-content MQWs.

The epitaxy was performed on templates consisting of sapphire substrate, 6μm n-GaN, 500nm 950°C n-GaN, and 190nm 900°C InGaN. The n-InGaN underlayer was designed to avoid V-pit defect formation.

The LEDs were fabricated with a 100μmx100μm mesa etch, p-GaN activation, and metal contact deposition.

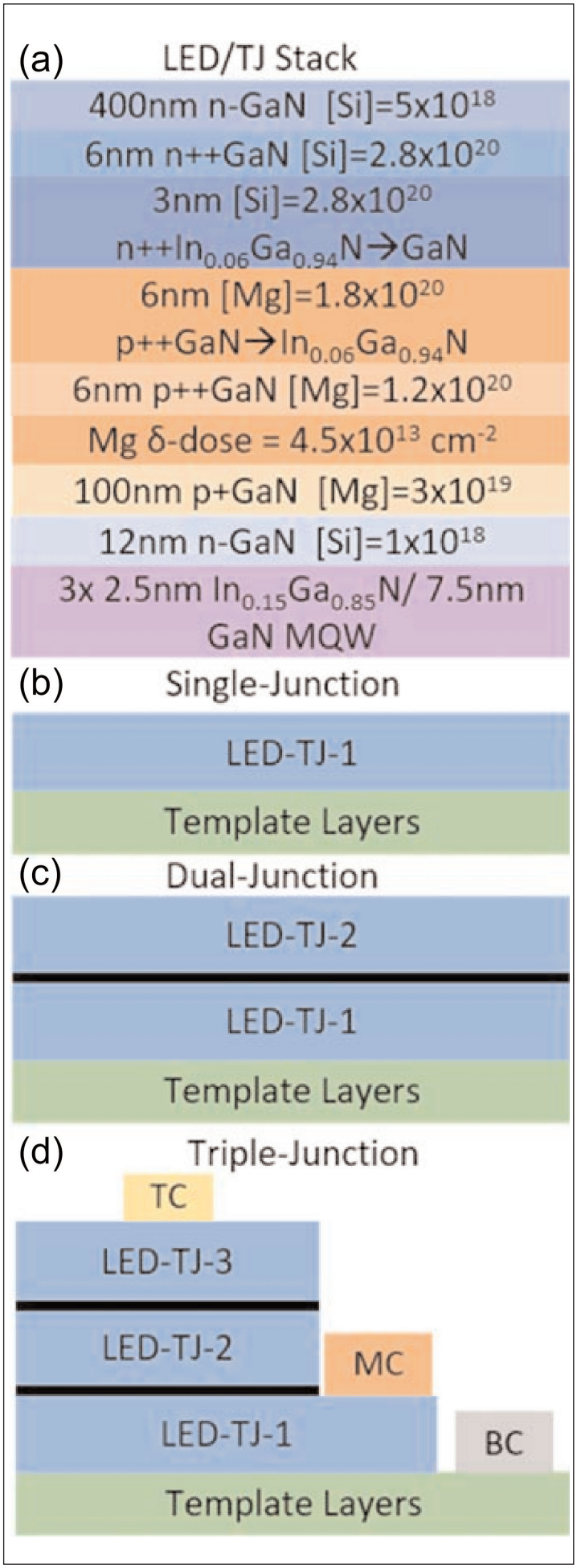

Figure 1. Epitaxial structure of (a) each LED/graded InGaN TJ period, (b) single-junction device, (c) dual-junction device, and (d) full three-junction device with top (TC), middle (MC) and bottom (BC) contacts.

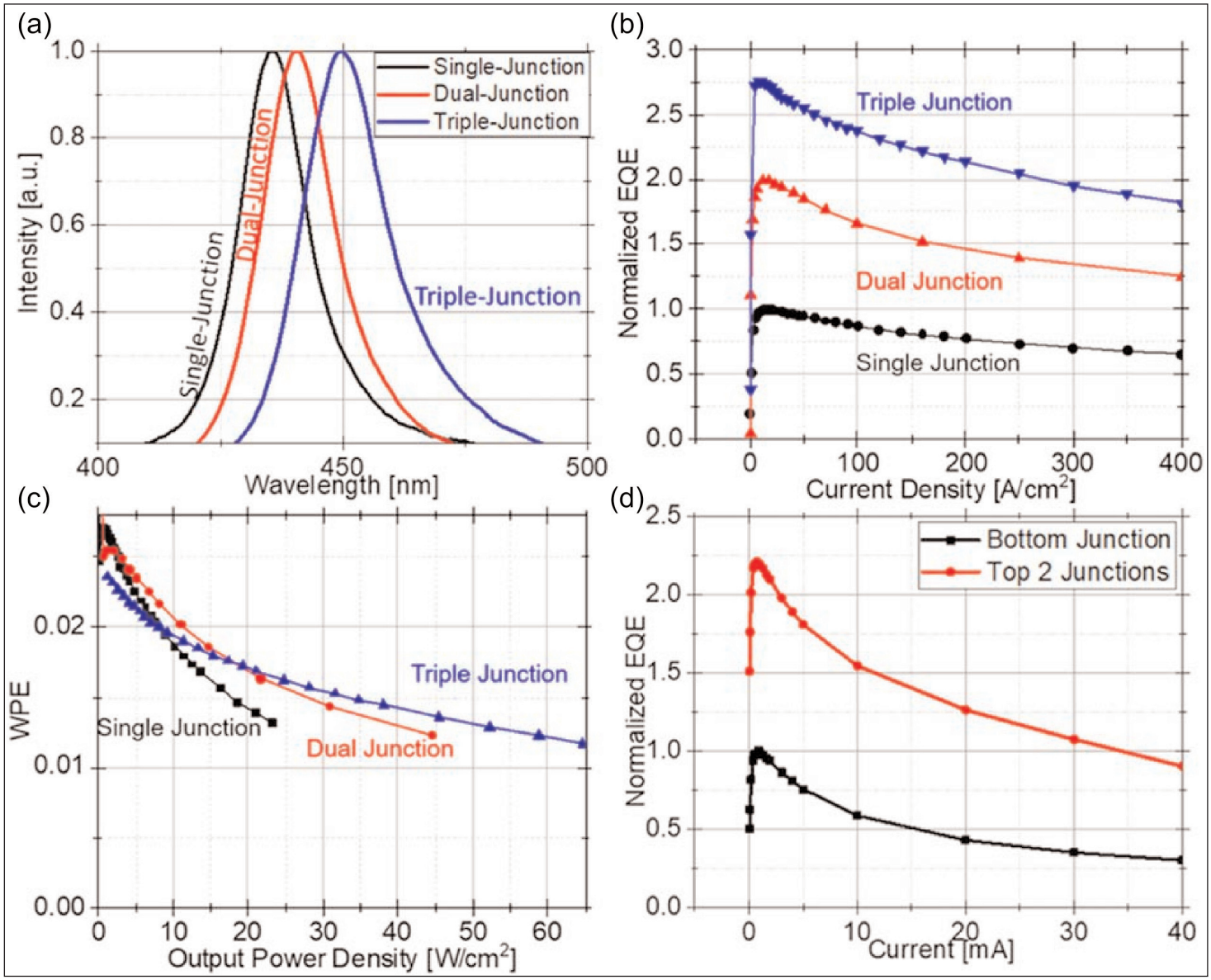

Figure 2. (a) Electroluminescence characteristics of single (black), dual (red) and triple (blue) junction devices at 50A/cm^2. (b) Relative EQEs. (c) WPEs as a function of output power. (d) Relative EQEs from bottom-most junction (black), and the top 2 junctions (red) of the 3-junction LED.

The p-GaN activation used a process developed by the team, and reported previously.

The bottom contact consisted of titanium/aluminium/nickel/gold, annealed at 850°C in nitrogen. The top ring-contact was aluminium/nickel/gold, annealed at 500°C in nitrogen. The middle contact was fabricated by etching 18μmx18μm from a corner of the device mesa and depositing aluminium/nickel/gold. This middle contact was designed to enable independent biasing of the bottom LED-TJ-1 "to probe the effects that thermal budget has on device performance". In fact, the researchers' measurements of forward voltage degradation suggested that dopant or indium diffusion occurred, degrading the triple-junction device's performance.

The voltage drops for 10A/cm^2 current density were 3.3V, 6.9V and 10.8V in 1-, 2- and 3-junction LEDs, respectively. The researchers point out that the increments for the TJ connections (210% for 2-junctions and 330% for 3-junctions over 1-junction) are "significantly better than results reported earlier for MOCVD-grown cascaded LEDs for 2-junction LEDs". The team also compares their result with a 312% increment for a 3-junction LED grown using MBE.

The Ohio/Sandia group attributes the improved junction scaling of the forward voltage to its use of a graded-composition rather than single-composition InGaN layer in the TJ structure.

On-wafer light output measurements were performed by collecting light from the sapphire side. At 50A/cm^2, the peak wavelengths were 435nm, 440nm and 449nm for the single-, dual- and triple-junction wafers (see Figure 2). The team suggests the differences were due to growth variations.

The peak external quantum efficiency (EQE) of the 2-junction device was 200% that of the 1-junction's.

However, the 3-junction EQE did not scale as well, reaching a peak of only 275%. The researchers comment: "The reduction in the EQE scaling for the 3-junction device is also suspected to be a result of thermal degradation of the bottom-most LED due to the thermal budget associated with growing the 3-junction structure."

The team broke out the EQE from the top two junctions and compared it with that from the bottom junction, using the middle contact of the 3-junction device. The top two junctions achieved an EQE more than twice that of the bottom, "suggesting a significant loss in output power for the lowest junction," the team writes.

On the basis of a spectroscopic study showing only a slightly blue-shifted, wider peak in the bottom junction, the researchers conclude that "the thermal budget associated with the lower junction does cause a degradation in the EQE, and is an issue that could be addressed through improvements in growth techniques or active-region design." The reduced power efficiency is attributed to an increased non-radiative recombination rate, "not captured in the electroluminescence spectra".

Finally, the wall-plug efficiency (WPE) was estimated. The 2-junction device demonstrated superior performance over the 1-junction device above 5W/cm^2 output power. The 3-junction LED had better WPE than this for output powers of 15W/cm^2.

The team comments: "The improvement in WPE with increasing output power shows that multi-active-region devices can be operated at significantly higher power density while maintaining high efficiency compared with the single-junction LED." ■

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More evidence provided for Auger causing GaN LED efficiency droop

Electron emission spectroscopy supports a three-body mechanism for energy sapping processes.

University of California Santa Barbara (UCSB) in the USA and Ecole Polytechnique in France have analyzed electron emission spectroscopy (EES) results on indium gallium nitride (InGaN) light-emitting diodes (LEDs), concluding that Auger recombination is the dominant cause of efficiency droop [Wan Ying Ho et al, Appl. Phys. Lett., v119, p051105, 2021].

Efficiency droop is a particular problem in III–nitride LEDs. External quantum efficiency (EQE) tends to peak in the injection current density range of 1–10A/cm^2.

The researchers used LED material grown by Seoul VioSys through metal-organic chemical vapor deposition (MOCVD) on patterned sapphire. The structure featured an 8-period quantum well. The p-contact metal consisted of palladium/gold (Pd/Au) with 2257 hexagonal apertures in a honeycomb arrangement. The hexagons had a 3.5μm apothem (perpendicular distance from a side to the center). The metal strips between the apertures were 3μm wide.

EES was enabled by depositing a sub-monolayer of cesium to create a negative electron affinity (NEA). The cesium layer was optimized by monitoring photo-excited electrons from the p-GaN contact layer.

The energy of the emitted electrons was measured using a spherical sector electrostatic analyzer operated in a constant-pass energy mode. The light output power (LOP) was monitored using a photodetector in continuous-wave mode at room temperature.

The peak external quantum efficiency was achieved at an injection current density of order 10A/cm^2. The EES experiments were made at current densities up to 45A/cm^2 in pulse mode to avoid self-heating effects.

The researchers attributed a stronger EES signal (Figure 1) than their previous work to using an epitaxial structure with a thinner p-contact region of 20nm p^{++}-AlGaN electron-blocking layer, 20nm p-GaN, and 20nm p^{++}-GaN surface. The EES showed four distinct peaks associated with photoelectric emission from diode-generated light on the Au and Pd contacts,

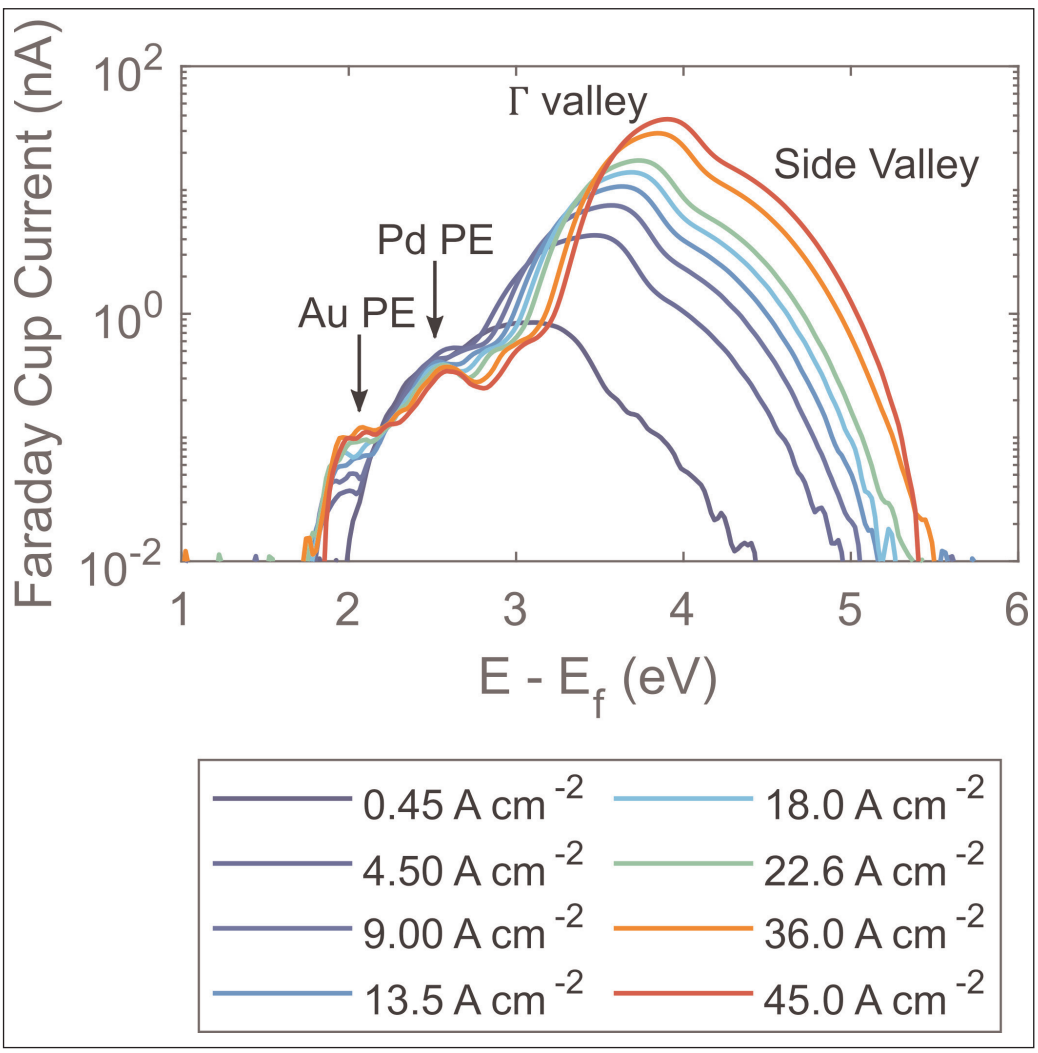

Figure 1. Energy distribution curves from EES experiments.

and hot electrons from the main conduction-band valley minimum (Γ) and the first side-valley.

The team reports: "The semiconductor-related peaks are one or two orders of magnitude larger than our previous works, which employed thicker p-regions, showing significant improvement in signal-to-noise ratio. This further implied that hot electrons are indeed generated in the bulk region and not by light or other hot-electron generation mechanisms at the surface."

The researchers see the Au EES signal as constituting an in-situ photometer that should vary linearly with the LOP. Theoretically the LOP should vary as the square of the carrier density (n^2) in the MQW, reflecting the two-body electron–hole (eh) recombination process.

The 'hot-electron' signal from the side valley is expected to indicate the three-body eeh process where the energy from electron-hole recombination is transferred to an 'Auger' electron, rather than a photon. The Auger electron may have enough energy therefore to be trapped in a side valley. A three-body process is expected to vary as the cube of carrier density (n^3).

Comparing the two signals would lead one to expect the side valley to vary as $LOP^{3/2}$ (cube of the square-root), as found experimentally (Figure 2). The main Γ valley signal also is mainly n^3, but the fit is improved with the inclusion of a square term, n^2, which the researchers suggest is due to trap-assisted Auger recombination (Figure 3).

Alternative explanations of droop as being due to electron overshoot/escape are apparently excluded since the ratio of side valley/Γ-valley signals increases with injection current. Overshoot/escape would lead to the opposite tendency, it is argued. From what I can make out, the overshoot/escape mechanisms should increase the number of Γ electrons, but not side-valley ones. ■

https://doi.org/10.1063/5.0054636

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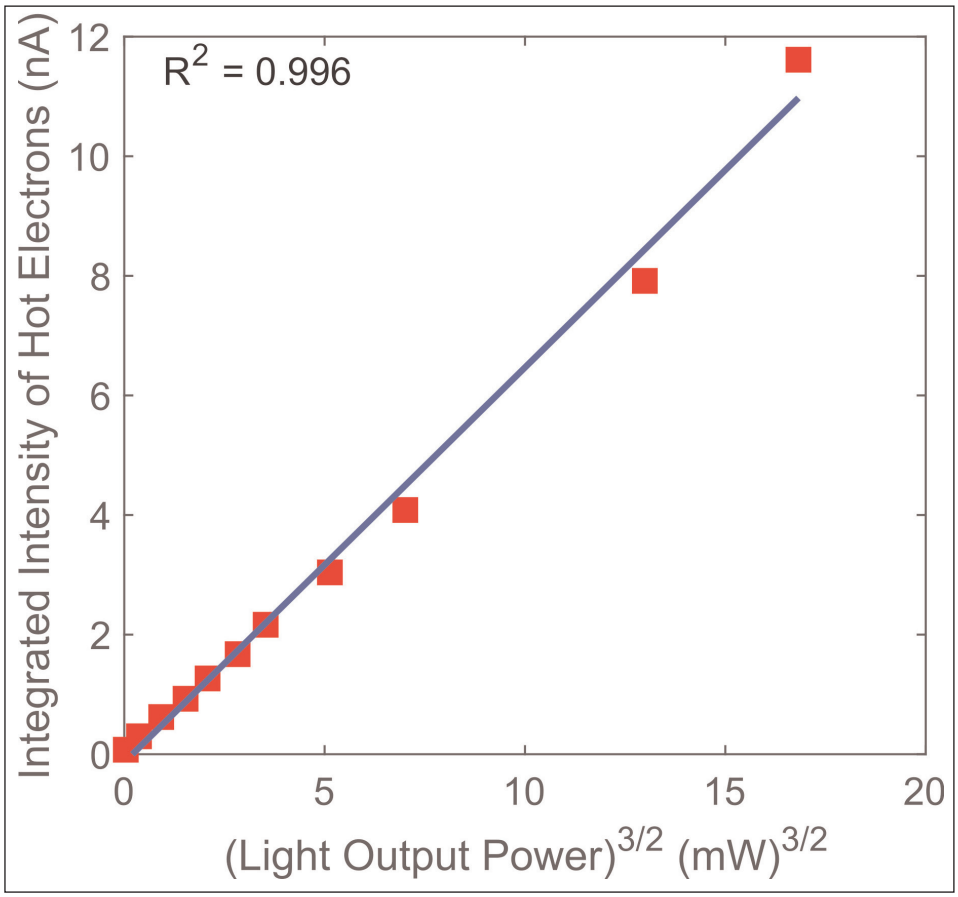


Figure 2. Side-valley peak intensity versus cube of the square root of LOP, and linear fit.

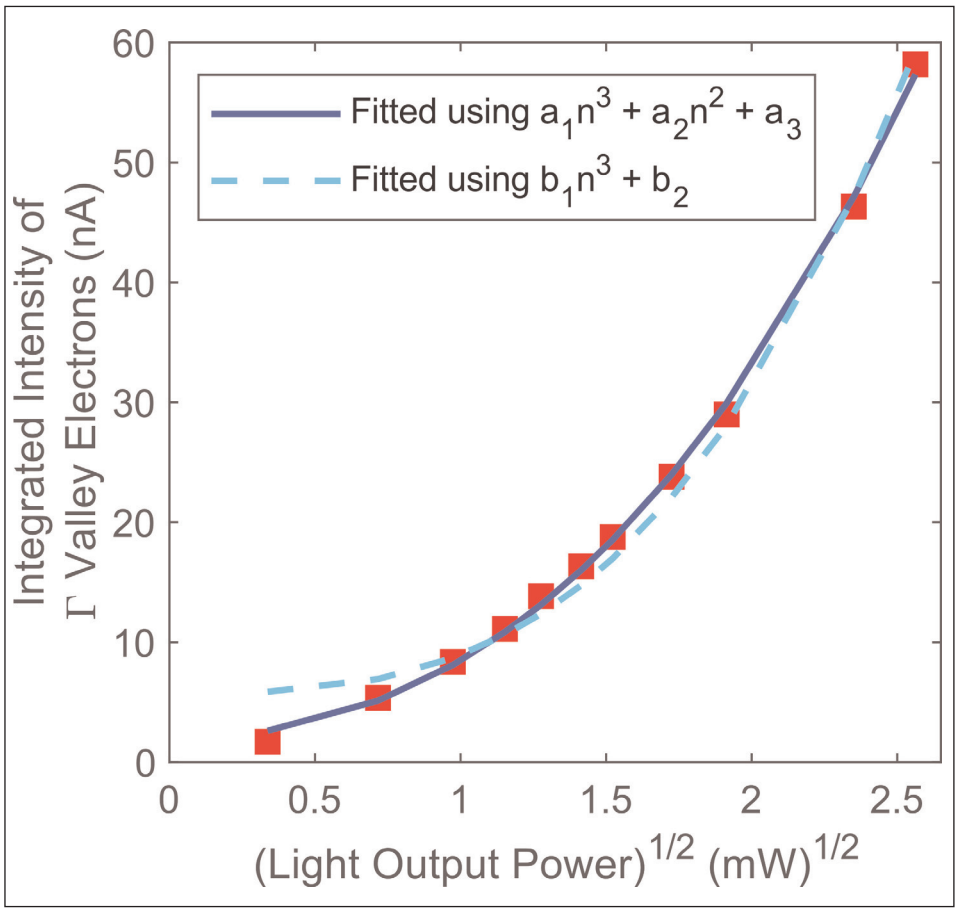


Figure 3. Γ-valley peak intensity versus square-root of LOP.

Epitaxy equipment market growing at 8% CAGR to $1.1bn in 2026

China comprised 57% of Aixtron's revenue in 2020 but just 13% of Veeco's, says Yole Développement.

The epitaxy equipment market — including metal-organic chemical vapor deposition (MOCVD), high-temperature chemical vapor deposition (HTCVD) and molecular beam epitaxy (MBE) — was $692m in 2020 and is expected to rise at a compound annual growth rate (CAGR) of 8% to about $1.1bn in 2026, estimates market research and strategy consulting company Yole Développement in its report 'Epitaxy Equipment for More than Moore'.

The MOCVD segment comprised over 60% of equipment market revenue in 2020, and is growing at a CAGR of 7% from 2020 to $630m in 2026. The HTCVD segment is growing at a CAGR of 9.5%, and will reach about $393m in 2026. The MBE segment is growing at a CAGR of 7.1%, and will be $68m in 2026.

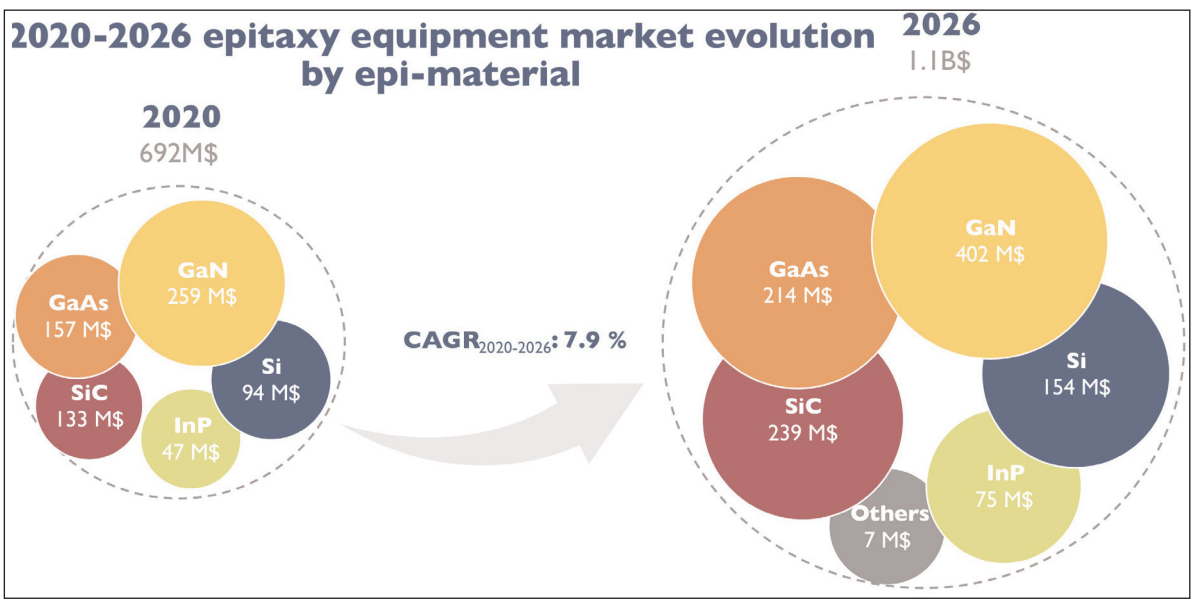
However, these figures do not do justice to the vitality and omnipresence of the epitaxy step in mission-critical applications in market segments such as automotive electric vehicles/hybrid electric vehicles (EVs/HEVs), consumer (smartphone, smartwatch, augmented reality/virtual reality AR/VR), and aerospace & defense.

"We are at a crucial period of history where each device around us is becoming smarter, greener, and more compact." says Vishnu Kumaresan PhD, technology & market analyst, Semiconductor Manufacturing at Yole. "Even the excruciating COVID-19 situation has had nothing more than a positive impact on the semiconductor industry by only further accelerating technological innovation. In such an innovation race to add more functionalities into our everyday devices using the More-than-Moore approach, the PPAC [power-performance-area-cost] factor is improved not only by scaling but also by using non-silicon materials and by heterogeneously integrating them to one another," he adds.

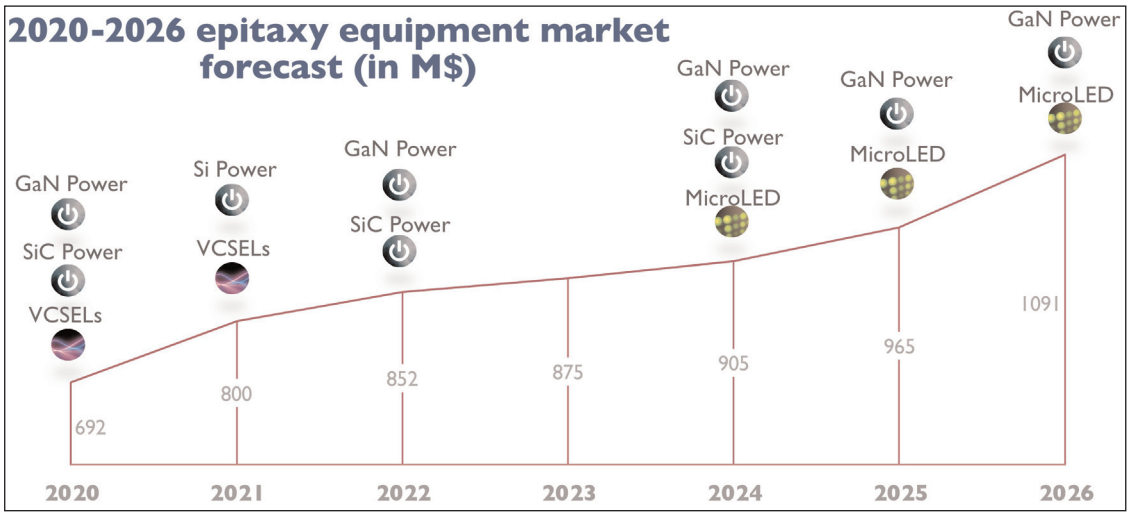
In this regard, the silicon market segment — along with other market segments including non-classical substrates such as gallium arsenide (GaAs), gallium nitride (GaN), silicon carbide (SiC) and indium phosphide (InP) — is growing at significant CAGRs. However, the choice of these materials comes with stringent material quality requirements and hence necessitates ultra-pure thin films grown using epitaxy equipment.

The choice of equipment type depends on various factors such as layer quality, growth speed, cost of ownership (COO) and the material systems that can be grown. Whereas MOCVD and MBE is mainly used for compound semiconductor materials such as GaAs, GaN and InP, HTCVD technology is dedicated to silicon and SiC-based device manufacturing. The HTCVD SiC market segment is mainly dominated by Japan's Tokyo Electron Ltd (TEL) and, in parallel, the HTCVD silicon epitaxy equipment market is dominated by US-based equipment maker Applied Materials.

The high demand for equipment is only satisfied by very few equipment vendors currently. In total, Yole identifies about 11 major epitaxy equipment vendors



in the More-than-Moore space. The top three — Germany's Aixtron, the USA's Veeco and China's AMEC — clearly dominated the market in 2020, with 62% market share by revenue. However, this market is more complex. Indeed, it is also occupied by various other front-end equipment giants. Yole identifies Applied Materials, Tokyo Electron Ltd (TEL), ASM International and Naura for example; some domain-specific players such as Taiyo Nippon Sanso, NuFlare, LPE; and also some unidentified start-ups from China.



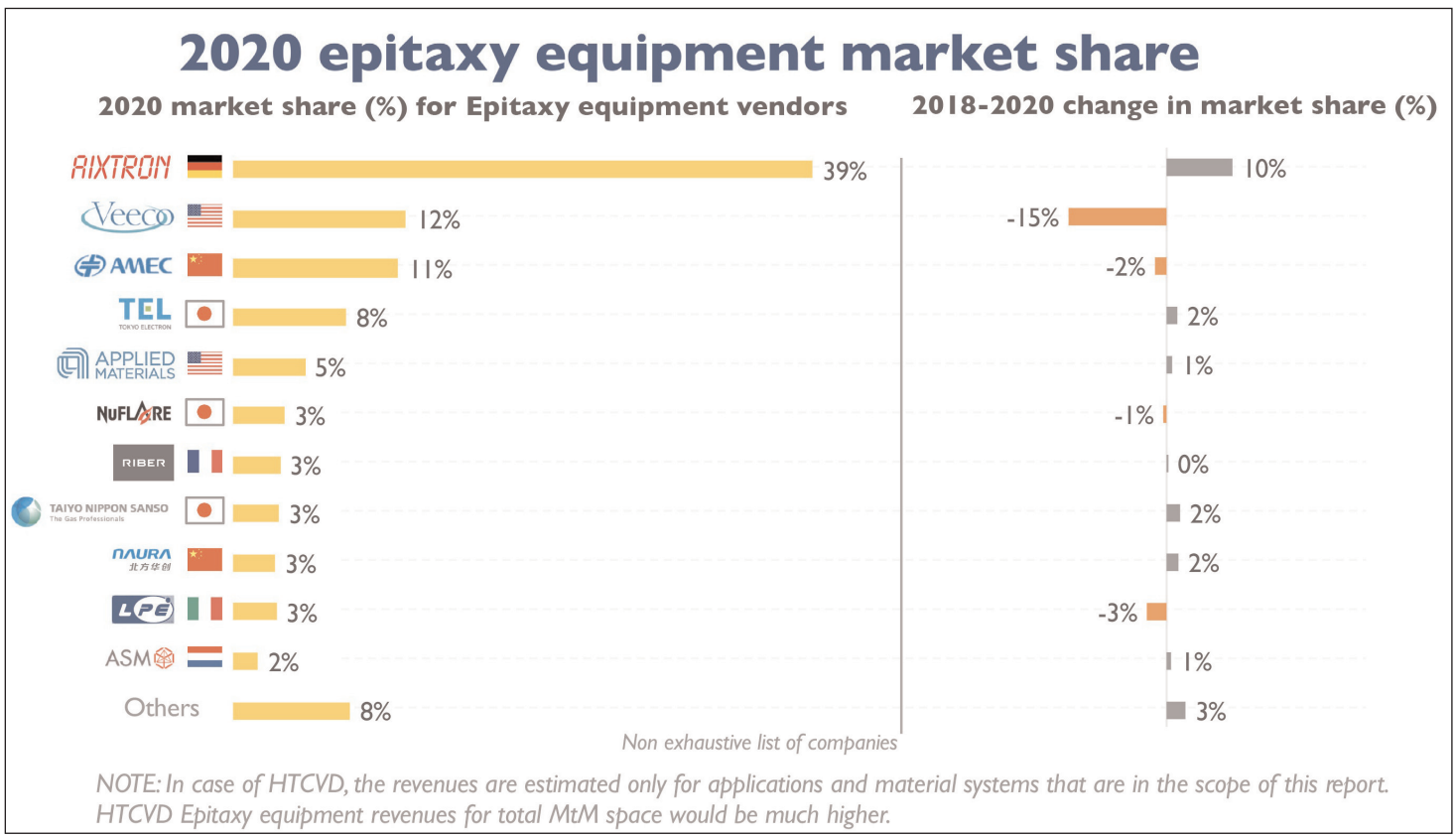
"The dominance by the top three players in 2020 was not a big surprise… it has remained the case at least since 2018," says Kumaresan. "However, if we look at the top two players, between 2018 and 2020, the German equipment company Aixtron increased its market share by 10%, while Veeco has seen its market share fall by 15%. One of the many reasons for this is the US–China trade tension, which has chosen the semiconductor industry as one of their battlegrounds. This battle is even more pronounced in the epitaxy equipment space, as the demand is primarily driven by China. As a result, 2020 resulted in one of the best sales years in China for Aixtron, with approximately 57% of their revenue coming from the region, in contrast to Veeco's mere 13% revenue."

Aixtron hence continues to be the leader in the overall epitaxy equipment market. However, Veeco remains in second place, due to its improved MBE revenue in 2020 (although in MBE in particular, France-based Riber continues to be the market leader).

In parallel, AMEC follows closely in third place, with a good volume of equipment shipped for LED devices.

With the geopolitical situation evolving and the supply chain ever more fragile, Yole expects the competition between equipment vendors to intensify in the coming years. ■

www.i-micronews.com/products/epitaxy-equipment-for-more-than-moore-2021



GaN complementary logic platform

Researchers see potential for monolithic peripheral control for power electronics, radio-frequency power amplifiers and harsh-environment applications.

Hong Kong University of Science and Technology (HKUST) and Peking University in China have reported progress in producing gallium nitride (GaN) complementary logic (CL) circuits on low-cost silicon [Zheyang Zheng et al, Nature Electronics, vol.4 (19 July 2021), p595].

The operation of the circuits was similar to that achieved with silicon complementary metal-oxide-semiconductor (MOS) p-type and n-type transistors (CMOS). However, the GaN complementary logic circuits were based on a MOS p-FET, but an n-type heterojunction field-effect transistor (n-HFET) with a

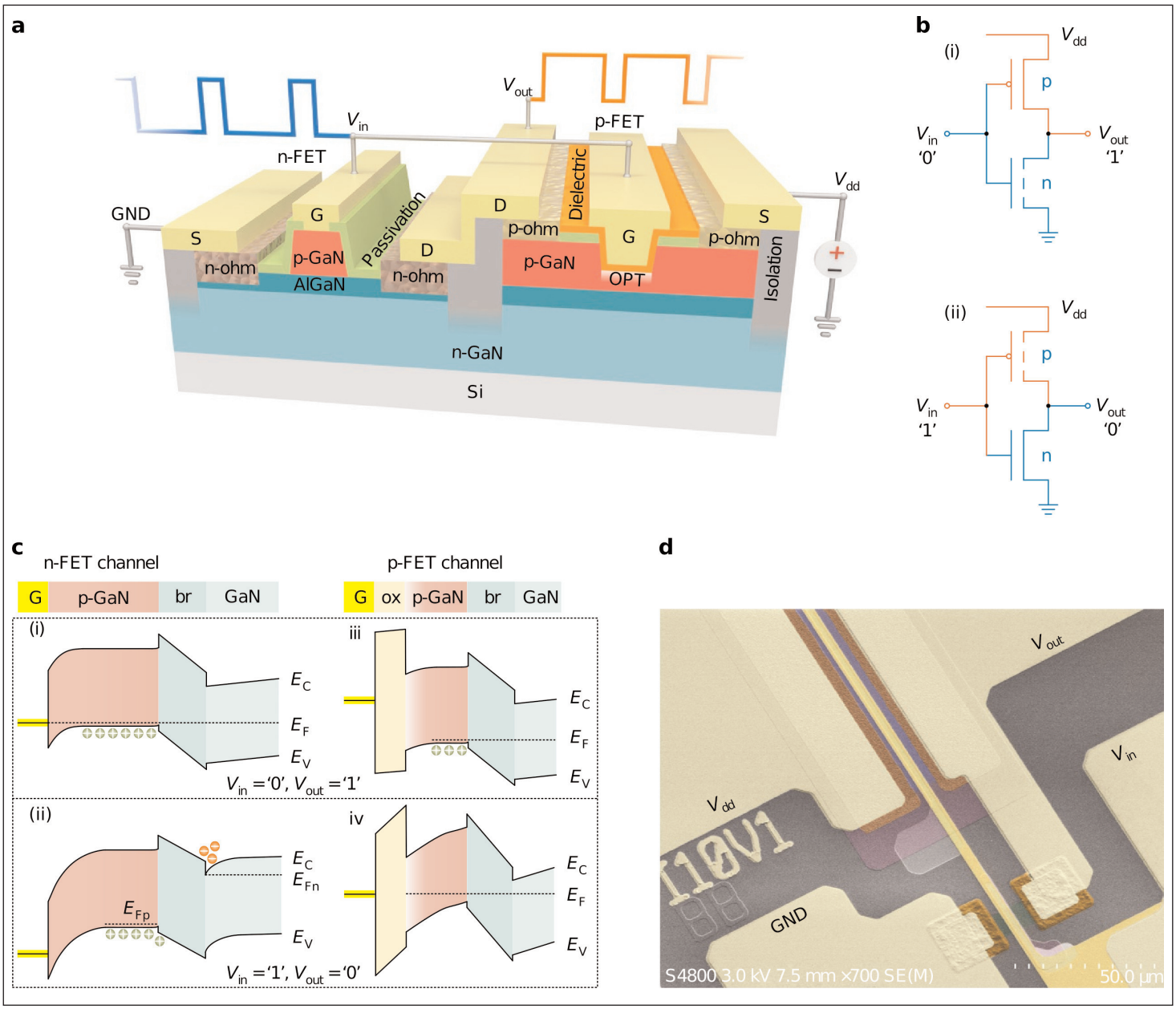


Figure 1. a, Schematic GaN complementary logic inverter. b, Schematic CL inverter circuit at two static logic states. c, Schematic energy band diagrams under different logic inputs. d, Scanning electron micrograph in false color.

p-GaN gate electrode. A key property of these devices was that they operated in 'enhancement-mode' with current blocking at 0V gate potential – i.e. 'normally-off' operation.

The researchers see potential uses in the control of circuits for power electronics, radio-frequency power amplifiers and harsh-environment applications. The team comments: "The desire of monolithically integrating peripheral circuits with GaN power switches that operate at intermediate frequencies offers a compelling yet relaxed opportunity for GaN complementary logic circuits. The typical operating frequencies are in the range of 100kHz to 10MHz, technically reachable for GaN CL circuits within acceptable costs."

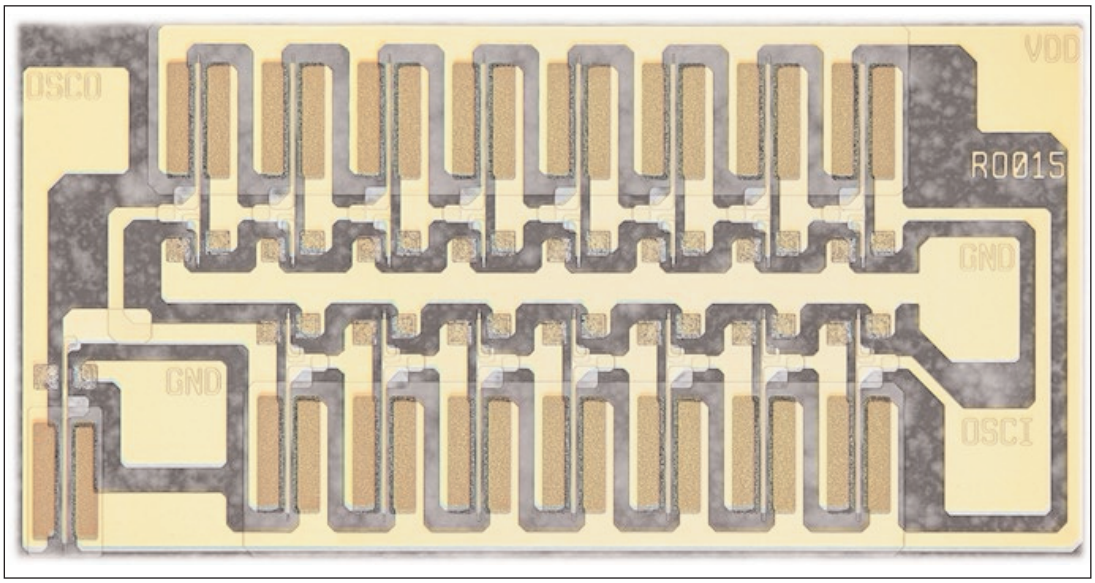


Figure 2. Confocal laser microscopy photograph of ring oscillator.

The researchers used commercial GaN on silicon (Si) wafers grown by metal-organic chemical vapor deposition (MOCVD). The layer structure on the p-Si wafer was 4μm GaN transition/buffer, 12nm aluminium gallium nitride (AlGaN) buffer, and 85nm p-GaN. Hall measurements on the material suggest a sheet hole density of $1.23x10^{13}/cm^2$ with $10.2cm^2/V\text{-}s$ mobility. The mobility is within the range of material specifically designed to create p-FETs (~$15cm^2/V\text{-}s$), rather than an off-the-shelf product aimed at power GaN n-FET applications.

The first fabrication step was the removal of p-GaN using plasma etching, leaving the p-GaN gate of the n-FET and material for the p-FET (Figure 1). Next, a 70nm silicon dioxide surface passivation layer was deposited. The ohmic source/drain contacts of the n-FETs were formed by opening windows in the passivation and evaporating titanium/aluminium/nickel/gold, followed by 850°C rapid thermal annealing (RTA) for half a minute. The p-FET ohmic contacts consisted of nickel/gold, annealed at 550°C in oxygen for 10 minutes.

The p-FET channel was formed by inductively coupled plasma (ICP) reactive ion etch of a trench, leaving 30nm of p-GaN material for the channel.

The desired enhancement-mode behavior for the p-FETs was realized using a one-minute oxygen plasma treatment of the p-channel surface by depleting holes through a shift of the valence band maximum away from the Fermi level with the formation of oxygen complexes with and/or passivation of the magnesium doping.

The p-FET gate insulation consisted of 20nm aluminium oxide (Al_2O_3). The plasma treatment resulted in a buried p-channel, which conducts holes away from the gate dielectric interface, reducing carrier scattering and disorder effects that increase electrical resistance.

The devices were isolated using fluorine ion implantation rather than mesa etch, avoiding current leakage through sidewall conduction. The gate electrodes and probe pads consisted of nickel/gold. The metal of the p-GaN gate of the n-FET formed a Schottky contact. The p-GaN enables enhancement-mode operation for the n-FET.

To balance the performance of the n- and p-FETs for complementary logic, the width of the p-FET was around 10x that of the n-FET. In specific measurements, the n-FET was 10μm wide and the p-FET 100μm. Other dimensions were: for the n-FET, 2μm gate-to-source, 3.5μm gate length, and 2μm gate-to-drain; the corresponding dimensions for the p-FET were 3μm, 1.5μm, and 3μm.

The performance of the basic complementary logic inverter circuit is described as 'rail-to-rail', with the 1-state output being equal to the supply voltage and the 0-state being ground. With the supply between 3V and 5V, a sharp transition from the 1-state to the 0-state occurs when the input reaches around half the supply voltage. However, with 2V supply there is an intermediate state with both of the FETs in the off-state when the input is ~1V. The voltage gain in the transition region for 5V-supply reached 80V/V.

Due to large on/off current ratios ~10^7, the static power dissipation is suppressed. The researchers comment: "This inverter unambiguously demonstrates the most important trait of CMOS circuits, that is, low static-state power dissipation, and thereby outperforms other logic circuit schemes, such as resistor–transistor logic or directly coupled FET logic (DCFL) structure, in terms of energy efficiency." ►

A 5V supply is commonly available for logic control sub-circuits of GaN power electronic systems. The noise margins were found to be 2.1V for the low state, and 2.6V for the high state. "Both noise margins are sufficiently large; therefore GaN complementary logic devices are equipped with high immunity to miscellaneous noises, such as electromagnetic interferences produced by high-frequency power switches," the team writes.

The researchers also subjected the inverter circuit to increased temperatures. "Despite a slight expansion in the transition window and deviations in V_{TH} at high temperatures, superior properties of the GaN complementary logic inverter, such as rail-to-rail operation, wide noise margins and sharp logic state transition, are well preserved," the team observes of measurements made at 200°C. Even at 350°C, the noise margins were 1.83V and the voltage gain reached 18.10V/V. Silicon circuits suffer increasing degradation problems beyond 125°C such as latch-up and other malfunctions from thermally induced leakage.

The p-FET performance was the limiting factor for continuous switching up to 2MHz. The researchers hope that further optimization of the channel recess etch and oxidation process will lead to devices capable of several MHz performance. Another potential booster would be scaled reduction of the device size with gate lengths as small at 180nm, although 250nm would probably be more realistic in terms of avoiding short-channel effects.

More complicated circuits such as NAND, NOR, and transmission (a CMOS-like switch) gates were fabricated. The researchers report: "The demonstration of a complete set of elementary complementary logic gates indicates that the n–p integration technology is a feasible approach to construct complicated combinational GaN complementary logic circuits."

Further demonstrations of multi-stage integration came in the form of a latch circuit and a ring oscillator. The latch consisted of cross-coupled inverters, giving a 1-bit memory storage. The researchers comment: "The capability of storing data enables the implementation of memory units (for example, static random-access memory) and sequential logic circuits. Therefore, it becomes feasible to construct finite-state machines or microprocessors using GaN."

The ring oscillator (Figure 2) consisted of 15 cascaded inverter and a 1-inverter output buffer. The oscillating period was 1.99μs and the fundamental frequency was 502kHz. ■

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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
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Fax: +49 89 96 2400122
www.csclean.com

Entegris Inc
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Fax: +1 978 436 6735
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IEM Technologies Ltd
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Bridgwater, Somerset TA6 5JJ, UK
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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.

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www.vacuumbarrier.com
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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

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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

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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.,
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22 Used equipment

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23 Services

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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

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7140 San Jose,
CA 95126, USA
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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

7–9 November 2021
8th IEEE Workshop on Wide Bandgap Power Devices & Applications (WiPDA 2021)
Crowne Plaza Redondo Beach and Marina, Redondo Beach, CA, USA
www.wipda.org

16–17 November 2021
Wide Bandgap Devices and Applications Short Course
Virtual, online event
E-mail: rasulliv@ncsu.edu
www.poweramericainstitute.org/shortcourse

16–19 November 2021
SEMICON Europa 2021 (co-located with productronica)
Messe München, Munich, Germany
E-mail: semiconeuropa@semi.org
www.semiconeuropa.org

6–8 December 2021
PVinMotion conference 2021, Conference & Exhibition on Solutions for Vehicle Integration
virtual event, hosted by Fraunhofer Institute for Solar Energy Systems ISE, Freiburg, Germany
E-mail: info@pvinmotion-conference.com
www.pvinmotion-conference.com

6–9 December 2021
2021 IEEE BiCMOS and Compound Semiconductor Integrated Circuits and Technology Symposium (BCICTS)
~~Monterey Marriott, Monterey, CA, USA~~
Now a virtual, online event
E-mail: cs@cshawevent.com
www.bcicts.org

7–9 December 2021
SEMICON West 2021 (Hybrid: Onsite & Virtual)
Moscone Center, San Francisco, USA
E-mail: semiconwest@semi.org
www.semiconwest.org

11–15 December 2021
67th IEEE International Electron Devices Meeting (IEDM 2021)
Hilton San Francisco Union Square Hotel, San Francisco, CA USA
E-mail: info@ieee-iedm.org
www.ieee-iedm.org

15–17 December 2021
SEMICON Japan 2021 (Hybrid: Onsite & Virtual)
Tokyo Big Sight, Tokyo, Japan
E-mail: semicon@sakurain.co.jp
www.semiconjapan.org/en

28–30 December 2021
SEMICON Taiwan 2021
Taipei Nangang Exhibition Center, Hall 1 (TaiNEX 1), Taipei, Taiwan
E-mail: semicontaiwan@semi.org
www.semicontaiwan.org/en

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13–18 February 2022)
24th European Microwave Week (EuMW 2021)
ExCel, London, UK
E-mail: eumwreg@itnint.com
www.eumweek.com

20–24 March 2022
37th annual Applied Power Electronics Conference (APEC 2022)
Houston, Texas, USA
E-mail: apec@apec-conf.org
http://apec-conf.org/conference/sessions/technical

25–27 April 2022
18th International Conference on Concentrator Photovoltaic Systems (CPV-18) and 13th World Conference on Thermophotovoltaic Generation of Electricity (TPV-13)
University of Miyazaki, Japan
E-mail:info@cpv-18.org
www.cpv-18.org

10–12 May 2022
PCIM (Power Conversion and Intelligent Motion) Europe 2022
Nuremberg, Germany
E-mail: pcim@mesago.com
www.mesago.de/en/PCIM/main.htm

15–20 May 2022
2022 Conference on Lasers & Electro-Optics (CLEO)
San Jose Convention Center,
San Jose, CA, USA
E-mail: CLEO@compusystems.com
www.cleoconference.org

30 May – 3 June 2022
IEEE 72nd Electronic Components and Technology Conference (ECTC 2022)
The Sheraton San Diego Hotel and Marina,
San Diego, CA, USA
E-mail: reg.ectc@gmail.com
www.ectc.net

10–15 July 2022
(postponed from 14-19 June 2020, then 4-9 July 2021)
20th International Conference on Metal Organic Vapor Phase Epitaxy (ICMOVPE XX)
Stuttgart, Germany
E-mail: info@icmovpexx.eu
www.icmovpexx.eu

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

11–16 September 2022
19th International Conference on Silicon Carbide and Related Materials (ICSCRM 2022)
Davos, Switzerland
E-mail: info@icscrm2021.org
www.icscrm2021.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)
MiCo, Milan, Italy
E-mail: eumwreg@itnint.com
www.eumweek.com

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

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

17–22 September 2023
26th European Microwave Week (EuMW 2023)
Berlin Messe, Germany
E-mail: eumwreg@itnint.com
www.eumweek.com
www.eumwa.org/en/26th-eumw-2023.html?cmp_id=20&news_id=208&vID=50

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