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COMPOUNDS & ADVANCED SILICON

Vol. 15 • Issue 7 • September 2020

www.semiconductor-today.com

Silicon carbide power electronics in the spotlight

Qorvo raises guidance • IGaN establishing GaN Epi Centre
SMART Photonics raises €35m • AFRL invests in NREL solar project

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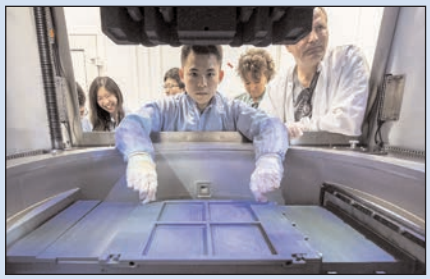
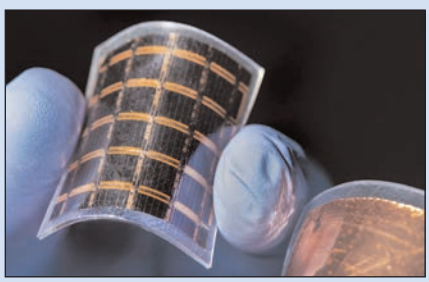
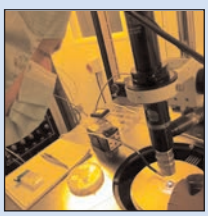


p22 GaN-on-SiC epiwafer maker SweGaN has been named to Sweden's Ny Teknik (New Technology) '33 List'.

p24 Kier has been contracted to build the Centre for Integrative Semiconductor Materials at Swansea University.



p53 The US Air Force Research Laboratory is investing in a dynamic hydride vapor phase epitaxy technique developed at NREL to adapt space-based solar technology for terrestrial applications.



Cover: Distributor Inseto has supplied the UK's University of Warwick with a PS4L probe system from SemiProbe for developing fabrication processes for SiC power semiconductor devices. An analyser that can inject thousands of volts and measure hundreds of amps. **p23**

editorial

GaN & SiC power semi sector evolving

Driven by demand from hybrid & electric vehicles (HEVs/EVs), power supplies and photovoltaic (PV) inverters, the market for silicon carbide (SiC) and gallium nitride (GaN) power semiconductors is forecasted to surpass $1bn in 2021 as it rapidly evolves from a startup-dominated business to one led by large-established power semiconductor manufacturers, reckons market research firm Omdia in its 'SiC & GaN Power Semiconductors Report — 2020' (see pages 74–75).

Mitsubishi Electric, for example, has now launched its second generation of full-SiC power modules, featuring a newly developed lower-power-loss SiC chip for industrial use (page 15). Also, funded by the US Air Force Research Lab (AFRL) in a Phase I Small Business Technology Transfer Research (STTR) project, Structured Materials Industries (SMI) has developed a low-temperature chemical vapor deposition (CVD) process for 4H-SiC, enabling higher-rate growth of thick epilayers (with reduced process cycle time and equipment wear) for high-voltage power devices (page 14).

Meanwhile, in partnership with the State University of New York (SUNY) Polytechnic Institute Albany, SMI has also been awarded a Phase I STTR contract by the US Department of Energy to develop pervasive manufacturing infrastructure — including improving large-wafer metal-organic chemical vapor deposition (MOCVD) uniformity — for GaN operating at high current and high voltage (>20A/>600V) for EV power electronics (page 16).

Manufacturers that are advancing GaN device capabilities include EPC, which has launched its latest family of 100V eGaN FETs, targeted at applications including LiDAR for autonomous cars (page 18).

The adoption of GaN devices in power applications such as fast chargers for consumer electronics continues to proliferate (especially as performance improves). For example, Navitas' GaNFast power ICs have been used by mobile accessory brand Spigen PowerArc in the new 20W ArcStation Pro, ahead of the expected release of the Apple iPhone 12 later this year. Meanwhile, China's OPPO has adopted GaNFast power ICs for what is claimed to be the smallest, thinnest and lightest 110W fast charger for smartphones, tablets and laptops (page 19). In addition to boosting its revenue through licenses to its manufacturing partner Nexperia, Transphorm has expanded its portfolio of high-voltage GaN power conversion devices, aiming to drive adoption for fast-charging power adapters (page 20). GaN Systems has announced a new reference design for a high-power-density 65W charger in consumer electronics, including mobile phones and laptops (page 21). The firm has also released a whitepaper demonstrating the reliability of its GaN devices, surpassing the criteria of both JEDEC and AEC-Q101 test specifications.

In Singapore, IGSS GaN (IGaN) is setting up an Epi Centre as a combined commercial and global joint lab for 4–8"-wafer MOCVD of GaN, to be operational by mid-2021 (page 22). Most recently, just on 29 September, Netherlands-based NXP Semiconductors opened its new 8"-wafer GaN fab at its plant in Chandler, Arizona, dedicated to 5G RF power amplifiers for cellular infrastructure. Already qualified and with initial products ramping in the market, the new fab is expected to reach full capacity by the end of 2020 (to be covered fully in our news pages next issue).

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

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

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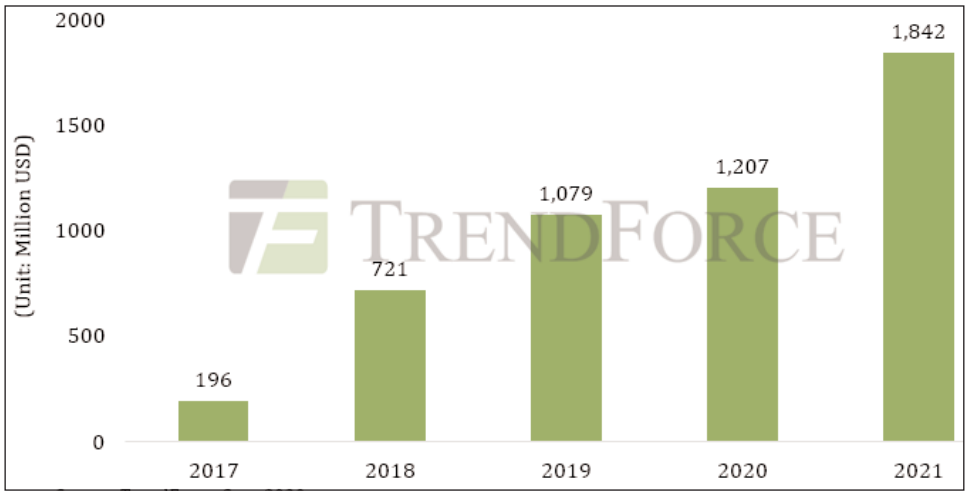
VCSEL revenue to grow 53% to US$1.8bn in 2021 due to integration of 3D sensing and 5G

2020 growth forecast reduced to 12%, driven by COVID-19

In early 2020, market research firm TrendForce forecasted the release of more than 10 high-end smartphone models equipped with 3D sensing solutions this year, which would drive up 3D sensing vertical-cavity surface-emitting laser (VCSEL) revenue (including whole 3D sensing infrared transmitter units) to US$1.404bn. However, as the COVID-19 pandemic put a damper on global smartphone shipment, and the Indian consumer market exhibited strong demand for entry-level and mid-range smartphone models, smartphone brand vendors have subsequently slowed down their pace of integrating 3D sensing solutions into high-end models. TrendForce is reducing its 2020 revenue forecast for 3D sensing VCSELs (for mobile devices including smartphones and tablets) to $1.207bn, a 12% increase year-on-year from $1.079bn in 2019.

Analyst Joanne Wu indicates that 3D sensing functions have become an indispensable part of flagship models as smartphone brand vendors engage in a spec war in this product segment. 3D sensing is mostly integrated into the rear cameras; its primary applications include range finding, background blur, 3D object detection, spatial modeling, and augmented reality (AR). In the future, 3D sensing functions are expected to be paired with 5G connectivity, in turn becoming a standard feature of high-end phones. Total revenue for 3D sensing VCSELs is projected to grow 53% year-on-year to $1.842bn in 2021.



2017–2021 VCSEL revenue (for 3D sensing applications).

The dominant suppliers of 3D sensing solutions currently include ams, Finisar, Osram, II-VI Inc, Lumentum, Sony, VPEC, LITE-ON, AWSC, and WIN Semiconductors. 3D sensing applications in the consumer electronics market include functions such as structured light, ToF (time of flight), and active stereo vision. In particular, ToF functions are integrated into a wide variety of applications due to their fast response times and long range.

At the moment, Apple and Samsung have each integrated ToF functions in their respective products, such as the iPhone and iPad Pro for the former and the S20+ and S20 Ultra 5G for the latter. In addition, direct ToF sensors are more power-efficient compared with other 3D sensing solutions. The integration of 3D sensing with 5G connectivity is expected to deliver a more interactive experience for users of mobile devices through functions such as gesture-control-enabled AR. Other possible 3D sensing applications are AR-assisted interior design, home renovation, home additions, and even integration with video games. 3D sensing solutions may even see cross-industry commercial opportunities in the future, concludes TrendForce.

www.trendforce.com

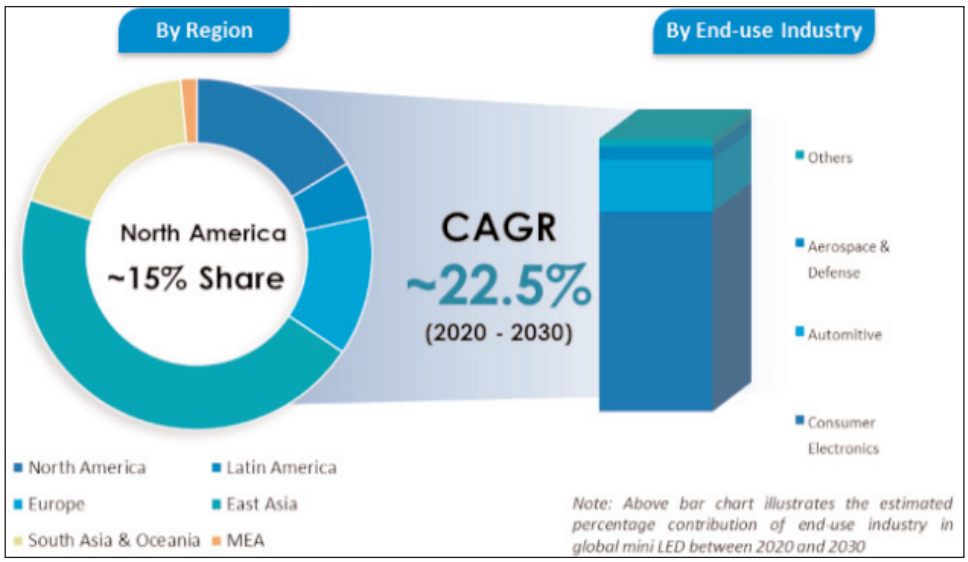
Mini-LED market to grow by 7.5x, at 22% CAGR, by 2030

Consumer electronics sector to grow from $150m to $1150m

Although demand for mini-LEDs has been hit by the COVID-19 outbreak due to decreased production by end-use industries and dwindling demand from consumers, the mini-LED market is still poised to expand 7.5-fold, at a compound annual growth rate (CAGR) of 22%, through 2030, forecasts a new study from Fact.MR. Standard mini-LEDs are estimated to account for 26% share of total market revenue in 2020, but are forecast to lose 2000 base points (BPS) in market share by 2030.

In recent years, the increasing popularity of organic light-emitting diode (OLED) TVs in China and India has been significantly influencing growth of the mini-LED market. With an increase in disposable income of a majority of the population in these countries, the inclination towards smart screens with higher lifespan and better performance is expected to open up numerous growth opportunities for the mini-LED market. Moreover, aspiring and affluent households have increased their spending on consumer electronics products and smart gadgets, which is set to drive demand from end-use industries in the mini-LED market.

Consumer electronics applications therefore continue to influence the growth strategies of market players, and are expected to contribute revenue of US$150m in 2020 and US$1150m by 2030, growing at a CAGR of 23%.



As the focus on Internet of Things (IoT) and smart devices becomes stronger worldwide, market players are eyeing potential opportunities in unexplored markets. Highly populous Asian countries, in particular, offer a huge customer base for leading manufacturers of mini-LEDs (with East Asia projected to hold a prominent share of global mini-LED market value, although North America is projected to see the highest growth rate during the forecast period).

High adoption of digitalization and a surge in the number of end-use industry product manufacturers are opening up new avenues for the mini-LED market. For example, the automotive segment is expected to grow at a 21.5% CAGR and create an absolute dollar opportunity of US$230m during the forecast period.

"Collaboration with end-use industry players and vertical integration for gaining market share and increasing brand awareness are important to gain traction as competition increases in the mini-LED market," says a Fact.MR analyst.

Vertical integration stands as prime strategy

Prominent players in the mini-LED market include Cree, Vishay, Revolution Lighting Technologies Inc, Orion Energy Systems Inc, Deco Lighting, and Epistar. Such key players are hence focusing on capacity expansion and vertical integration. Furthermore, companies are expanding their market reach with the help of e-Commerce and numerous digital platforms to reach their target customers.

In addition to the above strategies, companies are also collaborating with end-use industry players, notes the study.

www.factmr.com/report/4969/mini-led-market

Smartphone market to fall 7.9% from $458.5bn in 2019 to $422.4bn in 2020

Low- to mid-range segment to dominate, with fastest growth in $400–600 price band

According to a new price band forecast from the International Data Corporation (IDC) Worldwide Quarterly Mobile Phone Tracker, economic uncertainties have increased the downward pressure on smartphone prices globally, with 73% of shipments in 2020 expected to be priced below $400. Worldwide smartphone value is expected to decline by 7.9% from $458.5bn in 2019 to $422.4bn in 2020. The downward trend is intensified by consumers turning to devices priced in the low- to mid-range as they prioritize spending on essentials.

Overall, the low-to-mid-end segment ($100 to less than $400) dominated global smartphone shipments, with 60% market share in second-quarter 2020, and is expected to grow in the short term to 63% by next year. The mid-to-high-end segment ($400 to less than $600) grew market share by almost 4 points to 11.6% in Q2.

Devices from Samsung, Huawei and other Chinese vendors like Xiaomi, OPPO and vivo are the main vendors driving these segments.

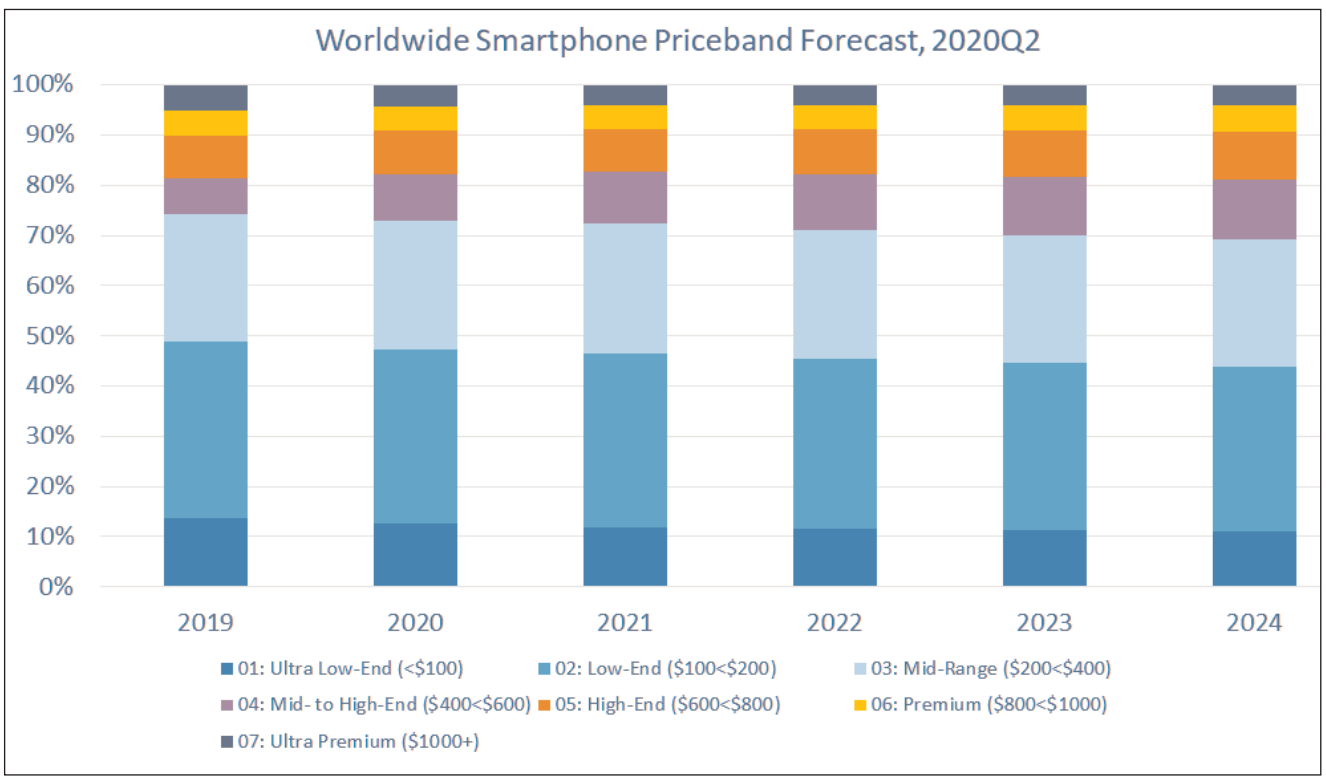
Apple also recently entered the mid segment with its new iPhone SE device, which has performed well, further validating the trend toward more budget-friendly devices.

"Rising unemployment rates and job uncertainty have influenced consumers' buying patterns towards economic and affordable products," says Sangeetika Srivastava, senior research analyst with IDC's Worldwide Mobile Device Trackers. "Subsequently, the overall portfolio in smartphones is moving toward low-to-mid-end devices. This has intensified competition, as market players need to continue presenting attractive deals and bundling offers to encourage consumers to purchase a new device, especially in the higher-priced segments."

The pressure on prices is reflected worldwide, though it is most obvious in developing regions like the Asia-Pacific excluding Japan and China (APeJC), Latin America, Middle East & Africa (MEA) and Central & Eastern Europe (CEE) where sub-$400 devices captured up to 85% of the market in Q2/2020. Even in the USA, devices under $200 increased their share by 10 points year-on-year to capture 27% of the market in Q2. In China, the mid-to-high-end segment ($400-600) grew the most, with an 8-point increase in market share to 21% in Q2.

"Looking forward, as consumers increasingly want a better value proposition from their phones, the low and mid segments ($100–200 and $200–400) will remain the most popular," says Nabila Popal, research director with IDC's Worldwide Mobile Device Trackers. "However, in the long term, IDC expects the fastest growth will be in the $400–600 price band as 5G sales grow and the average selling price (ASP) for 5G phones drops to $465 in 2024."

www.idc.com/tracker/showproductinfo.jsp?prod_id=37



Compound semiconductor market to grow at 11.1% CAGR to $212.95bn in 2027

Asia–Pacific to remain dominant, growing at 13.2% CAGR

The global compound semiconductor market generated $89.94bn in 2019, and is rising at a compound annual growth rate (CAGR) of 11.1% from 2020 to $212.95bn in 2027, reckons a report from Allied Research.

A surge in demand for epitaxial wafers for LED applications and the growing adoption of compound semiconductors compared with silicon-based technology is driving growth. However, the high cost associated with compound semiconductor components and materials is expected to restrain market growth. Nevertheless, the rise in usage of smart technologies is expected to provide new growth opportunities during the forecast period.

By material type, III-Vs comprised the largest segment of the compound semiconductor market in 2019, accounting for nearly a quarter of the total, and is expected to maintain its dominant share during the forecast period. However, the sapphire segment is forecasted to show the highest CAGR of 13.5%.

By deposition technology, chemical vapor deposition (CVD) comprised the largest segment in 2019, accounting for more a quarter of the total, and is expected to remain the largest segment throughout the forecast period. However, the molecular beam epitaxy (MBE) segment is forecasted to register the highest CAGR of 12.8% over 2020–2027.

By region, the Asia-Pacific contributed the highest share in 2019, accounting for nearly half of the total, and will maintain its dominance throughout the forecast period. In addition, it is expected to grow at the highest CAGR of 13.2% over 2020–2027.

Leading players analyzed in the report include Nichia Corp, Cree Inc, Qorvo, Samsung Electronics, Taiwan Semiconductor Manufacturing Company Ltd, NXP Semiconductor N.V., Texas Instruments Inc, Renesas Electronics Corp, Infineon Technologies AG, and STMicroelectronics NV.

www.alliedmarketresearch.com/compound-smiconductor-market

Qorvo raises quarterly revenue guidance from $925–955m to $1–1.03bn

Diluted EPS guidance increased from $1.90 to $2.14

Qorvo Inc of Greensboro, NC, USA (which provides core technologies and RF solutions for mobile, infrastructure and defense applications) has updated the financial guidance given on 29 July for its fiscal second-quarter 2021 (to end-September).

Broad-based mobile demand for Qorvo's 4G and 5G mobile products during the September quarter exceeded original expectations, so the firm has increased its guidance for revenue from $925–955m to $1–1.03bn. While non-GAAP gross margin is still expected to be about 50%, the guidance for diluted earnings per share has been increased from $1.90 to $2.14.

Qorvo raises $700m through offering of senior notes

Qorvo has raised $700m through an offering of senior notes maturing in 2031. Paying interest semi-annually at a rate of 3.375%, the notes will mature on 1 April 2031, unless redeemed earlier in accordance with their terms.

The notes were issued to qualified institutional buyers (pursuant to Rule 144A under the Securities Act of 1933, as amended) and to certain non-US people (in accordance with Regulation S under the Securities Act).

Qorvo is using the net proceeds of the offering, together with cash on hand and borrowings under its credit facility, to redeem all of its outstanding 5.50% senior notes due 2026.

www.qorvo.com

Skyworks launches LNAs for small-cell, massive MIMO and base-station applications

LNAs suitable for 2G/3G/4G/5G TDD and FDD infrastructure

To meet the challenging requirements of cellular LTE and 5G NR infrastructure applications, Skyworks Solutions Inc of Woburn, MA, USA (which manufactures analog and mixed-signal semiconductors) has launched the SKY67183-396LF and SKY67189-396LF low-noise amplifiers (LNAs).

The LNAs feature what is claimed to be ultra-low noise figure, exceptional linearity, and operate over a wide range of frequencies. To reduce PCB board space, the devices are housed in an ultra-compact 2mm x 2mm plastic surface-mount package.

The SKY67183-396LF and SKY67189-396LF are suitable for 2G/3G/4G/5G TDD and FDD infrastructure applications, including small-cell, massive MIMO, and macro base stations.

www.skyworksinc.com

Teledyne e2v HiRel launches frequency multiplier family

Teledyne e2v HiRel of Milpitas, CA, USA (part of the Teledyne Defense Electronics Group that provides solutions, sub-systems and components to the space, transportation, defense and industrial markets) has announced the latest addition to its expanding line of RF solutions.

Launching its new frequency multiplier product line, the TDFM001000 active RF MMIC frequency doubler is designed for high-reliability signal chain applications in demanding space environments. It is particularly suited to satellite transponders, transmit/receive modules, microwave-based communications, millimeter-wave point-to-point radio, and related processes.

The TDFM001000 is a 7.5–25.0/15.0–50.0GHz single-ended input (no external balun required) GaAs MMIC doubler with a +15.0dBm output drive. As an LO doubler it can be used to drive fundamental mixer devices. It uses a GaAs pHEMT device model technology and is based on electron-beam lithography to ensure high repeatability and uniformity. Features include: 100% on-wafer RF, DC and output power testing; 100% visual inspection to MIL-STD-883 Method 2010; RoHS compliant; and 260°C reflow compatible.

"This is the first frequency multiplier released by Teledyne e2v HiRel Electronics and is the latest addition to our rapidly growing portfolio of high-reliability RF solutions for aerospace and defense," says Mont Taylor, VP of business development for Teledyne e2v HiRel Electronics. "We will be introducing several new standard RF building block solutions in the months ahead to supplement our other lines including amplifiers, LNAs, PAs, DVGAs, DSAs, limiters, mixers, pre-scalers, PLLs, switches, and more."

www.teledynedefenseelectronics.co

pSemi appoints new VP of sales & marketing

Murata company pSemi Corp of San Diego, CA, USA — a fabless provider of radio-frequency integrated circuits (RFICs) based on silicon-on-insulator (SOI) — says Vikas Choudhary has joined it as vice president of sales & marketing, leading its worldwide sales, applications engineering, marketing and marketing communications teams, and responsible for driving its RF, power and sensor products into existing and emerging markets.

"Vikas adds a wealth of strategic sales and marketing experience to our executive team," says CEO Sumit Tomar. "He has a proven

track record of directing global teams of sales, product, channel marketing and engineering professionals to develop new products and generate hundreds of millions in revenue," he comments.

Choudhary has more than 25 years of broad experience in the global semiconductor, IC, hardware architecture and systems engineering industries. He has held numerous leadership positions of progressive responsibility while heading marketing, engineering, and strategy spanning eMobility and inertial sensors at Analog Devices. He was instrumental in establishing an R&D center for PMC Sierra India as a country manager.

Choudhary earned his master's degree in electrical engineering from UCLA and an MBA from Northwestern University's Kellogg School of Management. He is the editor of the book 'MEMS: Fundamental Technology and Applications' and has five issued patents and several journal and conference publications to his name.

www.psemi.com

Guerrilla launches InGaP HBT power amplifier in expansion into cellular market

24dBm output for applications requiring high native linearity over temperature extremes

Guerrilla RF Inc of Greensboro, NC, USA — a provider of radio-frequency integrated circuits (RFICs) and monolithic microwave integrated circuits (MMICs) for wireless applications — has launched the GRF5507, one of ten new ¼W linear power amplifiers (PAs) being released over the next two quarters as part of the firm's expansion into the cellular market. The new indium gallium phosphide (InGaP) heterojunction bipolar transistor (HBT) amplifiers were designed specifically for 5G/4G wireless infrastructure applications requiring exceptional native linearity over temperature extremes of –40°C to +85°C.

Spanning a frequency range of 700-800MHz, the GRF5507 variant is tuned to operate in the n12, n14, n28 and n29 5G new radio (NR) bands. The device can deliver over 24dBm of linear power over the entire –40°C to +85°C temperature range while maintaining ACLR (adjacent-channel leakage ratio) levels of better than –45dBc, IMD3 (third-order intermodulation distortion) levels <-20dBm, EVM (error vector magnitude) levels <1% and PAE (power-added efficiency) >15% — all without the aid of supplemental linearization schemes like digital pre-distortion (DPD).

The ability to beat the –45dBc ACLR performance metric without DPD is critical for cellular applications like home and commercial repeaters/boosters, femtocells, picocells and cable loss compensators associated with automotive 'shark fin' antennas, says the firm. In each of these use cases, the sensitivity to cost, power and size constraints prohibits the use of elaborate linearization techniques like DPD. Instead, designers must rely on the power amplifier's native linearity to meet the stringent emissions mask requirements imposed by the latest 5G and 4G standards.

During the development of the GRF55xx series, Guerrilla RF consulted directly with its base of customers to ensure that the devices delivered the best blend of power and linearity, thus maximizing the effective range and throughput for their cellular systems. The firm also designed the entire family of devices to be fully footprint compatible, enabling its customer base to rapidly customize their designs for a myriad of cellular frequencies.

"The GRF55xx family builds upon the groundbreaking work which we started a year ago with the release of the GRF5504/9 series of 5W InGaP HBT power amplifiers," says CEO & founder Ryan Pratt. "The new ¼W PAs were created specifically to meet the needs of our strategic customers in the cellular and automotive industries," he adds. "Together with the original GRF5504/9 series, the GRF55xx family will serve as the beachhead for Guerrilla RF's expansion into the growing power amplifier market."

The GRF55xx family comes in pin-compatible 3mm x 3mm, 16-pin QFN packages. The common footprint enables a single design to address multiple bands via simple component swaps.

Samples and evaluation boards are available now for the GRF5507. Prices start at $1.55 (10,000-up, FOB USA).

www.guerrilla-rf.com

Fukushima SiC Applied Engineering raises $30m in Series C funding

Fukushima SiC Applied Engineering Inc of Naraha, Fukushima, Japan, a silicon carbide (SiC) silicon carbide (SiC) power electronics products technology venture company that is developing boron-neutron capture therapy (BNCT), has raised $30m (JPY3.1bn) in Series C funding from investors including Japan's C:iz Investment LLP, Japan Post Investment Corp, San Francisco bay area-based Astellas Venture Management LLC, and SMBC Venture Capital Co Ltd. The funds are expected to be used for BNCT-related pre-clinical and clinical trial activities in Japan as well as activities to expand overseas activities including efforts to obtain regulatory approvals.

Boron-neutron capture therapy is a type of radiotherapy and a new way to treat cancer. A boron agent that reacts readily with neutrons is accumulated by the tumor cells, and the reaction between neutrons in a neutron beam and the accumulated boron is used to selectively destroy tumor cells.

Leveraging its proprietary SiC device technologies, Fukushima SiC Applied Engineering has developed a multi-port neutron radiation cancer treatment system that is said to be significantly more compact and lower cost than existing BNCT systems and has unique capabilities that open up the possibility of targeting deep-seated cancers and metastatic micro-tumors that have previously been difficult to treat with the ability to destroy tumor cells equivalent to heavy particle beam therapy.

The company has completed the development and manufacturing of its SiC-BNCT clinical trial machine (with six neutron sources) and is expecting to start clinical trials at the Kyoto Prefectural University of Medicine next year.

The technology development continues to be funded in part by the Ministry of Economy, Trade and Industry subsidy program for areas recovering from the 2011 tsunami and nuclear disasters.

www.en.fukushima-sic.co.jp

Richardson RFPD to distribute Hitachi ABB products

Richardson RFPD Inc (an Arrow Electronics company) — which specializes in the RF, wireless, IoT and power technologies sectors — has entered into a global franchise agreement with Switzerland-based Hitachi ABB Power Grids Ltd, a supplier of power semiconductors for the traction, industrial and energy transmission market segments, with production facilities in Lenzburg, Switzerland, and Prague, Czech Republic.

Hitachi ABB Power Grids' power semiconductor business product portfolio includes GTOs, IGBTs, IGCTs, SiC modules, thyristors and diodes spanning the power range of 150–12000A and 200–8500V. The agreement includes Hitachi ABB Power Grids' complete lineup of power semiconductor devices.

"The addition of Hitachi ABB Power Grids' product portfolio enables Richardson RFPD to service additional high-power applications for energy transmission, traction and industrial applications," says Richardson RFPD's president Rafael R. Salmi Ph.D. "We appreciate Hitachi ABB Power Grids recognizing our global reach with local technical support to initiate new design opportunities," he adds.

"Including Richardson RFPD as a channel partner increases our local presence in additional countries around the world," comments Rainer Käsmaier, Hitachi ABB Power Grids' managing director semiconductors. "Their strong knowledge of power semiconductors and the markets we serve offered a natural fit to assist in expanding the visibility of our products and capabilities."

www.richardsonrfpd.com/Supplier/Index/ABB

www.hitachiabb-powergrids.com

ROHM appoints Isao Matsumoto as president & CEO

The board of directors of ROHM Co Ltd of Kyoto, Japan has appointed Isao Matsumoto as its president & CEO.

Matsumoto has worked for ROHM since 1985. Most recently he was responsible for quality, safety and production as director, board member and managing executive officer.

"In recent years, issues related to the environment, resources and energy have taken on greater urgency, impacting not only various markets but society as a whole. At the same time, major changes are taking place in the automotive industry, including the evolution of AI and technological innovation for achieving autonomous driving," says Matsumoto. "ROHM will accompany this transition with its unique technology and product portfolio. We are focusing in particular on the automotive and industrial equipment sectors along with overseas markets, while strengthening our development capabilities centered on power and analog — together with a manufacturing system to support it," he adds.

Matsumoto graduated from department of metal engineering from Kyushu Institute of Technology.

www.rohm.com/eu

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- Same Footprint! MCCBs & ELCBs Interchangeable without Panel Modifications
- 18mm Per Pole Width(2P & 3P), IEC 35mm DIN Rail Mounting
- Higher Capacity SCCR ⇒ 18kA@ 240VAC UL489
- Lock Out Tag Out (LOTO) safety devices (fixed and removal types) are available as option.

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SMI develops processes for low-temp, high-rate homogeneous epitaxy of 4H-SiC

AFRL-funded STTR project involves University of South Carolina, Morgan State University and Mississippi State University

Funded by the United States Air Force Research Lab (AFRL) in a Phase I Small Business Technology Transfer Research (STTR) project 'Tooling and Processing for Low Temperature Homogeneous Epitaxy of 4H-SiC Using Novel Precursors', Structured Materials Industries Inc (SMI) of Piscataway, NJ, USA — which provides chemical vapor deposition (CVD) systems, components, materials and process development services — has developed low-temperature high-rate CVD growth for 4H-SiC (silicon carbide) epilayers.

The effort is to develop a CVD chemistry/process that supports a high growth rate at lower-than-standard temperatures while maintaining quality by effectively eliminating the silicon droplet and other defects. The result will be to enable the growth of thick 4H-SiC epilayers for power devices at relatively high rates and with greater process tool resilience.

In the STTR project, SMI worked with a team of academic institutions, including the University of South Carolina (USC), which has researched chloride- and fluoride-enhanced CVD growth. The program also includes researchers at Morgan State University and a researcher at the Mississippi State University (MSU) who are SiC growth and device experts. The SMI-led team offers expertise in enhanced process SiC material growth and device fabrication.

Thicker SiC films are desired for producing high-voltage devices, necessitating the development of processes with increased growth rates preferably at lower temperatures. Lower temperatures decrease wear on the reactor and decrease thermal cycle time — a more efficient growth rate also decreases process cycle time.

Previous SiC horizontal (left) and vertical (right) reactor systems built by SMI for the US Naval Research Laboratory and Penn State University, respectively.

SiC can operate with voltage drops of ~1.2kV per 10μm of thickness. Increasing precursor concentrations to achieve higher growth rates generally leads to the formation of homogeneous nucleation of silicon particles or droplets in the gas phase. Some of these droplets land on the substrate and make the epitaxial layer defective and hence useless for devices. While hardware design and process steps mitigate this problem, it can still be improved on. One solution is to develop an epitaxy growth process using a lower growth temperature of <1500°C (reducing gas-phase pre-reactions) but generally with a penalty of reduced growth rates.

Another issue is the degradation of graphite parts used in the growth reactor at higher temperature by reactant/process gases. The degradation of the parts continuously changes the thermal profile; leading to process instability and thus resulting in reduced production yield. Hence, a process with a modest reduction in growth temperature while achieving high growth rates will have a significant impact on tool life and throughput. SMI technology development within this STTR project will develop a low-temperature process using novel precursors and other enhancements.

"Now [that] we have an opportunity to create the tooling and processes that increases production yield, reduce cost and improve the quality of the SiC epilayers layers — all are critical for advancing the SiC power device manufacturing — we look forward to scaling the process and demonstrating devices, growth swiftly and efficiently at low temperatures," says principal investigator and SMI research scientist Dr Arul C. Arjunan.

"Routinely and robustly producing thicker device-quality defect-free SiC at high growth rates and at lower temperatures will be a great benefit to the rapidly growing SiC power device market for decades to come," believes SMI's president Dr Gary S. Tompa.

"The Air Force funding of this work recognizes the importance of addressing production costs and capabilities in the SiC supply chain and that an advanced process and the associated hardware to achieve this goal are needed sooner than later," says an STTR collaborator at USC. "Reducing SiC growth temperature while maintaining high quality at higher rates — and thus lowering costs — is the power device manufacturing dream," adds the STTR collaborator at MSU.

www.smicvd.com

Mitsubishi to launch second-generation full-SiC power modules for industrial use

More efficient, smaller & lighter power-electronics equipment targeted

Tokyo-based Mitsubishi Electric Corp is to launch second-generation full-SiC (silicon carbide) power modules featuring a newly developed SiC chip for industrial use.

The low-power-loss characteristics and high-carrier-frequency operation of the SiC-MOSFET (metal–oxide–semiconductor field-effect transistor) and SiC-SBD (Schottky barrier diode) chips in the modules are expected to facilitate the development of more efficient, smaller and lighter-weight power equipment in various industrial fields. Sales will begin in January 2021.

Specifically, the junction field-effect transistor (JFET) doping technology reduces on-resistance by about 15% compared with that of conventional SiC products (e.g. Mitsubishi Electric's first-generation SiC modules, with the same rating, for industrial use).

Reducing the mirror capacitance (i.e. the stray capacitance between the gate and drain in a MOSFET structure) enables fast switching and reduces the switching loss.

The built-in SiC-MOSFET and SiC-SBD help to reduce power loss by about 70% compared with that of Mitsubishi Electric's conventional silicon insulated-gate bipolar transistor (Si-IGBT) modules.

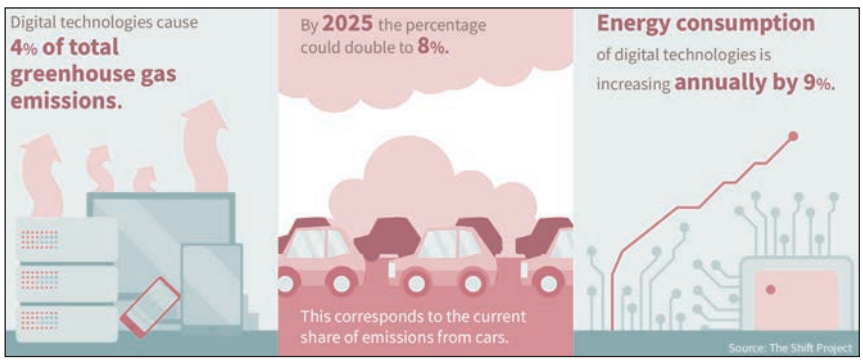
Power-loss reduction and high-carrier-frequency operation will facilitate the development of smaller and lighter external components, such as reactors and coolers, reckons Mitsubishi Electric.

www.mitsubishielectric.com

Lite-on uses Infineon's CoolSiC MOSFETs for SMPS achieving 80 PLUS Titanium certificate

The trend of digitalization has accelerated. Consequently, the number of server farms has risen and with it the power demand. Driven by global warming, the importance of higher energy efficiency of operations is therefore increasing. Introduced in 2004, the measurement standards defined by the North American 80 PLUS initiative can be used to evaluate and certify the efficiency of switched-mode power supplies (SMPS). A certificate is granted if the SMPS achieves at least 80% at defined load conditions. Solutions bearing the 80 PLUS certificate thus help in reducing the power demand of digitalization.

To meet the requirements for the highest-efficiency 80 PLUS Titanium certification, a 94% efficiency at a load of 50% is required for 115V input voltage and 96% for 230V, respectively. Power supply maker Lite-on Technology Corp of Taipei, Taiwan has achieved this target using 650V CoolSiC silicon carbide metal-oxide-semiconductor field-effect transistors (MOSFETs) from Infineon Technologies AG of Munich, Germany.



Lite-on management is convinced that silicon carbide has become mainstream for applications like solar inverters. Partnering with Infineon, their goal is to show that it is also relevant for the power supply market for servers. For this application, CoolSiC technology proves its sweet spot in performance and cost at a system level, says Infineon. Lite-on is introducing the SiC-based SMPS to the market, exceeding the requirement of 96% efficiency for the Titanium certification.

"Digital transformation affects all areas of our lives: politics, economy, society, and everyday life," says Stefan Obersriebnig, product line head High Voltage Conversion of Infineon's Power & Sensor System Division. "The backbone of this digitalization is the millions of servers in farms all around the globe," he adds. "Our CoolSiC technology enables the highest energy efficiency paired with unprecedented power density, which in turn significantly lowers energy consumption. This leads to a reduced carbon footprint as well as financial savings for the operator."

The efficiency of Lite-on's SMPS is based on Infineon's 650V discrete SiC MOSFETs. Two of the devices in a TO 247-3-package in totem-pole-setup are installed in the power factor correction (PFC) stage. Additionally, other semiconductors from Infineon support the design, from 650V CoolSiC Schottky diodes to various CoolMOS and OptiMOS power devices.

www.infineon.com

DOE STTR contract for SMI and SUNY Poly to co-develop 600V/20A GaN for EVs

SMI to develop large-wafer MOCVD GaN uniformity; SUNY Poly to optimize device structures

Structured Materials Industries Inc (SMI) of Piscataway, NJ, USA — which provides chemical vapor deposition (CVD) systems, components, materials and process development services — has been awarded a Phase I Small Business Technology Transfer Research (STTR) contract by the US Department of Energy (DOE) to develop pervasive manufacturing infrastructure for GaN (>20A/>600V) qualified for electric vehicle power electronics.

For the project, SMI is partnering with the State University of New York (SUNY) Polytechnic Institute Albany. The team will address issues related to the production of uniform-quality GaN materials on large-area substrates (4-inches and above), design and develop power devices that will perform at high current and high voltage (>20A, >600V, for electric vehicle on-board electronics) and develop production pathways. SMI will focus on developing novel reactor concepts to increase GaN material quality/uniformity across large wafer sizes, while SUNY will use reactor technology to optimize the developed materials and device structures on a 4" substrate. SMI will help to enable the commercialization of both device and reactor technology.

"Our partner at SUNY-Albany, professor Shahedipour-Sandvik, is an expert in the growth of III–N materials and device fabrication and was the first to report enhancement operation in an AlGaN/GaN HEMT," says SMI. The SUNY-Albany team recently reported a novel integrated body-diode AlGaN/GaN HEMT power device that enables dynamic tuning of the turn-on voltage (V_{on}) and substantially reduces off-current (I_{off}).

SMI III–N MOCVD system

"We are designing a concept MOCVD system to improve the yield and quality of GaN devices for vehicle power electronics," says principal investigator and SMI research scientist Dr Arul Arjunan. "The concept system will lead [us] to grow films with both thickness and quality uniformity. In addition to this, we will aim to improve the quality of the film to achieve better devices than currently existing," he adds. "The success of this program will increase the efficiency of hybrid electric and electric vehicles."

In Phase I the team will demonstrate GaN power devices at the 100mm wafer scale, which can operate at >600V and >10A (with a Phase I reach goal of >20A and >600V). "At the end of the Phase I program we will define the product scale-up pathways for 100mm, 150mm and 200mm wafer production and packaged device production and we will firm-up customers for the developing processes and device technology," says SMI.

"Improving power efficiency and lowering costs will help bring greater numbers of more environmentally friendly vehicles to market sooner," believes SMI's president & CEO Dr Gary S. Tompa.

In the past, SMI has worked on several different III–N funded research programs and has built tools for III–nitride R&D.

www.smicvd.com
www.sunypoly.edu

HRL's ultra-linear GaN HEMTs exceed 30GHz targets in DARPA's DREaM project

Phase 2 to target 94GHz operation

HRL Laboratories LLC of Malibu, CA, USA (which is co-owned by The Boeing Company and General Motors) says that a team led by principal investigator Dr Jeong-Sun Moon has met and exceeded the performance metrics defined by the US Defense Advanced Research Project Agency (DARPA) Dynamic Range-enhanced Electronics and Materials (DREaM) program, which aims to improve dynamic range in millimeter-wave (mm-wave) electronics.

Specifically, HRL has demonstrated a low-noise gallium nitride (GaN) high-electron-mobility transistor (HEMT) with record linearity — the ratio between output third-order intercept power (OIP3) and DC power consumption (PDC) — for such devices. OIP3/PDC of 20dB at 30GHz was achieved, at least 10 times greater than conventional GaN HEMTs [International Microwave Symposium, 2019].

In parallel, HRL's DREaM GaN transistors demonstrated power-added efficiency (PAE) of greater than 70% at 30GHz, which is said to be a vast improvement over reported PAEs of other mm-wave T-gated AlGaN/GaN HEMT devices [Electronics Letters, April 2020].

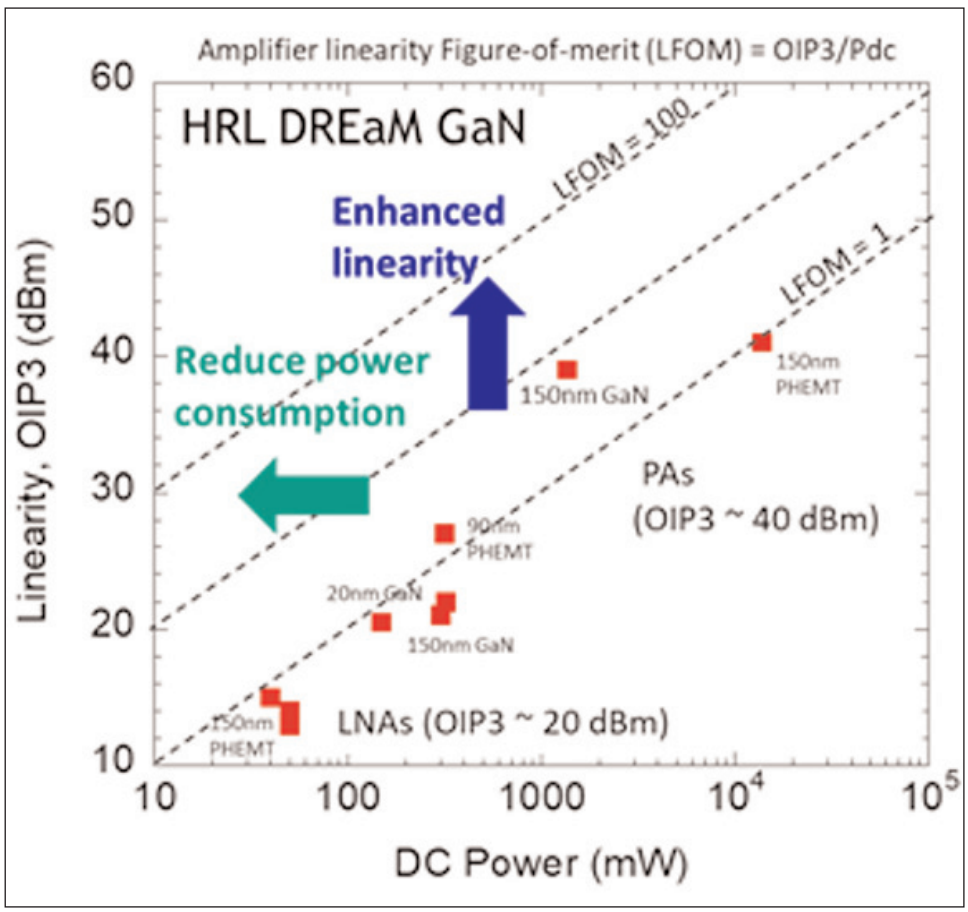
"We began our efforts in the DREaM project to develop advanced ultra-linear GaN transistors for mm-wave frequencies that enable transmission and reception without distortion across the electromagnetic spectrum," Moon says. "This technology will enable secure ultra-wideband communication with higher data rates, while reducing the draw on the power sources of end-user platforms, such as ships, aircraft or satellites."

With the initial goals reached, DARPA will now take the DREaM program into its second phase. With an even more challenging amplifier performance goal of 94GHz, DARPA hopes to implement wideband low-noise amplifiers with ambitious end-user needs in mind.

HRL's team also includes engineers Bob Grabar, Joel Wong, Mike Antcliffe, Erdem Arkun, Isaac Khalaf, Peter Chen, Chuong Dao, Andrea Corrion and Dave Fanning.

The work is supported by the United States Air Force (USAF) under Contract No. FA8650-18-C-7802.

www.hrl.com



The DREaM project's ultralinear GaN HEMTs enable secure ultra-wideband communication with higher data rates while reducing power draw on end-user platforms, such as ships, aircraft or satellites. © 2020 HRL Laboratories.

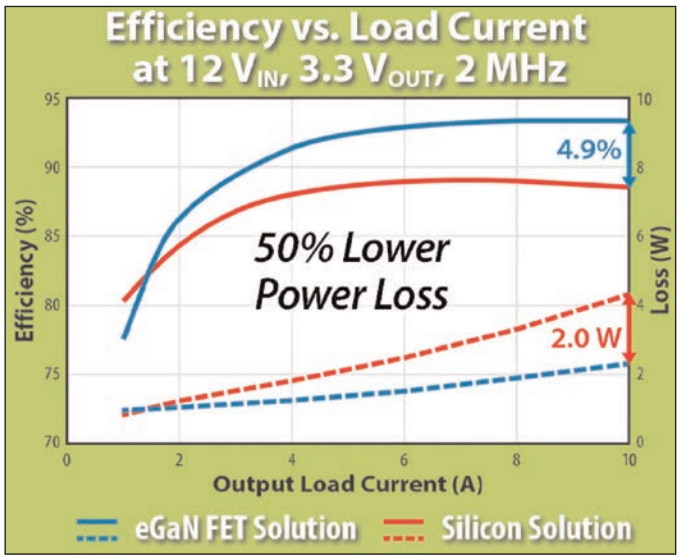
EPC launches latest 100V eGaN FET family

$R_{DS(on)}$ nearly 20% lower and DC ratings higher than prior generation

Efficient Power Conversion Corp (EPC) of El Segundo, CA, USA — which makes enhancement-mode gallium nitride on silicon (eGaN) power field-effect transistors (FETs) for power management applications — says that it is advancing the performance capability while lowering the cost of off-the-shelf gallium nitride transistors with the introduction of the EPC2218 and EPC2204 100V eGaN FETs. Applications include synchronous rectification, class-D audio, infotainment systems, DC–DC converters (hard-switched and resonant), and light detection & ranging (LiDAR) for autonomous cars, robotics and drones.

The EPC2218 (3.2mΩ, 231A_{pulsed}) and the EPC2204 (6mΩ, 125A_{pulsed}) have nearly 20% lower on-resistance ($R_{DS(on)}$) as well as increased DC ratings compared with prior-generation eGaN FET products. The performance advantage over a benchmark silicon device is even higher.

The EPC2204 has 25% lower on-resistance, yet is three times smaller in area (at 1.5mm x 2.5mm versus 3.3mm x 3.3mm). Gate charge (Q_G) of 6.4nC (typical, at 5V_{GS}) is less than half that of the silicon MOSFET benchmark's 15nC (typical, at 10V_{GS}) and, like all eGaN FETs, there is no reverse recovery charge (compared with 29nC QRR typical for the silicon MOSFET benchmark at 40V), enabling lower-distortion class-D audio amplifiers, as well as more efficient synchronous rectifiers and motor drives.



"With the clear superiority of these new 100V eGaN FETs, one might expect them to be priced at a premium. However, EPC has priced these state-of-the-art 100V transistors comparable with their aging ancestor, the silicon power MOSFET," says co-founder & CEO Alex Lidow. "Designers can take advantage of devices that are higher performance, smaller, more thermally efficient and at a comparable cost," he adds. "The displacement of the power MOSFET with GaN devices continues to accelerate."

All products and boards are available from distributor Digi-Key Corp.

The EPC2218 is priced at $2.09 each and the EPC2204 at $0.99 each (in 2.5k reels), with half-bridge development boards EPC90123 and EPC9097, respectively, both priced at $118.75.

www.epc-co.com/epc/Products/eGaNFETsandICs/EPC2218.aspx

EPC Space appoints Spirit as distribution partner

Rad-hard eGaN FETs and ICs targeted at power conversion

To support its accelerating growth in the defense and aerospace markets, EPC Space LLC of Haverhill, MA, USA has appointed Spirit Electronics as a distribution partner, focusing on these key market segments.

EPC Space was established in June as a joint venture between Efficient Power Conversion Corp (EPC) of El Segundo, CA, USA — which makes enhancement-mode gallium nitride on silicon (eGaN) power field-effect transistors (FETs) for power management applications — and VPT Inc of Blacksburg, VA, USA (part of the HEICO Corp subsidiary HEICO Electronic Technologies Group).

The JV is focused on designing and manufacturing high-reliability, radiation-hardened enhancement-mode GaN-based power conversion devices for space and other harsh environments, targeting critical spaceborne environments in applications including power supplies, light detection & ranging (LiDAR), motor drive, and ion thrusters.

In operation since 1979 and located in Phoenix, Arizona and Irvine, California, Spirit Electronics supplies products and services to the Department of Defense, aerospace and telecom industries.

"Spirit Electronics' knowledge of the market, along with their extensive history and proven success working with defense and aerospace customers, makes them an ideal partner to represent EPC Space's rad-hard gallium nitride products," comments EPC Space's CEO Bel Lazar.

Spirit Electronics' partnership with EPC Space will "allow us to bring the unmatched reliability and performance of GaN power semiconductors to defense and aerospace customers, so they can design leading-edge power and motor drive system solutions," says Spirit Electronics' CEO Marti McCurdy.

www.epc.space
www.spiritelectronics.com

Navitas' power ICs adopted for OPPO's 110W Mini

OPPO's fast charger shrunk by 12x

Navitas Semiconductor Inc of El Segundo, CA, USA says that phone maker OPPO has adopted its gallium nitride (GaNFast) power ICs to enable what is claimed to be the world's smallest, thinnest and lightest 110W fast charger for phones, tablets and laptops.

Measuring only 65.5mm x 45.5mm x 12mm (36cc), OPPO's 110W Mini fast charger is over 12x smaller than the 96W charger supplied with the Apple MacBook Pro 16". With GaNFast technology, fast-charger design has finally caught up with the demand for slimline laptops, tablets and phones, says Navitas. With its ultra-thin 12mm profile, the fast charger is now 20% lower profile than the Dell XPS 13 or MacBook Air.

The savings in size and weight are possible due to gallium nitride, which can run up to 20x faster than silicon chips, it is reckoned. Navitas' GaNFast power ICs monolithically integrate GaN power, GaN analog and GaN logic circuits on the same chip, to enable faster, reliable, efficient operation.

The 110W Mini SuperVOOC charger was launched on 15 July by OPPO's chief charging technology scientist Jialiang (Jeff) Zhang, who said "GaN devices will trigger a technological revolution in the field of power supplies," adding: "Only GaN devices can support high-frequency, low-loss operation."

Navitas and OPPO design engineers partnered to develop a new two-stage, very high-speed (MHz) 'Pulsed-DCX' converter topology that allows the use of slimline 'planar' transformers to replace legacy 'wire-wound' transformers and eliminates the bulky electrolytic capacitors that can take up 40% of silicon-based designs. The first stage uses NV6125 GaNFast power ICs to isolate and step-down the voltage, with the second stage controlling the current for optimal battery charging. The 110W Mini includes a power factor correction (PFC) function and is rated for universal AC input, so it can be used worldwide. The full 110W rating is available via USB-PPS, with 65W fast charging for SuperVOOC and USB-PD protocols.

"Laptop users suffer from heavy, bulky, tangled chargers every time they travel, or even just commute. The 110W Mini is the featherweight fast charger that lifts the burden," says Stephen Oliver, Navitas' VP marketing & investor relations. "OPPO's dedication to fast charging and pioneering adoption of GaNFast technology to enable new topologies is a clear game-changer," he adds. "Now, consumers can carry a single, small, flexible fast charger that meets all their needs from their laptop and tablet to phone and earbuds — and charge them at incredible speed."

www.oppo.com/en

Navitas' GaNFast power ICs used in Spigen's ArcStation Pro 20W GaN wall charger targeted at Apple iPhone 12

Mobile accessory firm Spigen Inc of Irvine, CA, USA and Navitas Semiconductor have announced a new 20W gallium nitride (GaN) wall charger, the Spigen PowerArc ArcStation Pro, ahead of the expected Apple iPhone 12 release later this year.

Founded in 2009, Spigen makes cases, screen protectors and other accessories for smartphones. The firm recently launched its new brand Spigen PowerArc, specializing in ultra-fast charging solutions for mobile devices.

"Industry rumors indicate that the iPhone 12 will release without an 'in-box' charger," says Spigen's product @ marketing manager Bobby Lee. "The ArcStation Pro proactively fills that void and delivers lightning-fast charging in the smallest possible form factor, with an elegant design and fold-flat AC pins," he adds. "With 20W of charging power and a USB Type-C output, it can also charge AirPods, iPads and any number of other phones and tablets via USB-C to Lightning or USB-C to C cables."

A powerful upgrade over former Apple chargers, the ArcStation Pro embraces GaN technology, which is reckoned to run up to 100x faster than silicon chips. Navitas' GaNFast power ICs monolithically integrate GaN power, GaN analog and GaN logic circuits on the same chip, to enable faster, reliable, efficient operation — in a very small size. At just 39.5mm x34.5mm x 27.7mm (1.55-inch x 1.35-inch x 1.09-inch), and featuring smooth-folding AC-pins, the charger is 30% smaller than Apple's existing 18W wall chargers.

"Spigen's PowerArc is the leading-edge fast charger, ahead of Apple's iPhone 12 and differentiated by its accessible, affordable price point and commitment to quality," comments Stephen Oliver, Navitas' VP marketing & investor relations.

The Spigen PowerArc ArcStation Pro retails for US$19.99, which is reckoned to be a major saving versus Apple chargers.

www.Spigen-powerarc.com
www.navitassemi.com
www.GaNFast.com

Navitas gains Lip-Bu Tan as advisor and investor

Cadence CEO also founder of Walden International and WRVI Capital

Navitas Semiconductor Inc of El Segundo, CA, USA says that Lip-Bu Tan, founder & chairman of Walden International, founding managing partner of WRVI Capital, and CEO of Cadence Design Systems Inc, has joined it as a strategic advisor and investor.

Founded in 2014, Navitas introduced what it claimed to be the first commercial gallium nitride power ICs. The firm says that its GaNFast power ICs integrate GaN power field-effect transistors (FETs) with drive, control and protection circuits to enable 3x faster charging in half the size and weight.

Tier-1 OEMs including Lenovo, Xiaomi, OPPO and NVIDIA have adopted GaNFast power ICs for their next-generation smartphone, tablet and laptop chargers.

"Lip-Bu is a pioneer in technology investment, with rich experience and an impressive track record of investing in, supporting and helping semiconductor companies navigate and create extraordinary growth and market leadership," comments Navitas' CEO Gene Sheridan. "His deep industry influence, insights and connections will accelerate Navitas' market and financial success," he believes.

"Navitas is the leader in the fast-charging GaN power semiconductor field," comments Tan.

Tan currently serves on the boards of directors of Cadence, Hewlett Packard Enterprise, Schneider Electric and SoftBank Group. He serves on the board of trustees and the School of Engineering Dean's council at Carnegie Mellon University, is a member of the College of Engineering advisory board at University of California Berkeley, the board of Global Semiconductor Alliance, and a member of The Business Council and Committee 100. He is the recipient of the 2016 GSA Morris Chang Exemplary Leadership Award.

Tan gained a Bachelor of Science Degree in Physics at Nanyang Technical University in Singapore in 1978, followed by a Master of Science in Nuclear Engineering at MIT in 1981, then a Master's in Business Administration from the University of San Francisco in 1983.

www.navitassemi.com

Transphorm's Q2/2020 revenue boosted by licensing to Nexperia

COVID-19 delayed customer development programs in near term

For second-quarter 2020, Transphorm Inc of Goleta, near Santa Barbara, CA, USA — which designs and manufactures JEDEC- and AEC-Q101-qualified high-voltage (HV) gallium nitride (GaN) field-effect transistors (FETs) for high-voltage (HV) power conversion applications — has reported revenue of $6.3m, up from $1.1m last quarter and $0.5m a year ago. This was largely due to $5m of licensing revenue from manufacturing partner Nexperia, related to funding of technology development, as well as $0.7m from Transphorm's three-year contract with the US Navy. For first-half 2020, revenue was $7.4m, up from just $1m in first-half 2019.

Operating expenses have been cut from $5.1m last quarter to $4.2m in Q2/2020 (level with a year ago), comprising R&D expenses of $1.6m and sales, general & administrative (SG&A) expenses of $2.6m.

Net loss has been cut further, from $5.9m ($0.21 per share) a year ago and $4.2m ($0.13 per share) last quarter to $2.3m ($0.06 per share) for Q2/2020. During the quarter, cash and equivalents have fallen from $14.6m to $9.4m.

Highlights in first-half 2020 are listed as:

- introducing SuperGaN Power FETs with the launch of the Gen IV GaN platform;
- partnering with Microchip Technology Inc to combine high-reliability GaN with a digital signal controller in support of accelerating GaN adoption;
- announcing Hangzhou Zhongheng Electric Co's development of an ultra-efficient, GaN-based power module using Transphorm's GaN devices;
- raising $19.7m in net proceeds from a private placement of common stock in February; and
- having its common stock listed on the OTC market and being recently granted DTC eligibility.

"We continue to successfully expand our comprehensive portfolio of high-voltage GaN power conversion devices, while working to drive increased adoption of our products for targeted applications, including the emerging opportunity in fast-charging power adapters," says Transphorm's chief executive officer Mario Rivas. "Although the COVID-19 pandemic has impacted certain customers, resulting in delays of their internal development programs that could adversely affect the pace of adoption and revenue in the near-term, we are confident that our pipeline of customer engagements and design wins will drive future long-term growth."

www.transphormusa.com

GaN Systems surpasses toughest reliability requirements

Devices surpass criteria of JEDEC and AEC-Q101 test specs

GaN Systems Inc of Ottawa, Ontario, Canada (a fabless developer of gallium nitride-based power switching semiconductors for power conversion and control applications) has released a whitepaper showing that GaN is reliable, with the firm's devices surpassing the criteria of both JEDEC and AEC-Q101 test specifications.

The whitepaper 'Qualification and Reliability of GaN Power Semiconductors: A Collaborative Approach with Partners and Customers' provides an overview of an enhanced qualification strategy and processes developed by GaN Systems and its customers. Results based on the application of these new test methods on GaN Systems devices are also demonstrated in the paper.

Existing qualification guidelines and standards for GaN power transistors are applied with silicon transistors as the foundation, which already have several decades of use and reliability data behind them. Since GaN and other wide-bandgap transistors are different in material and construction, qualification requires a closer look at how and which testing guidelines apply, says GaN Systems. Renewed reliability testing methods are especially important as the mission profiles that model electronic system lifetimes are ever changing.

GaN Systems and its partners from the global automotive, industrial and high-reliability (HiRel) industries have taken the lifetime and reliability challenge on to create an approach that draws considerations from JEDEC and AEC-Q and an understanding of industry challenges in qualification testing. GaN Systems' whitepaper reviews this, and outlines:

- The collaborative approach strategy which looks at device failure modes, transistor test design, and manufacturing process feedback.
- Enhanced product qualification processes using JEDEC and AEC-Q101 tests as a baseline and additional test methods to account for differences between silicon and GaN, and test results of GaN Systems' devices.
- Definition of lifetime models by determining failure mechanisms and applying a failure mode and effects analysis (FMEA), builds parts, and test-to-failure processes. Test results of GaN Systems' devices are also shown.

"The assumption that GaN is unproven or unreliable is no longer in question. In the last few years, we've seen global companies continue to use and introduce innovative products and systems using GaN Systems' power semiconductors as the basis for design," says CEO Jim Witham. "It is clear that the work we have done with our customers to create an enhanced reliability test set ensures that GaN Systems' devices demonstrate industry-leading performance and lifetime in the most challenging environments."

www.gansystems.com/reliability

GaN Systems unveils 65W QR charger reference design

Demand rises for GaN chargers for consumer electronics

GaN Systems has announced a new reference design for a high-power-density 65W QR (quasi-resonant) charger targeted at the consumer electronics market, including mobile phone and laptop computer applications.

The reference design consists of an operating charger and design documentation, providing a complete and simple-to-implement solution that assists customers in accelerating product development, roll out and commercialization, says the firm.

Driven by the immense consumer demand for smaller, lighter, more energy efficient and faster charging devices, GaN has become the technology of choice to deliver these benefits, the company states. GaN makes this possible with attributes such as extremely high switching speed, low on-resistance and zero reverse recovery, the firm adds. The GaN-based reference design exceeds many designs and is a better alternative to a multi-chip, monolithic solution and other discrete solutions, it is claimed.

Key details include:

- input: 90–265V, ~ 50/60Hz;
- output: USB-C 5V3A, 9V3A/12V3A/15V3A/20V3.25A 65W max;
- EMI: CISPR22 Conduction and Radiation Class B;
- power density with case: 18.5W/in3;
- supports PD3.0, PPS, QC, QC4.0+, BC1.2;
- comprehensive protection: OVP, OCP, SCP and open loop.

GaN Systems says that the 65W QR reference design makes it straightforward for power system designers to develop high-performance charging solutions, while benefitting from fewer re-designs, fewer PCB re-spins, and fewer trips to the lab for testing. The reduced development time enables companies to accelerate the time to market for new products.

"Smaller, lighter and higher power are all features that are shifting from 'want' to 'need' in the consumer electronics markets, and the rapid adoption of GaN is an indication of that shift," says Larry Spaziani, VP of global sales. "This reference design is another great addition to our tools library."

www.gansystems.com/design-center

IGaN establishing $73m GaN Epi Centre by mid-2021

4–8” GaN-on-Si epiwafer MOCVD to supplement GaN chip fabrication

Following what it says are demonstrated successes in pilot lines of customers, Singapore-based IGSS GaN Pte Ltd (IGaN) — which develops and commercializes gallium nitride-on-silicon/silicon carbide (GaN-on-Si/SiC) technology — is setting up an Epi Centre as a combined commercial and global joint lab for 4–8” metal-organic chemical vapor deposition of GaN.

With IGaN, its holding company IGSS Ventures (IGSSV) and select partners investing US$73m to expand GaN epi production capacity and mass production of 8” GaN fabrication technologies, the GaN Epi Centre should be operational by mid-2021.

The Epi Centre aims to capitalize on demand from applications such as power and renewable energy, 5G wireless communication and data centres, which require high switching frequencies, efficient energy management and the ability to perform under high power densities.

The Epi Centre brings together customers, universities, research institutes and tool vendors to collaborate on the future development of GaN technologies, as the quality of epiwafers is critical to GaN device manufacturing, notes Raj Kumar, IGaN’s CEO and founder of IGSSV.

“What the industry lacks today is a concerted effort to enhance the overall GaN ecosystem to lower cost barriers so that technology adoption can happen at the pace the market is moving,” says Kumar. “We projected more than nine years ago that, at 8” wafer dimensions, GaN-on-Si capabilities become a competitive and powerful solution to create the right balance between superior performances and cost competitiveness. A commercial centre and joint lab hosting several top specialist brands and leading vendors is a timely market response to creating strategic partnerships that fast-track innovation, growth and customer value,” he adds. “Capitalizing on the recognizable Singapore brand, second-to-none IP standards, its known semiconductor infrastructure and IGaN’s in-house expertise, I truly believe we can set standards, create benchmarks and lead the global movement in GaN adoption.”

IGaN credits its roots in the proprietary GaN-on-Si growth recipe resulting from hundreds of millions of dollars of research by various research institutes and university groups in Singapore over 14 years. The firm itself subsequently spent six years refining the technology and going beyond its original licensing capabilities, securing multiple partnerships focused on strengthening its capacity to supply 8” GaN-on-Si epiwafers.

“Singapore’s existing semiconductor environment, strengths and industry framework form an instrumental base to develop an ecosystem for niche technologies,” reckons Raj. “Case in point for us is IGaN’s collaboration with Nanyang Technological University. Established to develop a GaN manufacturing technology that can be adopted by existing silicon wafer fabs to produce high-volume and low-cost GaN products, such partnerships and our global customer base have paved the way for the eventual realization of our Epi Centre vision next year.”

www.igssgan.com

SweGaN selected for second year on list of Sweden’s hottest tech startups

GaN-on-SiC epiwafer firm grew 300% in 2019

SweGaN AB of Linköping, Sweden, which manufactures custom gallium nitride on silicon carbide (GaN-on-SiC) epitaxial wafers (based on a unique growth technology) for telecom, satellite, defense and power applications, has been named for the second year in a row to the Ny Teknik (New Technology) ‘33 List’ of Sweden’s most promising and innovative young companies. This year’s contenders included 270 companies.

With headquarters in the technology hub of Linköping, SweGaN manufactures QuanFINE GaN-on-SiC wafers using patented growth technology. The QuanFINE wafers are sold to manufacturers of components and devices for satellite communication, telecom and defense applications, as well as manufacturers of power electronics used in electric vehicles, solar inverters and more.

Earlier this year, SweGaN reported 300% year-on-year revenue growth in 2019, with a doubling of commercial orders and collaboration in multiple European Union (EU) projects.

www.swegan.se

Inseto supplies SemiProbe system for Warwick's silicon carbide power device development

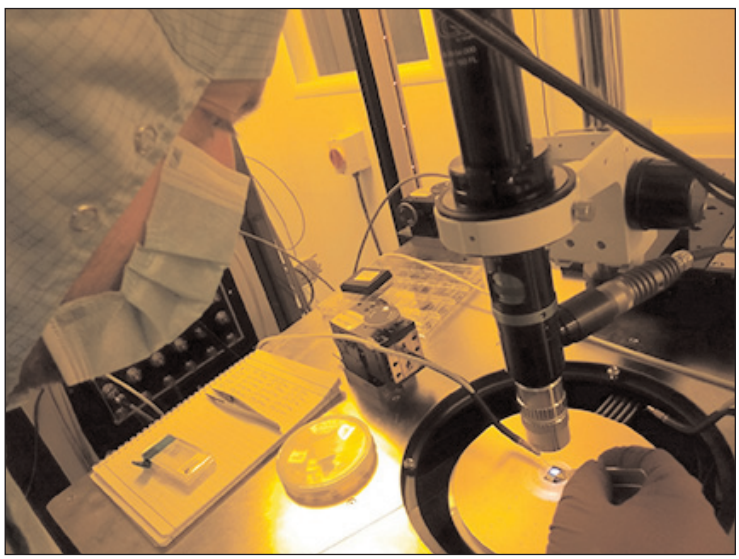
Prober to apply voltages up to 10,000V & measure currents up to 100A

Inseto (UK) Ltd of Andover, UK (a distributor of equipment and materials to the semiconductor, microelectronic & advanced technology sectors) has supplied the UK's University of Warwick with a PS4L probe system from SemiProbe Inc of Winooski, VT, USA for developing fabrication processes for silicon carbide (SiC) power semiconductor devices. The PS4L provides an accurate and repeatable means of mechanically interfacing fabricated prototype devices — as die or still on the wafer — with an analyser that can inject thousands of volts and measure hundreds of amps.

"We're involved in a number of projects that are pushing the boundaries of silicon carbide power device research that will hopefully lead to the volume manufacture of device types that can currently only be fabricated in silicon," says Dr Peter Gammon, associate professor (reader) in SiC Power Electronics at the University of Warwick. "The PS4L is an invaluable tool in our endeavours as not only can it handle the high power from/to the analyser but it is semi-automated, allowing us to collect a large amount of data from highly repeatable tests."

Gammon adds that most commercially available SiC power devices are unipolar structures, such as diodes and MOSFETs, which are well established and commercially available with high voltage ratings.

"We're looking beyond these though, at bipolar devices that include IGBTs [insulated-gate bipolar transistors] and thyristors, because they will further enable highly efficient and ultra-high-voltage applications, such as traction inverters and high-voltage direct current in a low-carbon society," says Gammon. "For example, silicon IGBTs are typically rated up to about 2000V. As part of our work with the UK Engineering and Physical Sciences Research Council (EPSRC) Centre for Power Electronics, we are today producing silicon carbide IGBTs rated to 10,000V, with scope to go to 30,000V in the future."



The PS4L is enabling Gammon's team to apply voltages of up to 10,000V and measure currents of up to 100A to confirm the performance and breakdown voltages of their devices. "While we're heading towards the production of IGBT and MOSFET switches, we're able to do much of our work on simple structures such as diodes, in order to evaluate the repeatability of our fabrication processes," says Gammon.

Following the supply and commissioning of the SemiProbe equipment, a software interface was written by Gammon's team to enable the PS4L and the high-voltage parameter analyser to work together. "Both OEMs were incredibly supportive and gave us access to the source code of their respective products," notes Gammon.

The equipment is in use at the University of Warwick, one of just a few universities in the UK with SiC fabrication capabilities, and it has already enabled Gammon's team to capture data from larger test batches than would have otherwise been practical before. Also, there is more confidence in the data collected through automated processing, as it removes the discrepancies of manually obtained data, such as probe tip to pad alignment inconsistences and variations in contact force.

"Our new equipment represents a real game-changer and the support Inseto provided has been exemplary throughout the entire process, from them understanding our requirements through to ensuring the PS4L was fit for purpose now and in the future," comments Gammon.

https://go.warwick.ac.uk/peater
www.inseto.co.uk/equipment/wafe

Kier appointed for CISM building project at Swansea

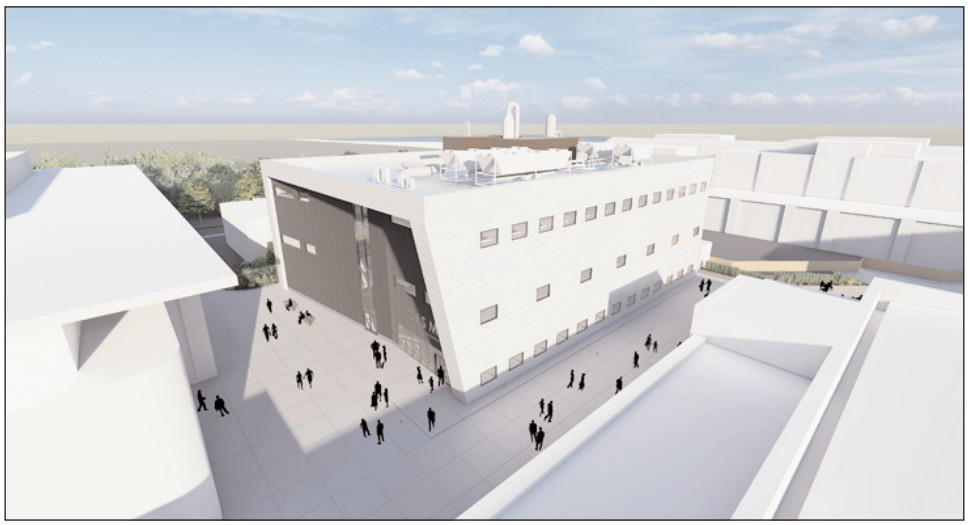
Centre for Integrative Semiconductor Materials to complete in 2022

A new facility at Swansea University that will bring together research with technology development in semiconductor science and engineering is one step closer with the execution of the main build contract with Kier for the Centre for Integrative Semiconductor Materials (CISM), which will be located in the engineering quarter on the Bay Campus.

Work has already started on the three-storey building, which will be 4320m^2 in size, and will house a clean fabrication environment, research laboratories and office facilities. Kier will use sustainable, energy-efficient building techniques and renewable energy technology including solar photovoltaics (PV) and heat recovery on the project. Throughout the duration of the project, Kier will work with its local supply chain, of which about 20% will be from the surrounding Swansea area, to deliver the building.

In July 2019, the facility received £30m in funding from the UK Research Partnership Investment Fund (UKRPIF), which is administered by Research England in partnership with the Higher Education Funding Council for England (HEFCE).

Due for completion in 2022, CISM will provide research and innovation support for the CSConnected cluster, a growing network of regional semiconductor industry partners including IQE, SPTS Technologies, Microchip and Newport Wafer Fab. The cluster partners also include Swansea and Cardiff Universities, the Welsh Assembly Government and the Cardiff Capital Region City Deal in a coordinated effort to deliver critical mass and a competitive advantage for semiconductor manufacturing in the region.



The CISM building design (credit: Stride Treglown).

It is reckoned that the facility will be uniquely placed to deliver economic and social benefits to the south Wales region, particularly in the post-Covid era, as its facilities and research will bring new opportunities that can be met by a skilled local population and which will anchor compound semiconductor businesses in the region.

CISM will "play a key part in putting Wales on the map as a major player in the rapidly growing UK semiconductor industry," reckons professor Paul Meredith, Ser Cymru National Research Chair and Swansea University CISM project lead. "When completed, the CISM building will be a hub for connecting research, innovation and manufacturing to drive economic growth in this region," he adds.

"The Centre for Integrative Semiconductor Materials is set to be a vital building in aiding the growth of the semiconductor industry in the UK," says Jason Taylor, operations director for Kier Regional Building Western & Wales. "This latest award builds on our relationship with Swansea University, having delivered the Impact building last year as well as a number of other refurbishment projects over the last five years. We will continue to work with our local supply chain to deliver this important project for the university," he adds.

"CISM is a welcome addition to the CSconnected family that will play a critical role within the cluster, complementing and greatly enhancing the technology offering from across our region," says Chris Meadows, director of CSconnected Ltd.

http://csconnected.com
www.swansea.ac.uk

Riber receives €1m-plus order for MBE services in USA

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 a major order for MBE services worth more than €1m from an industrial customer in the USA.

The order involves the full refurbishment of a production system in order to modernize its function and components. The upgrade will enable the system to be used for new applications.

The order will be completed during first-half 2021.

www.riber.com

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Picosun's ALD boosts UVC LED reliability and lifetime

Picosun Group of Espoo, Finland says that its atomic layer deposition (ALD) thin-film coating equipment has been used to deposit passivation and barrier films in ultraviolet-C (UVC) LEDs that have achieved excellent reliability and lifetime improvements at customer and collaboration partner Taiwan's National Chiao Tung University (NCTU).

An UVC LED with 50nm ALD Al_2O_3 passivation and normal packaging (no hermetic seal) maintained 80% of its original efficiency after 500hrs environmental test at 85% humidity and 85ºC temperature.

ALD passivation layers could replace the expensive hermetically sealed package of the LEDs and thus lower the costs of the final device.

To reach maximum light output and long operating lifetime, LED chips require surface passivation to eliminate parasitic currents caused by traps and defects. Also, barrier coating is typically needed, as LED materials are sensitive to moisture. ALD is suitable for manufacturing both the passivation and barrier films and, when LEDs are micron size, it is the only coating method capable of producing sufficiently high-quality films on the required small scale. Ultra-thin, pinhole-free ALD films do not suppress light intensity and provide reliable protection against ambient conditions, whereas their superior conformality ensures no thickness variation between chip facets (a typical side-effect of other coating methods that can lead to uneven distribution of film stress or thermal expansion behavior and risk physical damage of the chip).

"We have used Picosun's ALD technology already for years with great success," comments NCTU professor Hao-Chung Kuo. "Our Picosun ALD equipment yields superior quality films, which has helped us to achieve several breakthroughs in our LED research," he adds. "Picosun has a local presence in Taiwan and we appreciate the prompt response of their customer support if we ever have any issues. At the phase when R&D results are to be ramped up to industrial-level production, the scalability of Picosun's ALD technology is a huge benefit."

Short-wavelength UVC radiation destroys bacteria and viruses, so UVC LED technology is topical now during the COVID-19 pandemic. Small, lightweight LEDs enable versatile design of portable, compact disinfecting equipment, consume less power than other UVC sources, are durable, and pose no risk of hazardous material leaks such as mercury lamps, for example.

www.picosun.com

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First proof that safer, 222nm UV-C effectively kills SARS-CoV-2 virus

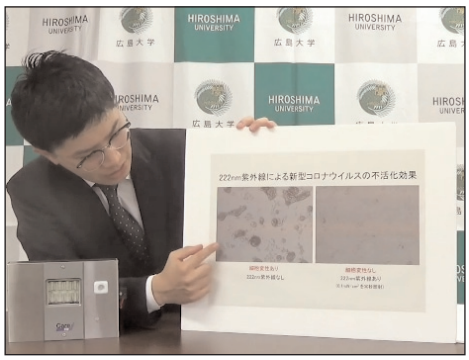
Disinfection of occupied public spaces possible

A study by Hiroshima University has found that using UV-C light with a wavelength of 222nm which is safer to use around humans effectively kills SARS-CoV-2 — the first research to prove its efficacy against the virus that causes COVID-19 (Hiroki Kitagawa et al, 'Effectiveness of 222-nm ultraviolet light on disinfecting SARS-CoV-2 surface contamination', American Journal of Infection Control, DOI: 10.1016/j.ajic.2020.08.022).

Other studies involving 222nm UV-C (far-UVC) have so far only looked at its potency in eradicating seasonal coronaviruses that are structurally similar to the SARS-CoV-2 but not on the COVID-19-causing virus itself.

An in-vitro experiment by Hiroshima University showed that 99.7% of the SARS-CoV-2 viral culture was killed after a 30s exposure to 222nm UVC irradiation at 0.1mW/cm2.

Tests were conducted using Ushio's Care222 krypton-chloride excimer lamp. A 100 microliter solution containing the virus (about 5x106TCID50/mL) was spread onto a 9cm sterile polystyrene plate. The researchers allowed it to dry in a biosafety cabinet at room temperature before placing the far-UVC lamp 24cm above the surface of the plates.



Hiroshima University found that using UV-C light with a 222nm wavelength, which doesn't harm living cells in the human eye and skin, effectively kills SARS-CoV-2. This is the first study that proves its potency against the virus that causes COVID-19.

222nm versus 254nm UV-C

UV-C light with a wavelength of 222nm cannot penetrate the outer, non-living layer of the human eye and skin so it will not cause harm to the living cells beneath. This makes it a safer but equally potent alternative to the more damaging 254nm UV-C germicidal lamps that are increasingly used in disinfecting healthcare facilities.

Since 254nm UVC harms exposed human tissue, it can only be used to sanitize empty rooms. But 222nm UVC can be a promising disinfection system for occupied public spaces including hospitals where nosocomial infections are a possibility.

However, the researchers propose further evaluation of the safety and effectiveness of 222nm UV-C irradiation in killing SARS-CoV-2 viruses in real-world surfaces, as their study only investigated its in-vitro efficacy.

The far-UVC research is one of the four COVID-19 studies conducted by Hiroshima University scientists that received funding from the Japan Agency for Medical Research and Development (AMED). Drs Hiroki Kitagawa, Toshihito Nomura and Hiroki Ohge of Hiroshima University Hospital's Department of Infectious Diseases, and Dr Takemasa Sakaguchi of the Hiroshima University Graduate School of Biomedical and Health Sciences were behind the study (under grant number JP20he0922003). Many laboratories in the university are conducting research on the novel coronavirus as part of the 'Hiroshima University CoV-Peace-Project'.

www.ajicjournal.org/article/S0196-6553(20)30809-9/fulltext
www.hiroshima-u.ac.jp/en/bhs

SETi and Seoul Viosys begin mass production of Violeds UV LED module

99.9% of coronavirus sterilized in 3 seconds

Seoul Semiconductor subsidiaries Sensor Electronics Technology Inc (SETi) of Columbia, SC, USA — which makes UV-A, UV-B and UV-C deep-ultraviolet LEDs (emitting at wavelengths of 200–430nm) — and Seoul Viosys Co Ltd (which makes UV LED products) have started mass production of a UV LED module designed to sterilize 99.9% of the coronavirus in 3 seconds using Violeds, a UV LED technology developed by Seoul.

Seoul Viosys is also developing a Photon Shower device that applies the UV LED technology to contribute to the safety of medical staff and patients who have been struggling amid the COVID-19 pandemic.

The BIO research team at Seoul Viosys has conducted numerous R&D projects with in-house laboratories cultivating and sterilizing various bacteria and viruses. In April, a Violeds sterilization test conducted with a research group at Korea University demonstrated that Violeds sterilizes coronavirus.

The new Photon Shower is a whole-body sterilization solution that uses only light to sterilize various germs on the surface of peoples' clothing in seconds when they enter it. This sterilization function can also be added to conventional air shower devices that are used for dust removal only.

The Photon Shower using Violeds technology is expected to contribute to minimizing infections in hospitals in the future. According to the US CDC (Centers for Disease Control and Prevention) statistics, more than 14,000 people die annually from hospital infections in the USA alone.

"There are countless industrial fields where the Violeds UV LED module, which sterilizes 99.9% of viruses on the surface of everyday objects in just three seconds, can be applied," says Mike Berens, SETi's director of sales. "It has been supplied to US escalator manufacturers to be applied to escalator handle sterilization solutions, and we expect global customer demand to increase in the future."

Jointly developed by SETi and Seoul Viosys through more than 20 years of R&D, Violeds UV LED technology uses only light to sterilize, and can be optimally designed depending on the application by considering the following five factors: wavelengths from 200nm to 400nm, distance to objects, light irradiation time, brightness of light (intensity), angle and area of irradiation surface. This technology has already been applied to the International Space Station (ISS) of the National Aeronautics and Space Administration (NASA), and is also applied to various home appliances and automobiles, including air conditioners, air purifiers, water purifiers and dishwashers.

Applying this technology, Seoul Viosys is producing the VAC Series air purifier (which is optimally designed to filter and sterilize 99.9% of bacteria and virus particles in 30 seconds) and the VSM+ Series multi-sterilizer device, which sterilizes the surface of everyday objects, removing 99.9% of bacteria and virus particles in 10 minutes.

www.s-et.com
www.seoulviosys.com

Toyoda develops DUV LED light module for sterilization

Taking advantage of technology accumulated over 30 years in the development and production of blue light-emitting diodes, Toyoda Gosei Co Ltd of Kiyosu, Aichi Prefecture, Japan has developed a deep-ultraviolet (DUV) LED light module for use in the sterilization of water, air and surfaces.

Deep UV LEDs emit short-wavelength ultraviolet light that can destroy the genetic materials of viruses and bacteria. They are promising as a new sterilizing light source that can be used in place of mercury lamps, for which there is environmental concern.

With the aim of spreading applications of this technology, Toyoda

Gosei has been developing products in modules or units with waterproof or heat-dissipation features. In a joint experiment conducted with Japan's Biomedical Science Association (a certified non-profit organization consisting of specialists from national research institutes and universities in medicine, pharmaceutics, veterinary medicine, agriculture etc) using human coronavirus 229E (HCoV-229E), which has genetic materials similar to those of the virus that causes Covid-19 (SARS-CoV2), these modules were demonstrated to be highly effective in sterilization.

Toyoda Gosei is cooperating with the Toyota Group and other companies to develop applications for water, air and surface sterilization that contribute to safer and healthier living.

www.toyoda-gosei.com

Seoul Semiconductor's WICOP Bi-color LEDs used in headlamp of latest model of Audi A4

WICOP Gen2 mini Bi-color emitter shrinks footprint

Seoul Semiconductor Co Ltd has supplied WICOP Bi-color (2 colors in one package) LED products for the daytime running lights (DRLs) and front turn signals in the headlamp of the 2020 Audi A4 (B9 facelift).

This is the first example of Seoul Semiconductor's WICOP (wafer-level integrated chip on PCB) product being mounted on an Audi headlamp. The WICOP Bi-color LED is a core patented technology of Seoul Semiconductor that realizes both white and yellow in one package. It is designed to directly mount the LED chip on the board without an additional package.

"Due to the narrow space between the light-emitting surfaces of the Bi-color LED, it is technically beneficial to light up one cavity with yellow for turn and white for DRL," says Dr Michael Hamm, head of development headlamps at Audi. "This advantage opens up the possibility of slimmer headlamp designs."

The 2020 Audi A4 with Seoul Semiconductor's WICOP Bi-Color LEDs (Source: Audi).

In the meantime, Seoul Semiconductor has already developed the more compact WICOP Gen2 mini Bi-color emitter, including the advantages of the existing WICOP in combination with an even slimmer footprint.

"The [WICOP Gen2] family has been developed as a light source suitable for automobile main functions, daytime running lights and turn indicators," says In Heum Park, VP of Seoul Semiconductor's automotive division. "Actually, we are developing WICOP UHL (Ultra High Luminance), with excellent high-luminance and heat-dissipation performance for the next generation of slim headlamps," he adds. "Accordingly, European headlamp customer inquiries for our innovative products have increased and we have been engaged with customers in more than 20 headlamp projects for next-generation cars."

WICOP technology is widely applied not only to vehicle lighting but also to high-brightness TVs and LCD backlights for mobile phones, flash for smartphone cameras, and high-power general lighting, as it has high thermal conductivity and is easy to configure light, thin and compact lenses, says Seoul Semiconductor.

Seoul Semiconductor wins lawsuit versus Factory Depot

US court issues permanent injunction against Philips display and Feit light bulb products

South Korean LED maker Seoul Semiconductor Co Ltd has obtained a permanent injunction in a patent infringement lawsuit against The Factory Depot Advantages Inc that sold Philips electronic products and Feit lighting products.

The US District Court for the Central District of California issued a permanent injunction against the sales of a Philips signage display product manufactured by an affiliate of TPV Technology, the world's largest manufacturer of computer monitors. This Philips brand product incorporated LED packages informed of products from Taiwanese LED maker Lextar Electronics. There was no dispute in the permanent injunction order that the accused products infringed Seoul's patents. Seoul previously obtained another permanent injunction judgment against the sales of a Philips brand LED TV in a patent infringement lawsuit filed against Fry's Electronics.

The latest permanent injunction also prohibits the sale of certain filament LED bulbs of Feit Electronics. Seoul is the only licensed filament LED component supplier under the Regents of the University of California's (Santa Barbara) filament LED patents.

In recent years, Seoul has actively pursued enforcement against products suspected of infringing its patents. As a result, Seoul and its affiliates have obtained six permanent injunctions, including two recall orders, of infringing products during the past three years.

"Intellectual property is an incredible tool that allows people to break through class barriers and enable small businesses and young entrepreneurs to compete with anyone, even global conglomerates," says founder Chung Hoon Lee. "Some companies abuse complicated patent laws and infringe other patents or have unlawful access. We hope that Seoul's success story will reinforce the importance of R&D and the protection of intellectual property," he added.

www.SeoulSemicon.com

Bridgelux recognized twice in 2020 IES Progress Report

Bridgelux Inc of Fremont, CA, USA (a vertically integrated manufacturer of solid-state light sources for lighting applications) has received two selections for inclusion in the 2020 Illuminating Engineering Society (IES) Progress Report: (1) the new Vesta Flex family of two-channel drivers with interchangeable controls for tunable white lighting systems, and (2) the Gen 8 Vero and V Series chip-on-board (COB) LED products, which have what is claimed to be market-leading efficacy.

The IES reviews industry-wide submissions of light sources, lighting components, luminaires, research and publications for inclusion in its annual Progress Report. Acceptance is based on an impartial judging process to evaluate each submission on its uniqueness, innovation and significance to the lighting industry.

The Vesta Flex family of specification-grade, NFC-programable, tunable white LED drivers and control modules is designed to accelerate the adoption of human centric lighting. Vesta Flex is compatible with multiple traditional wired, and new wireless lighting control ecosystems, including wired DALI2 and 0-10V controls, and wireless control options from WiZ, WiSilica, Silvair and Casambi. This system enables simplified future-proof design flexibility for luminaire manufacturers to develop luminaires with control interoperability to meet the needs of any lighting project. Optimized to work with Bridgelux Vesta Series tunable white LED sources, this combined lighting system is designed to work together out of the box, simplifying the design process and accelerating time to market.

The eighth-generation V Series, Vero Series and Vero SE Series product families deliver up to 185lm/W (at nominal drive current). This luminous efficacy is benchmarked at the popular 3000K 80CRI (color rendering index) color point, with efficacies above 200lm/W possible at other color points across what is claimed to be the industry's broadest range of COB products. Gen 8 COB products also feature up to 3x overdrive capability, delivering a 30% increase in maximum lumens per LES size to support the continuous trend toward luminaire miniaturization, as well as significant increases in lumens per dollar to further reduce the costs of solid-state lighting. Available in LES sizes ranging from 8mm to 29mm, Gen 8 products deliver 800–16,000lm at nominal currents in a wide range of CCT and CRI options to support a wide variety of lighting applications.

"Vesta Thrive was the winner of a 2020 LightFair Innovation Award, and both Vesta Flex and Thrive were Sapphire Awards finalists at the Strategies In Light conference," notes Jason Posselt, VP of global marketing at Bridgelux.

www.bridgrelux.com

Everlight convicted in Korea for misappropriating Seoul Semi's trade secrets

South Korean LED maker Seoul Semiconductor Co Ltd says that the Korean Suwon District Court has convicted Taiwan-based Everlight Electronics Co Ltd of criminal misappropriation of its trade secrets. Three former employees of Seoul who left the firm and went to work at Everlight were also criminally convicted of trade secret misappropriation. Everlight and the former employees are subject to criminal sentences, says Seoul Semiconductor.

Everlight was sentenced to the maximum criminal fine permitted under Korean law for the commission of such a crime. The Court also sentenced the former employees with criminal probation with the possibility of prison time.

According to Seoul Semiconductor, the criminal investigation began as a result of Everlight's solicitation of a former engineer and sales employee from Seoul. The former employee had special knowledge of Seoul's automotive LED technology utilizing its proprietary WICOP (wafer-level integrated chip on PCB) technology — the world's first package-less LED — in which Seoul invested KRW560bn over seven years. The former employee used a false name while working at Everlight to escape detection, Seoul Semiconductor says. The Korea Prosecutors' Office criminally indicted Everlight for violating the Industrial Technology Protection Act, as well as the Trade Secret Protection Act. The former employees were charged and arrested with the same violations.

Seoul says that it has achieved US$1bn of annual revenue in LED sales, and that it invests about 10% of its revenue into R&D every year and holds more than 14,000 global patent rights.

"Intellectual property is a ladder that enables small businesses and young entrepreneurs to compete with global conglomerates. It allows people to break through barriers of class and origin with rapid business growth," says Seoul's founder Chung Hoon Lee. "Intellectual property enables industrial revolutions. It gives us a tool to fight global poverty, facilitate culture and research activities, grow small businesses into global enterprises, and drive the national economy by creating jobs," he adds. "We should not allow unethical companies to steal intellectual property for monetary gain."

www.SeoulSemicon.com
www.everlight.com

Lumileds issues 2019 Sustainability Report

Products saved 3.93 million metric tons of CO_2 emissions

Lumileds LLC of San Jose, CA, USA has released its 2019 Sustainability Report, which details its progress in supporting the transition to a worldwide low-carbon economy. In the report, Lumileds highlights how its lighting solutions contribute to positive changes in energy usage, safety, and health and well-being. The firm follows a formalized sustainability agenda that identifies specific priorities and tracks progress.

The sustainability objectives are based on creating value for customers through sustainable innovations, reducing the environmental footprint of the firm's operations, driving improvements in the supply chain toward compliance with the Responsible Business Alliance (RBA) and preventing injuries. Lumileds has aligned its sustainability efforts with external frameworks such as the United Nations Sustainable Development Goals (SDGs) and identified four SDGs to make the most significant contribution: climate action, good health and well-being, affordable and clean energy, and responsible consumption and production.

Lumileds says that its development of energy-efficient, low-carbon LED lighting technologies supports urgent action to combat climate change. Its LED lighting products have helped end-users reduce their greenhouse-gas emissions (GHG) emissions by an amount that is 35 times greater than Lumileds' GHG emissions in 2019. Compared with conventional lighting, the firm's products emitted 49% less total carbon dioxide in 2019, saving 3.93 million metric tons of CO_2 in the illumination and automotive market, it is reckoned.

For Lumileds, 2019 was a transformative year. Despite economic challenges in the industry, the firm's scientists and engineers continued to increase product performance while achieving significant reductions in energy use and water consumption. Lumileds also lowered its carbon emissions and waste.

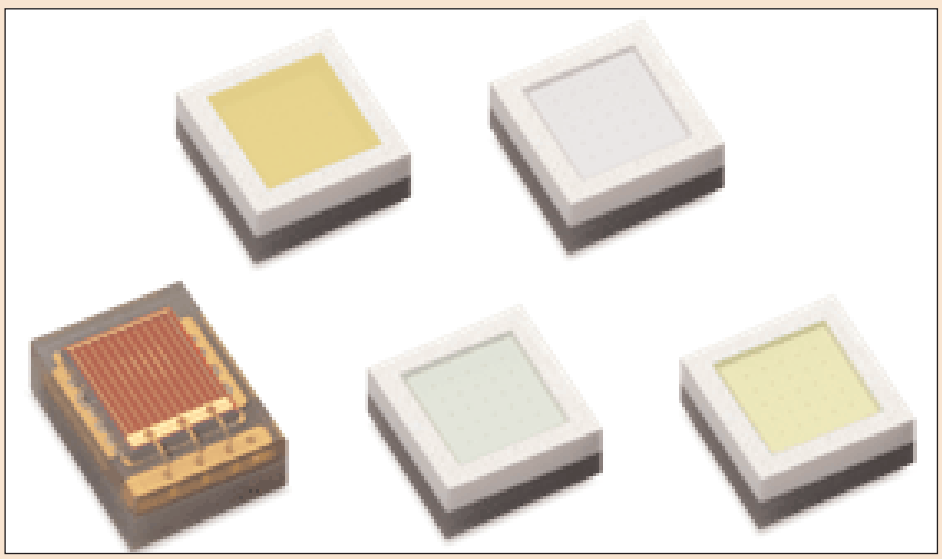
"Maintaining a safe environment for our worldwide employees is the highest priority, and the current pandemic has only reinforced that intention," says Jan van Rompay, director of sustainability. "The 2019 report highlights our commitment to safety and our strong performance in occupational health and safety. In 2019 over 15,000 injury prevention actions were performed at our sites," he adds. "Our global effort during the pandemic has been a stress test for our governance mechanisms and a demonstration of their resilience in managing extreme events."

www.lumileds.com/wp-content/uploads/files/SR66-lumileds-2019-sustainability-report.pdf

Lumileds launches LUXEON Rubix color LEDs

3A drive current in 1414 package enables design flexibility

Lumileds LLC of San Jose, CA, USA has launched the small (1414-packaged) and powerful LUXEON Rubix – a new color LED building block – designed to deliver maximum flux at drive currents up to 3A as well as what is claimed to be unmatched design flexibility (with uniform focal height), as engineers are freed from the design constraints of pre-configured modules and can create custom arrays with smaller optics supporting smaller-size luminaires.



"LUXEON Rubix introduces a size and power ratio that has never before existed for color LEDs," claims product marketing manager LP Liew. "Think of LUXEON Rubix as pixel-like – uniquely shaped arrays are possible, optics can be smaller, and exceptionally high light density allows solutions across a broad range of lighting segments to take new forms and increase their value," he adds.

Tested and binned at 85°C, the LUXEON Rubix's typical flux output is 85lm (red), 310lm (green), 112lm (blue) and 1635mW (royal blue). Typical output for white is 440lm at luminous efficacy of 93lm/W.

www.lumileds.com/products/color-leds/luxeon-rubix

Lumileds names Matt Roney as chief executive officer

Jonathan Rich becomes executive

Lumileds LLC of San Jose, CA, USA has announced the appointment of Matt Roney as chief executive officer, effective 1 October. He most recently served as president of Lumileds' Automotive business unit and succeeds Dr Jonathan Rich, who will continue with the company as executive chairman of the board.

"Matt has nearly 25 years' experience in the automotive industry, and his performance and leadership throughout his career have given us even greater confidence in his ability to drive long-term innovation and growth at Lumileds," comments Rob Seminara, senior partner at Apollo Global Management.

Lumileds' new CEO Matt Roney.

"Lumileds has a long history of innovation in conventional automotive lighting and is a pioneer of leading-edge LED technology for the consumer electronics, automotive and general illumination markets," says Roney. "I look forward to building on the foundation Dr. Rich has put in place to further advance our technologies and increase the value we deliver to customers across a broad set of industries."

Prior to joining Lumileds, Roney served as chief operating officer for Stanley Infrastructure (a division of Stanley Black & Decker). Previously, he was president of Paladin Attachments (which was acquired by Stanley Infrastructure). He also spent eight years at TRW Automotive (now known as ZF TRW) in roles of rising responsibility, including VP & general manager of its $2.5bn Global Steering business.

Roney has a BS in Electrical Engineering from Cornell University, an MSE in Mechanical Engineering from Purdue, and an MBA from Harvard Business School.

www.lumileds.com

Lumileds launches LUXEON 3030 HE Plus Deep Dimming mid-power LEDs

LED-to-LED flux uniformity down to 1% across entire dimming curve

Lumileds has introduced what it says is the first LED engineered for architectural applications that require uniform light output through the entire dimming range and operating conditions.

The new LUXEON 3030 HE Plus Deep Dimming mid-power LED is designed for LED-to-LED flux uniformity across the entire dimming curve – down to 1% – that is required to achieve consistent visual performance. From full intensity above nominal current of 65mA to 1% intensity at 0.65mA, every LED will provide the same flux performance in the application.

Key to the performance is forward voltage variance of just 0.10V, which simplifies driver design and compatibility. The single 3 SDCM color bin ensures color consistency at any CCT (correlated color temperature). Lumileds says that its 3V 3030 package is a proven, high-efficacy industry-standard platform that allows for drop in replacement of existing 3030-footprint LEDs.

Top: inconsistent LED performance when dimming. Bottom: Smooth, consistent deep-dimming with LUXEON 3030 HE Plus Deep Dimming.

"Inconsistent flux performance has long been a problem for luminaire manufacturers and they've found work-arounds by either adding components or managing LED selection from the bins they receive," says product marketing manager Mei Yi. "Both work-arounds add cost, complexity and time to the manufacturing process. With LUXEON 3030 HE Plus Deep Dimming we provide consistent flux performance across the dimming range directly at the LED level."

The new deep-dimming LEDs are available across the entire CCT range from 2700K to 6500K and with minimum color rendering indexes (CRIs) of 80 or 90. The new 3030 LEDs deliver the highest efficacy across all LUXEON 3030 mid-power product lines, from 162 lumens to 210 lumens per watt, depending on CCT and CRI. Typical forward voltage is 2.71 plus or minus 0.05V.

The LUXEON 3030 HE Plus Deep Dimming LED is immediately available.

www.lumileds.com/3030DD

Osram launches new generation of Oslon Compact PL and Oslon Black Flat S LEDs

Osram Opto Semiconductors GmbH of Regensburg, Germany says that, via leaps in performance, the latest versions of its Oslon Compact PL and new versions of its Oslon Black Flat S LED product families are targeted at further increasing market penetration of LEDs in headlights (both high-beam and low-beam).

In a few years, LEDs will be the predominant light source in car headlights, since their compactness and energy efficiency in particular are major advantages over conventional technologies, says Osram Opto. LEDs also make it easy to achieve the brightness values required by manufacturers. In recent years, technical advances have contributed to the increasing popularity of LED-based headlamps. Due to their compact dimensions, LEDs allow enormous freedom in design. Now LED makers are looking to improve the already very high level of quality, in terms of brightness, energy efficiency and thermal performance.

Osram Opto is hence launching a new generation of 1- to 4-chip versions in the Oslon Compact PL product family. Like their predecessors, the ceramic components have an electrically insulated pad that makes it much easier to dissipate heat from the package. Higher current is therefore possible, which allows the 1-chip version to achieve a brightness of 395lm at 1A with a chip area of 1mm^2. Due to the very small dimensions of 1.9mm x 1.5mm x 0.73mm, the product is suitable for ADB (adaptive driving beam) systems and in extremely space-saving system designs.

In addition, the Oslon Black Flat S family has been expanded to include 1- and a 2-chip versions. The special lead-frame-based components feature a high contrast values (>1:200) and very low thermal resistance, allowing for higher currents. The 1-chip variant reaches a brightness of 395lm at 1A. The square lighting surface of the UX:3 chip makes optical design particularly easy for headlight manufacturers, claims the firm.

The different technology concepts of the Oslon Black Flat S and Oslon Compact PL enable users to choose the best possible combination of LED and PCB for their systems, says Osram Opto. Due to the luminous efficiency values of up to 130lm/W at 1A, headlights with smaller heatsinks or even without heatsinks are conceivable in the future, leading to a potential reduction in system costs.

"LEDs such as the Oslon Compact PL and the Oslon Black Flat S will lead to an increasingly high penetration rate in vehicles, including small- and mid-sized cars," reckons Florian Fink, marketing manager Automotive Exterior at Osram Opto. "We always work in close cooperation with our customers to constantly improve our established product families and to push the limits of achievable brightness values even further in future," he adds.

The package dimensions remain the same in the new product generations of the Oslon Compact PL and Oslon Black Flat S, allowing headlamp manufacturers to exchange the products.

www.osram.com

UCSB patent enforcement campaign expanded

Nixon Peabody has expanded its patent enforcement campaign on behalf of the Regents of the University of California (UC) with new litigation against six leading retailers and suppliers of filament LED lighting products.

Building on a first phase launched in 2019, a new complaint filed with the International Trade Commission (ITC) seeks an investigation into the unauthorized importation and sale after importation of UC's patented filament LED lighting technology by General Electric, Savant Systems, Feit Electric, Home Depot, Ikea and Satco Products.

Light bulbs made with UC's patented filament LED technology are often referred to as 'Edison' or 'vintage' LED light bulbs since they resemble Thomas Edison's iconic light bulbs with glowing filaments visible inside glass bulbs, but they also include bulbs with frosted glass. Filament LED lighting products are increasingly popular, with a wide range of bulbs, fixtures and other products that incorporate UC's patented technology being available through retailers and suppliers, and appearing in a growing number of homes and businesses around the world, says Nixon Peabody.

The campaign's goal is to license UC's patents covering work at University of California Santa Barbara (UCSB) and to protect licensees from unlicensed competition. Revenue from licensing helps UC to support more of the educational opportunities and academic research that produce innovations like filament LEDs. In the year since the campaign was launched, more than a dozen retailers and suppliers have licensed UC's patented technology and are now authorized to import and sell filament LED lighting products.

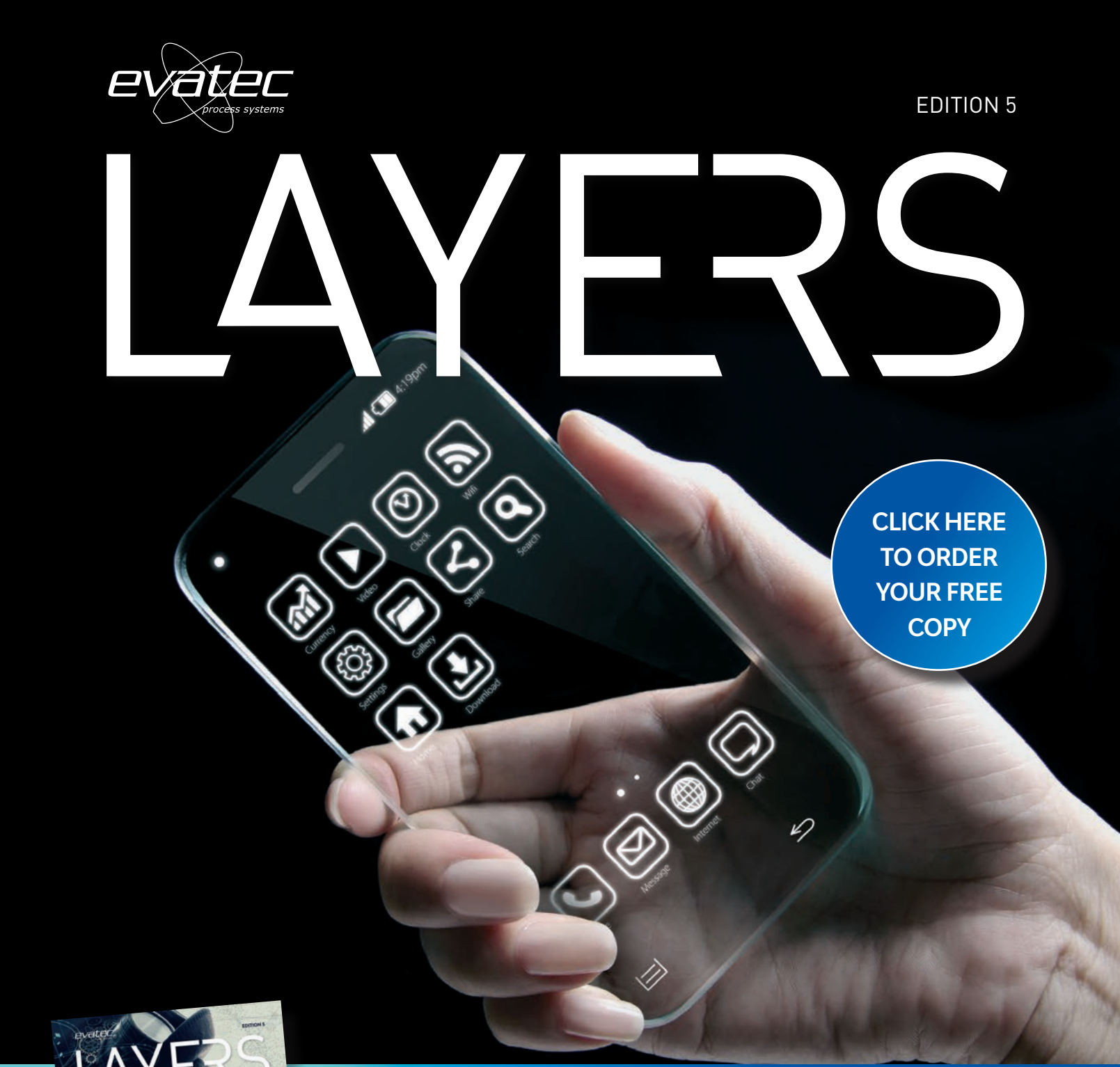
"The new litigation is an important next step in addressing what is becoming ubiquitous infringement, so that UC is rightfully compensated for the exploitation of its inventions and the important benefits they provide to society," says Nixon Peabodypartner Seth Levy.

https://filamentpatent.ucsb.edu
www.nixonpeabody.com

evatec process systems

EDITION 5

LAYERS



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

Stefan Seifried, Head of BU Optoelectronics

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SemiNex launches multi-junction 1310–1550nm laser for LiDAR systems

Low-cost, long-range, eye-safe alternative to 9XX nm diodes and 1550nm fiber lasers

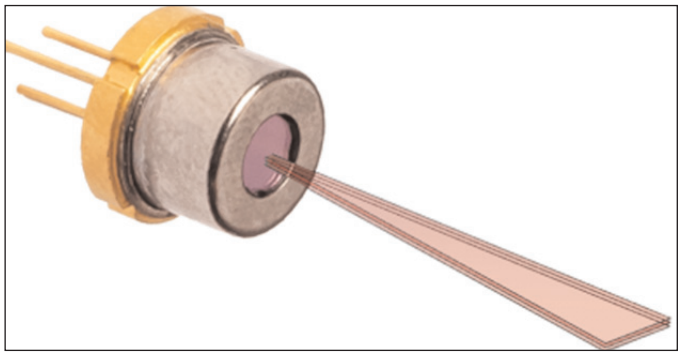
SemiNex Corp of Peabody, MA, USA — which was founded in 2003 and designs and makes indium phosphide (InP)-based high-power infrared diode lasers for military, medical and industrial applications — has made available product samples of a patent-pending, multi-junction laser diode that emits more than 20 times the photons/second over more than 3x the range at eye-safe wavelengths of 1310–1550nm compared with 905nm light detection & ranging (LiDAR) systems, which should enable mass-market auto-driving cars to finally become a reality. Ready for immediate high-volume production, the multi-junction laser diode is a drop-in replacement for most compact laser drivers used for existing 9XX nm diode systems.

The new laser makes use of three monolithic solid-state laser junctions that produce 80W at 1550nm with 95μm aperture width and yield more than 3x the power of existing laser diodes at this wavelength.

For the past ten years LiDAR manufacturers have taken two laser approaches for time-of-flight LiDAR systems: 905nm laser diodes or 1550nm fiber lasers.

Typical time-of-flight LiDAR systems using multi-junction 905nm lasers are limited to a range of 100m due to the eye-safety acceptable emission limits (AEL) of International Electrotechnical Commission (IEC) regulations. The limited visibility of 100m would require a vehicle's speed to be 25mph or less. So, 905nm lasers are restricted to niche applications such as private security systems, warehouse automation, and limited-use public driving functionality.

The alternative 1550nm fiber lasers are impractical for mass-market deployment because of their size and cost.



So, until now, there has been no solution that offered the low-cost, small size and efficiency of 905nm laser diodes with the eye-safety and extended range of 1550nm fiber lasers. Neither of these past approaches meet the automotive industry goals to enable LIDAR commercialization. The lack of efficient and inexpensive 200m eye-safe LiDAR has therefore held back the industry from commercializing autonomous vehicles and seeing any meaningful mass-market deployment at speeds greater than 25mph.

"SemiNex invested three years in R&D to create a long-range and cost-effective solution to overcome the short-range limitations of existing technologies," says CEO David Bean. The new multi-junction laser enables high-power, longer-range (>250m), lower-cost, eye-safe LiDAR solutions for autonomous trains, planes and automobiles.

Until now, there has been no solution that offered the low-cost, small size and efficiency of 905nm laser diodes with the eye-safety and extended range of 1550nm fiber lasers

"Now there is a low-cost, long-range, eye-safe alternative to 9XX nm diodes and 1550nm fiber lasers," adds director of sales & marketing Ed McIntyre.

The LiDAR market for automotive and industrial applications is expected to be $981m, limited to short-range applications. However, with improvements in technology and broader acceptance, the market is expected to grow to $2.8bn by 2025. A major challenge with the existing LiDAR technology for autonomous vehicles has been to find a cost-effective laser diode that can provide high peak power at eye-safe wavelengths for long-range applications. Operating at 1550nm, the SemiNex triple-junction device provides three times the peak power of a single emitter, improving the resolution and penetration effectiveness in bad weather while remaining eye-safe. It can be operated at pulse widths of 2–100ns at 200–400kHz pulse repetition rate. SemiNex offers multi-junction devices emitting at wavelengths between 1310nm and 1550nm through various aperture widths and with cavity lengths to meet specific customer requirements.

"The SemiNex multi-junction laser diodes will allow vehicles to autonomously navigate at higher speeds that can't be achieved with the existing technology; this could finally enable driverless cars to be a reality within the next 5 years," reckons McIntyre.

The multi-junction device is available in double- and triple-junction configurations in various packaging and submount configurations. Samples in either TO-9 or bare die configuration at 1550nm are available for immediate delivery.

www.SemiNex.com

Sheaumann Laser expands to new headquarters

Range to be extended from GaAs- to InP-based lasers

Sheaumann Laser Inc, which designs and makes laser diodes and modules for sensing, imaging, telecom, navigation and illumination applications in the industrial, defense and medical sectors, moved its headquarters in August from a leased facility in Marlborough, MA, USA to a 57,800ft^2 facility at 5 Federal Street, Billerica, bought in October 2019 and since renovated.

As one of the few vertically integrated laser manufacturers in the USA, Sheaumann says that the relocation allows it to significantly expand its workforce and production capabilities to meet the growing demand for laser-based technologies across a variety of industries.

The move is supported by a $2.34m grant from the Massachusetts Manufacturing Innovation Initiative (M2I2). This award, paired with Sheaumann's matching funds, enabled the purchase of laser manufacturing equipment to expand production and streamline existing processes. The firm will broaden its wafer growth capabilities, expanding its existing near-infrared gallium arsenide (GaAs) wavelength range (780–1080nm) offerings to include indium phosphide (InP) wavelengths (1120–1875nm).

Sheaumann says that the building purchase signifies its commitment to keep its production in the USA, and the expansion will necessitate training and hiring additional skilled personnel from the region as the firm grows its workforce by 40%.

"The M2I2 capital grant helps immensely in supporting Sheaumann's passion for innovative technology by helping broaden our capabilities in laser growth to include InP wavelengths," says president Gary Sousa. "The expansion of new technology and personnel will help Sheaumann nearly double its current product line, allowing us to continue to compete with overseas foundries while maintaining all production activities in Massachusetts,"

The Billerica facility has triple the space of Sheaumann's original location in Marlborough and includes 15,000ft^2 of cleanroom space for its manufacturing and R&D activities, along with dedicated space that meets quality and security regulations specific to the defense and spacecom sectors. Sheaumann says that vertical integration of R&D, epitaxial wafer growth and packaging gives it the control and flexibility to create custom solutions for OEMs with unique requirements. In addition, the firm has plans to develop an incubator space for photonics-based startups with complementary process needs. Qualified candidates will be able to lease cleanroom and office space.

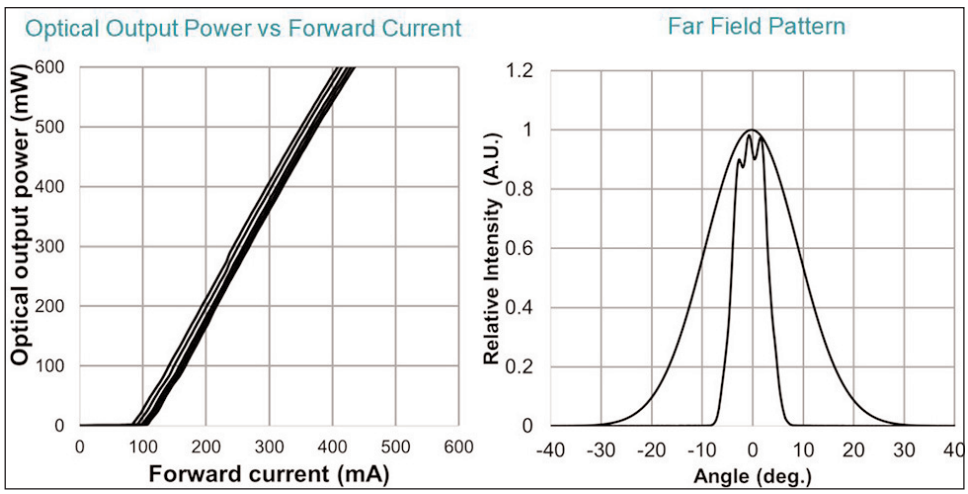
www.sheaumann.com

Ushio adds new 600mW 405nm violet lasers

Wall-plug efficiency, slope efficiency and lifetime increased

Ushio Inc (Japan) has added to its violet laser diode (LD) product line-up by releasing the HL40113MG and HL40115MG (with two different internal circuits — the latter has a built-in monitoring photodiode). The new models emit at a wavelength of 405nm and have continuous wave (CW) optical output power of 600mW. Although they share characteristics with existing Ushio lasers, they bring several improvements, including wall-plug efficiency (WPE), slope efficiency (the amount of input current used for optical light output power), and an extended overall lifetime.

For comparison, HL40113MG and HL40115MG offer a seven-point increase in wall-plug efficiency (to 28.6% and 21.4%, respectively) over the existing HL40063MG and HL40065MG laser diodes, further reducing power consumption and heat dissipation requirements. The HL40113MG and HL40115MG also provide an 18% improvement in slope efficiency, allowing advances in overall system optimization.



The HL40113MG and HL40115MG also improve their laser diode lifetime by 40% compared with the HL40063MG and HL40065MG.

The new lasers have a low operating current of 500mA and voltage of 4.2V (typical) and come in standard MG (TO-56) can packages. They are optimized for applications such as laser direct imaging, e.g. photolithography and PCB making, plus bio-medical and life science use.

www.ushio.eu

Hamamatsu completes new building at Shingai factory

Optoelectronic device production starting in October

After starting construction on it in July 2019, Japan's Hamamatsu Photonics K.K. has completed its Shingai Factory Building No.2 in Hamamatsu City, Shizuoka Prefecture, which should start operations in October to meet increasing demand for optoelectronic devices, x-ray image sensors and x-ray flat-panel sensors.

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

Costing 6.5bn yen, construction of the new building will consolidate the firm's opto semiconductor production processes, which are currently located in different locations at the Shingai Factory and associated companies. These will now all take place in the new factory building, streamlining production efficiency and creating a more robust supply system through labor saving and automation. The building will accommodate about 400 staff.

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

External view of Shingai Factory Building No. 2.

Specifically, the four-story steel-frame structure (with a building area of 4473m^2 and total floor space of 15,631m^2) comprises:

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

To ensure business continuity against natural disasters (which have been increasing in recent years), the firm has made anti-disaster measures more robust by incorporating earthquake and flood control measures into the building structure. At the same time, the new building is designed to actively incorporate eco-friendly measures such as LED lighting, heat-insulated walls, a solar power plant, and rainwater reuse systems.

www.hamamatsu.com

SMI to co-develop III–N photocathodes with Cornell and SUNY Albany

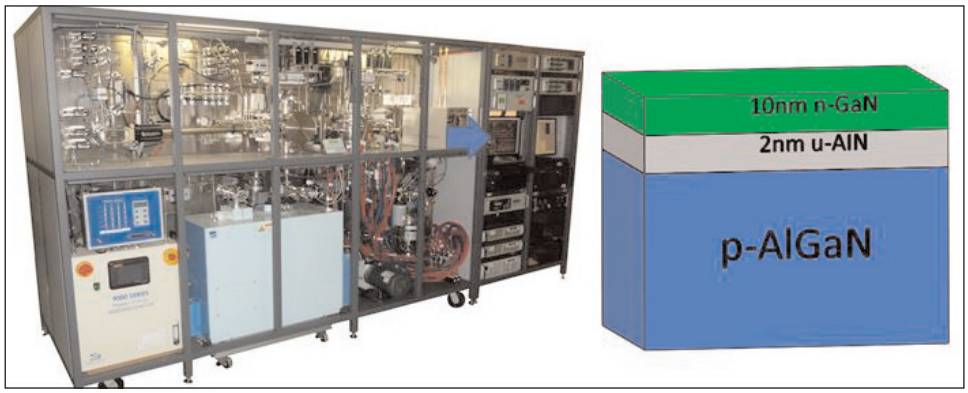
DOE-funded project targets use in electron accelerators

Structured Materials Industries Inc (SMI) of Piscataway, NJ, USA — which provides chemical vapor deposition (CVD) systems, components, materials and process development services — has been awarded a US Department of Energy (DOE) Phase I Small Business Innovation Research (SBIR) contract for a nine month project — in partnership with Cornell University (CU) and the State University of New York (SUNY) Polytechnic Institute-Albany — to grow III–N structures using metal-organic chemical vapor deposition (MOCVD) and to fabricate high-brightness photocathodes (PCaths).

The high-brightness PCaths are needed for DOE facilities and laboratories employing electron accelerators and are used for free-electron lasers (FEL), ultrafast electron microscopy, and diffraction, among other applications.

The primary material of focus is III-N layers with high chemical electro-negative surfaces that may yield the highest-brightness low mean transverse energy (MTE) electrons, and sufficiently high quantum efficiency for electron accelerator and electron diffraction microscopy applications.

"The III-N material system is familiar for its applications in LEDs and high-power, high-frequency devices; but it has also been identified to exhibit negative electron affinity (NEA) in properly designed structures with proper surface treatment," notes principal investigator and SMI research scientist Dr Arul Arjunan. "When properly tuned, these properties lead to high-brightness emission of electrons when illuminated with a light which has a wavelength less than the bandgap," he adds. "These materials hold great promise to perform better than conventional alkali-antimonide, alkali-telluride, gallium arsenide (GaAs) or metal PCaths that are highly reactive and rapidly degrade over hours to at most months due to chemical poisoning or loss of alkali metals even in isolated ultra-high-vacuum (UHV) enclosures. The III–N based photocathodes to be developed in this project will represent a new advancement in photocathode stability."



SMI III–N MOCVD tool (left) and a general III–N photocathode structure.

"This is an exciting area of fundamental high-energy physics research," says SMI's president & CEO Dr Gary S. Tompa. "This work is a nice connection to my early work in forming negative electron affinity surfaces for generating negative hydrogen ion beams, and this work may be able to contribute in that area as well," he adds.

In the past, SMI has worked on several different III–N funded research programs and has built tools for R&D of III–nitrides, including bulk material growth tools.

www.smicvd.com
www.sunypoly.edu

Compound Semiconductor Centre involved in UK National Quantum Technologies Programme projects

Lasers for magnetometers in detecting micro-defects and grading batteries

Compound Semiconductor Centre Ltd (CSC) — a joint venture founded in 2015 between Cardiff University and epiwafer foundry and substrate maker IQE plc of Cardiff, Wales, UK — has announced its involvement in two new projects funded by Innovate UK under the UK National Quantum Technologies Programme.

In July, CSC formally initiated a new £1.9m project in collaboration with partners including III–V optoelectronic foundry Compound Semiconductor Technologies Global (CST Global) of Glasgow, Scotland, Cardiff University, semiconductor and MEMS device manufacturer INEX Microtechnology Ltd of Newcastle -upon-Tyne, UK, National Physical Laboratory (NPL) and the University of Nottingham to develop a compact laser-pumped atomic magnetometer. The novel sensor correlates the interaction between alkali-metal atoms and an external magnetic field to infer minute changes in surface structures. This allows the detection of micro-defects in materials and objects that are not visible or hidden from view under protective coatings. A wide range of applications includes:

- detection of corrosion under insulation (which costs £4 trillion globally in downtime and repairs);
- in-line material characterization and quality control across the >£1.5bn steel industry;
- accurate detection of underground assets to reduce excavation time and cost during repairs and maintenance (such as transmission lines, gas and water pipes).

"The global non-destructive test market is worth £7bn annually, and higher-sensitivity in-line sensor solutions are desperately required to help meet the net-zero greenhouse-gas target by 2050 via reducing fugitive emissions in aging infrastructure, and increasing materials production efficiency," says CSC project manager Denise Powell.

In August, CSC started work on a new £5.5m project with nine industry and academic partners led by British battery maker AMTE Power. CSC's focus is on developing high-performance compound semiconductor laser sources for quantum magnetometers, to enable extremely high-sensitivity magnetic field measurements to grade new batteries leaving the factory and reduce the time taken for the ageing process from weeks to days. This new quantum sensing technology will cut the cost of production and provide additional capability in grading the quality of batteries for electric cars and other uses in the electrification revolution. An immediate application is integration in UK efforts to build a Gigafactory for battery production in the next few years, in anticipation of 50% of UK vehicle production being wholly or partially electric by 2030.

"We need radically new methods of battery assembly, testing and screening to enable truly high-volume battery manufacture to meet the demands of electrification of transport," says CSC project manager Ali Anjomshoaa. "This project is a great example of the application of UK-derived quantum science to address real-world problems and drive the future of the British automotive, transport and energy industries," he adds.

"These projects are the latest in a portfolio of innovative technologies that are translating quantum science into UK-based manufacturing to address new global opportunities," says CSC director Wyn Meredith. "It is essential that we continue to focus on exploitation of our word-class research to keep the UK at the forefront of the industries of the future."

http://uknqt.epsrc.ac.uk
www.inexmicro.com
www.compoundsemiconductorcentre.com

SMART Photonics' Series C round raises €35m

New funding to be used to expand fab capacity and speed photonic integration development

Independent pure-play indium phosphide (InP) photonic integrated circuit (PIC) foundry SMART Photonics of Eindhoven, The Netherlands has raised €35m in a Series C investment round from a Dutch consortium.

Lead investor Innovation Industries is said to be one of Europe's most active independent photonics investors, with investments across the photonics value chain. The funding includes a contribution from the Ministry of Economic Affairs and Climate Policy of The Netherlands through the Brabant Development Agency (BOM), as well as participation from KPN Ventures, PhotonDelta and existing shareholders.

Founded in 2012, SMART Photonics says that it has attracted a global customer base, consisting of leading US, European and Asian customers as well as a range of start-ups developing applications using integrated photonics. Its aim is to be the leading independent foundry for photonic integrated circuits. The firm's integration technology enables customers to design chips for various next-generation communication and highly accurate sensor applications in telecoms, healthcare, smart mobility and sustainable industrial processes.

SMART Photonics will use the new funds to expand its capacity for wafer manufacturing at the High Tech Campus in Eindhoven, accelerate the development of its photonic integration technology and firmly establish the technology in the marketplace.

The new funding will "allow us to scale up our volumes as we support our customers in bringing their first commercial products using photonic integration technology to the market," says CEO Johan Feenstra. "I am very grateful for the tremendous support we received from our investors, PhotonDelta partners and our long-term R&D partner the Eindhoven University of Technology in making it happen," he adds.

SMART Photonics' company-office at the High Tech Campus in Eindhoven.

"The company is perfectly positioned as Europe's leading independent foundry for integrated photonics through its flexible production process of photonic integrated circuits, proprietary process design kit (PDK) and tremendous know-how," comments Innovation Industries' general partner Nard Sintenie. "For Europe to maintain a leading position in the development of new technologies for the rapid-growing photonics industry, we believe it is essential to invest in infrastructure... SMART will contribute to a strong and healthy photonics ecosystem that will drive cutting-edge technology development, ensuring continued formation of exciting start- and scale-ups in this attractive industry," he adds.

"Recognized as one of Europe's key enabling technologies, photonics has the potential to drive economic growth and provide solutions to some of the most pressing societal and environmental challenges of our time," comments Miriam Dragstra, chief compliance officer of the Brabant Development Agency (BOM), which played an important role in the deal sourcing. "SMART Photonics allows Dutch technology companies to play a leading role in the development of this promising technology. Therefore, BOM is committed to supporting the financial and strategic development of this game changer," she adds.

"SMART Photonics fulfils a key function within our growing European photonics ecosystem and is of utmost importance as the fabrication of photonic integrated circuits enables innovative products in many application domains," says PhotonDelta's CEO Ewit Roos. "Thus, the growth of SMART Photonics has a profound impact as it leverages the scale of activity and innovation of the entire supply chain of integrated photonics in Europe. We are thrilled to participate in this round as the national growth accelerator for the Dutch integrated photonics industry," he adds.

www.smartphotonics.nl

VLC designs transmitter photonic integrated circuit for CiViQ quantum communications project

Fraunhofer-HHI to fabricate chips in JePPIX MPW run

As a partner in the project CiViQ, photonic integrated circuit (PIC) design house VLC Photonics of Valencia, Spain (which has experience with various material platforms including silicon photonics, indium phosphide (InP), silicon nitride, PLC and polymer) has designed a new InP PIC for secure quantum communications in networks.

The current progress in quantum technologies is expected to promote new opportunities with integrated photonics, opening up market prospects in secure communication, aerospace, defence, sensing and light detection & ranging (LiDAR).

As part of the European Quantum Flagship initiative — and funded by the European Union's Horizon 2020 research and innovation program under grant no. 820466—- the CiViQ project focuses on cost-efficient, high-integration and high-performance quantum communication technologies to deploy continuous-variable quantum key distribution (QKD) into the optical telecoms network infrastructure. In this context, PICs can play a crucial role.

CiViQ hence unites, for the first time, a broad interdisciplinary community of 21 partners, involving major telecom firms, integrators and developers of QKD. The work aims to advance both QKD technology itself and the emerging 'software network' approach to lay the foundations for future seamless integration of the two.

As a design house that supports PIC development, VLC Photonics has expertise in photonic building blocks and system design, circuit layout generation and validation, foundry consultancy and fabrication management, and bare-die characterization and testing, as well as providing support in packaging.

In the CiViQ project, VLC is facilitating the transformation of a bulky optical system (built in a lab) into a photonic integrated design circuit layout in a standard 4mm x 6mm cell-size, sufficiently flexible to satisfy the various requirements from QKD system partners. Taking advantage of the 'generic purpose' process available for prototyping and concept validation, the chips can then be fabricated through a JePPIX (Joint European Platform for Photonic Integration of Components and Circuits) multi-project wafer (MPW) run of the InP foundry at CiViQ partner Fraunhofer Heinrich-Hertz-Institut (HHI) of Berlin, Germany (a research center for mobile and stationary communication networks).

Conceived by QKD system partners Instituto de Ciencias Fotónicas (ICFO, Spain), Centre National de la Recherche Scientifique (CNRS, France), Max Planck Institute for the Science of Light (MPL, Germany), Technical University of Denmark (DTU, Denmark) and Huawei Technologies Düsseldorf (HWDU, Germany) together with HHI and VLC, the first generation of the continuous-variable QKD transmitter consists of a low-linewidth laser and the modulator PIC, which includes a high-extinction electro-absorption modulator (EAM), an IQ modulation scheme and a variable optical attenuator (VOA). The compact design exhibits a good compromise between system complexity, redundant optical paths for monitoring the performance, and distribution of electrical paths for driving the components.

After VLC has provided the specific design of the chip and HHI has fabricated it, the modulation system of the transmitter will be characterized by VLC, as well as by ICFO and CNRS, to consider the functionalities as an independent component device. In a second stage, the integrated narrow-linewidth laser, currently being developed by HHI, will also be integrated in the transmitter. This integrated transmitter will be then used in continuous-variable QKD systems developed within CiViQ to meet network security demands.

www.vlcphotonics.com
www.civiquantum.eu
www.hhi.fraunhofer.de

AegiQ secures £1.4m UK funding to develop III–V-based quantum photonics

Sheffield spin-off joins pilot project for secure quantum communications

UK-based quantum photonics start-up AegiQ has secured £1.4m in funding from Government agency Innovate UK (which provides funding and support for business innovation as part of UK Research and Innovation) to develop secure quantum communications for fiber-optic and satellite-based applications. AegiQ will join a global pilot project to provide scalable, high-performing semiconductor technology for next-generation telecoms.

AegiQ has been awarded Innovate UK funding as part of a consortium of companies. It will build communication infrastructure resistant to hacking by new quantum methods. The start-up is also championing the use and development of quantum photonic technologies.

Co-founded by chief executive officer Dr Maksym (Max) Sich, chief technology officer Scott Dufferwiel, Maurice Skolnick and Jon Heffernan, AegiQ is a spin-out from the University of Sheffield and part of the UK government's £70m funding initiative for quantum technology.

AegiQ is developing III-V-based quantum photonics, which is a superior method in terms of reliability and security, and leverages existing industrial processing techniques. The firm, which is part of this year's Creative Destruction Lab's Quantum Stream cohort, has also been named one of the Quantum Computing Hardware Companies Building the Future.

"Existing software-based encryption of telecom networks is vulnerable to quantum attack," says Dufferwiel. "The risks are losing control of our communications and being faced with massively compromised security from quantum hackers. With the rise of quantum computing, standard encryption methods are no longer fit for purpose. A wide range of industries will require these quantum solutions in the near term," he adds.

Quantum cryptography is viewed by the telecoms industry as the key to future-proofing security, by addressing advances in quantum computing that make traditional messaging encryption methods vulnerable to attacks. The UK National Quantum Technologies Programme expects "Quantum technologies to lead to major advances in [...] the finance, defence, aerospace, energy, infrastructure and telecommunications sectors."

"Thousands of AegiQ systems will be required in each data center around the world, as they transition to using quantum technologies for communication and cloud computing," says Sich. "Deploying our scalable technology with mass-production capabilities into initiatives like this project will position the UK as a world-leader in manufacturing quantum communications," he reckons.

AegiQ is currently raising its seed round of investment. The Innovate UK funding will also enable the firm to invest in further R&D and production of its technology, underpinning the technology used in areas such as quantum communications, quantum sensing and information processing.

www.aegiq.com
www.epsrc.ukri.org

Rockley listed among top 10 British tech firms to watch

Rockley Photonics of Pasadena, CA, USA (formed in 2013 to develop a versatile, application-specific silicon photonics platform for optical integration in sensor systems and communications networks) has been listed in The Sunday Times' '10 Tech Ones to Watch' list for 2020, which identifies promising private British tech companies from a cross-section of industries that are well positioned to grow rapidly.

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

Rockley's photonic technology platform was developed with a focus on high-volume manufacture of highly integrated optical/electronic devices for high-performance applications. Exploiting optimized waveguide dimensions, it is said to offer significant benefits over conventional solutions including the production of higher-density optical circuits, the ability to create more complex integration, better manufacturing tolerances, superior power handling, lower loss and higher-efficiency photonic IC interfaces. The firm says that its technology can be adapted to be application specific, while simplifying manufacturing, assembly, test and validation, and optimizing power, size and cost of complex optical systems.

Rockley is now delivering a new class of non-invasive sensor for health-related sensing and monitoring applications. Its technology enables personalized monitoring of a much larger set of physical and chemical biomarkers than those currently available.

Rockley also develops and supplies photonic chipsets for datacoms applications. Integrated photonics eliminate the need for traditional discrete components and deliver lower-cost, highly scalable solutions for data-center connectivity. It increases bandwidth density, delivers lower energy consumption and significantly reduces the issue of heat.

"Our technology is flexible and powerful and drives multiple applications for a wide range of high-growth market sectors, including consumer sensors, healthcare and data communications," says Rickman.

Rockley has raised $165m from investors including Applied Materials, Morningside Technology Ventures and Ahren Innovation Capital. A total of $300m in equity and NRE (non-recurring engineering) funding has been raised to date to support commercialization of its unique technology platform.

www.rockleyphotonics.com
www.fasttrack.co.uk/

Kyoto's KP-H photodiode achieves 40GHz bandwidth

Integrated condenser lens & chip-on-carrier mounting supports 400G

Japan's Kyoto Semiconductor Co Ltd has developed the KP-H KPDEH12L-CC1C lens-integrated chip-on-carrier indium gallium arsenide (InGaAs) high-speed photodiode to support 400Gbps transmission systems that use PAM4 (Pulse Amplitude Modulation 4) both within and between data centers.

Currently, Kyoto has achieved transmission speeds of mainly 100Gbps by bundling 4 lanes of 25Gbps. However, there are growing demands in the market for 400-800Gbps transmission speeds. The Institute of Electrical and Electronics Engineers (IEEE) set the PAM4 standard, which corresponds with 4-bit signal to one modulation. The transmission speed per photodiode reaches 50Gps (= 400Gps/4 lanes/2 (PAM4)). The transmission bandwidth required for the photodiode to achieve this speed is 35–40GHz.

With the introduction of the new photodiode, Kyoto is supporting the increasing speeds and capacity requirements for transmission systems in 5G networks and beyond.

The 0.6mm x 0.48mm x 0.25mm size of the carrier on which the photodiode is mounted, and the width and length of the electrode pattern formed on the surface of the board (with little attenuation at high frequencies), are optimized using electromagnetic simulation. As a result, Kyoto claims that it has achieved an industry-leading 400Gbps and 40GHz as a frequency band with an integrated transimpedance amplifier. The KP-H photodiode has passed Telcordia GR-468-Core qualification (the standard reliability test for communication equipment).

As well as being mounted on a carrier that is optimally designed to achieve high frequency, a condenser lens is integrated on the backside of the KPDEH12L-CC1C photodiode, allowing incoming light to collect in the light absorption area, and making it easy to align the optical fiber with the photodiode. The photodiode chip is mounted on a carrier twice as big as the chip itself.

Mass production of the KP-H KPDEH12L-CC1C photodiode is scheduled to start in November.

www.kyosemi.co.jp

CompoundTek and NTU to co-develop tunable laser source for silicon photonics

Project targets compact footprint, scalability, high yield and low cost

Singapore-based silicon photonic (SiPh) foundry services provider CompoundTek Pte Ltd is working with Singapore's Nanyang Technological University (NTU) on a three-year joint R&D collaboration for 'O, C, L-band Silicon Photonics tuneable Lasers for Communications and Other Emerging Applications'.

A primary objective is to develop a high-performance tunable laser that has a compact footprint and is scalable, high-yield and suited for low-cost manufacturing. By replacing the commonly used array of single-wavelength lasers with a single wavelength-tunable laser, the much-simplified design architecture reduces the complexities of optical wavelength division multiplexing (WDM) systems, and will additionally lower wavelength contention and inventory costs for commercial products, notes CompoundTek.

The SiPh platform today offers scalability, cost-effectiveness and manufacturability of the matured silicon CMOS process. However, one of the key disadvantages of SiPh is the non-availability of a highly efficient silicon laser integrated with SiPh circuits. Hybrid SiPh, integrating SiPh devices with a III–V compound semiconductor optical amplifier (SOA), offers the best of both worlds, enabling low propagation loss and high integration densities while providing efficient optical gain and flexibility for spectral engineering. This integration is one of the key research areas at NTU's The Photonics Institute.

CompoundTek says that the collaboration reinforces its aim to advance R&D to enhance SiPh technology offerings and deliver on the firm's commitment to its technology roadmap. Since its launch in 2017, CompoundTek has more than 20 global commercial customers in over nine countries and over 20 research institutes and universities in various applications such as telecoms, automotive light detection & ranging (LiDAR), datacoms, biosensing/bio-medical, artificial intelligence (AI), quantum computing and smart sensors.

www.eee.ntu.edu.sg
https://compoundtek.com

CompoundTek's wafer edge coupling targets silicon photonics commercialization from Q1/2021

Product test time being reduced by up to 40%

CompoundTek has confirmed its development for a 8"/12" agnostic silicon photonics wafer test hub. Expansion will be centred on addressing two key areas of market demand: wafer-level edge coupling capability and test time reduction for commercial product companies.

Silicon photonic wafer test is currently performed by vertical optical coupling of the light into the device under test (DUT), contrary to the actual end-application where light is coupled horizontally into the device through the coupler at the edge of the die. Creating a mismatch between the wafer test environment and final application often leads to potential gaps in SiPh test coverage, reinforcing the need for real-world-based test scenarios to screen out failures.

CompoundTek's development of the new wafer edge coupling technologies aims to increase the coverage of existing SiPh wafer test by including the detection of fails due to edge couplers.

Due to be offered to key customers from first-quarter 2021, the wafer-level edge coupling capability is being developed alongside expansion efforts of the firm's Test Executive Systems (TES). Representing a key challenge to broader market SiPh adoption, long test time per wafer — varying from 36 hours to as long as 96 hours, depending on the test type needed and coverage — is unlike the well-established CMOS logic product supply chain.

Long test time is attributed to the complex opto-electrical (DC and RF) tests and, without a standardized SiPh wafer test solution capable of balancing test coverage with competitive test time, successful integration of optical components on a chip for SiPh devices is delayed, creating roadblocks to mass-market adoption of SiPh technologies.

CompoundTek says that recent breakthroughs via optimization of its proprietary TES executive can potentially reduce customers' product test time by up to 40%, to as short as 1.5hrs (from 2.5hrs) or 70hrs (from 96hrs). Enabling large volumes of device-performance data necessary to carry a design from concept to qualification and subsequently into production, TES aims to accelerate market adoption of wafer-level SiPh test services.

Going beyond this, and to further improve test time, CompoundTek has also started work on strategies for test parallelism to drive down the cycle time of SiPh wafer test. Estimated to be completed in two years, TES is poised to improve test cycle time by an additional 40%, making it a likely candidate for the first-of-its-kind service that better integrates SiPh value chain and solidify the manufacturing ecosystem, it is reckoned.

Scintil appoints Soitec's R&D director as board observer

InP/Si PIC developer targets 800 & 1600Gb/s prototypes this year

Scintil Photonics of Grenoble, France, a fabless developer of silicon photonic fully integrated circuits (comprising multi-wavelength lasers, waveguides, wavelength filters and photodetectors) has appointed Ionut Radu, director of R&D at engineered substrate manufacturer Soitec of Bernin, near Grenoble, as an observer on its board of directors.

"His presence is a testament to the innovative designs underpinning our silicon photonic integrated circuits, which we are developing at an industrial level," says Pascal Langlois, chairman of Scintil's board.

Soitec will be the first industrial company represented on Scintil's board, which comprises eight members.

Scintil says that it gained Soitec's support due to the unique design approach of its photonic integrated circuits (PICs) for high-speed optical communications applications, particularly for data-centers, where improving efficiency is a major challenge.

Soitec's role at Scintil is part of its long-term strategy to be actively engaged in providing material solutions for photonics markets and supporting startups through its involvement in venture capital funds, such as Innovacom, a Scintil shareholder. Soitec is therefore an indirect investor in Scintil.

"Scintil has unique solutions for developing high-speed optical communications photonic ICs, which also hold great promise in bringing advantages to 3D sensing and quantum photonics applications," comments Thomas Piliszczuk, executive VP of global strategy at Soitec.

Enabling the integration of all the features needed to develop a fully integrated photonic IC, Scintil's photonic platform is claimed to be the first in the market to provide optical communication applications with smaller, cost-effective, scalable and mass-producible PIC solutions.

Currently, 71.5% of data transmission occurs over short distances and inside data centers. Higher bit rates, reduced power consumption and cost are critical factors in meeting the growing traffic demand. Scintil says that its technology addresses these challenges with optical engines that are photonic fully integrated circuits, combining the high-end of silicon and indium phosphide (InP) photonic through wafer-scale bonding of InP on Si. It uses a commercial silicon photonic foundry to fabricate its PICs.

"Soitec brings to Scintil deep technological expertise, vision and global market experience," comments Scintil's president & chief technology officer Sylvie Menezo.

"Scintil's disruptive PIC technology is key to improving the energy efficiency of data-center transceivers and sensors," says Radu. "We at Soitec look forward to supporting the management team in its drive to bring these products to market within the next few years."

Scintil has teams based in Grenoble, France, and Toronto, Canada. In 2019, it raised €4m ($4.4m) from private funds, and an additional €4m in national grants and bank loans. The firm recently reached an agreement with a commercial foundry for prototyping and volume production. It is targeting a set of prototypes this year (800Gb/s and 1600Gb/s) for entry into the market at the end of 2022.

www.scintil-photonics.com

AMF and DenseLight sign MoU to co-develop SiPho optical engine with integrated InP lasers

InP lasers to be integrated via PDKs for customer PIC designs

Commercial pure-play silicon specialty foundry Advanced Micro Foundry Pte Ltd (AMF) — a spin-off of the Institute of Microelectronics (IME), a research institute of Singapore's Agency for Science, Technology and Research (A*STAR) — and Singapore-based DenseLight Semiconductor Pte Ltd, a vertically integrated end-to-end indium phosphide (InP) laser light solutions provider with its own InP metal-organic chemical vapor deposition (MOCVD) technology and wafer fab, have entered into a memorandum of understanding (MoU) to jointly develop silicon photonics solutions with integrated lasers.

The data traffic within data centers is projected to grow rapidly over the next five years due to an economy increasingly relying on online solutions and the deployment of 5G technology, boosting demand for high-speed data-center interconnect. Silicon photonics (SiPho) technology is uniquely placed to support these requirements, and SiPho-based solutions began being deployed to support the transition from 100G to 400G data rates, notes DenseLight. However, silicon photonics chips for these applications require the subsequent attachment of an InP-based external laser light source, and the associated challenges can impact the final optical performance and cost of the interconnects.

AMF and DenseLight say that, by joining forces, they are combining their respective expertise in silicon photonics manufacturing and laser development to develop an integrated 'low loss - low cost' SiPho optical engine with integrated laser light source. Rather than off-the-shelf modules with a limited range of specifications, the companies will focus on the development of laser-on-chip integration solutions that can be applied directly onto customer photonic integrated circuit (PIC) designs. The solutions will then be offered through AMF's pure-play foundry services with DenseLight's matching laser integration as part of the AMF process design kits (PDKs).

It is reckoned that the availability of such made-to-order turnkey silicon photonics optical engine solutions with integrated light sources will contribute to lower assembly costs and shorten development cycle times of transceivers (400G/800G) and fiber sensing products.

"For the first time, two Singapore companies are working together to locally develop unique solutions that will promote the widespread adoption of silicon photonics by the data communication industry and by other emerging technologies," says AMF's president Dr Patrick Lo.

"This MoU creates a unique partnership between two synergistic Singapore-based companies to deliver turnkey SiPho-based solutions to both datacom and fiber sensing customers," says DenseLight's president & CEO Rajan Rajgopal. "Our proprietary DPHI technology enables the integration of InP-based photonics devices to SiPho platforms for efficient light coupling into waveguides."

www.advmf.com
www.denselight.com

POET signs development & supply deal with European optical systems firm for 400G data-center application

Contract includes engineering funding & PO for initial production units

POET Technologies Inc of Toronto, Ontario, Canada — designer and developer of the POET Optical Interposer and photonic integrated circuits (PICs) for the data-center and telecom markets — has signed a development and supply agreement with a "leading European optical systems company with global operations for a 400G data-center application".

The contract includes a nominal amount of non-recurring engineering (NRE) funding to design optical engines based on the POET Optical Interposer for a 400G application, along with a purchase order for initial production units. The design and development stage is expected to extend through March 2021, with production planned for June, consistent with the firm's updated roadmap presented at its shareholder meeting on 26 August. The customer is a provider of optical networking systems for data-center and enterprise applications. However, due to confidentiality, their name and the specifics of the end application cannot be disclosed.

Also, as highlighted at the recent shareholder meeting by CEO Dr Suresh Venkatesan, unprecedented levels of demand are driving massive investments in global internet infrastructure. 400G represents the next generation of optical interconnect solutions for datacoms, now in the initial stages of adoption by cloud data-center operators. POET says that such demand translates directly to fiber and related optical devices, including for optical engines based on the Optical Interposer, a platform that — using wafer-level semiconductor manufacturing techniques and packaging methods — integrates diverse electronic and photonic components into a single chip-scale device at lower cost and higher performance.

"The agreement is further evidence of the expanding customer interest in POET's optical engines and the pace at which our product development is progressing," says president & general manager Vivek Rajgarhia. "Over the next several months, we expect demand from additional customers will increase further as we continue to demonstrate the full capabilities of the Optical Interposer," he adds. "Our platform utilizes a novel approach to integrating key electronic, photonic and optical components into a full transmit and receive optical engine, broadly applicable to data-center and telecommunications products. We look forward to reporting our progress on a regular basis and announcing additional customer engagements and partnerships as we are able."

www.poet-technologies.com

SFP-DD MSA releases updated 4.1 hardware spec

Updated mechanical connector dimensions supersede prior versions

The Small Form Factor Pluggable Double Density (SFP-DD) Multi-Source Agreement (MSA) Group has announced its updated 4.1 hardware specification and drawings for the SFP-DD pluggable interface designed to enable high-speed 100+Gbps high-density networking equipment. The SFP-DD form factor uses 2-lane pluggable modules, is backward compatible with SFP+, and offers improved host-to-module management communication based on a two-wire interface (TWI).

The SFP-DD revision 4.1 hardware specification includes added features to support ResetL, dual-function IntL/TXFaultDD and ePPS. Newly added timing tables will also allow for low-speed signals, soft control and module status. The former chapter 7 Management Interface is now part of chapter 4, Electrical Specification. The updated hardware specification includes port mapping, optical connectors and module color coding moved out of Mechanical and Board Definition chapter 5 and into a new chapter 5. Lastly, TS-1000 Normative Module and Connector performance requirements were added as Appendix A.

New approach enables greater interoperability

Targeting support of optical modules up to 3.5W, the SFP-DD form factor addresses the technical challenges of achieving a double-density interface and ensuring mechanical interoperability for module components produced by different manufacturers while still enabling the use of legacy SFP modules. This updated specification supersedes previous versions and has updated mechanical connector dimensions. Users should note that the connector dimensions specified in the 4.1 supersede all previous versions.

SFP-DD MSA promoters include Alibaba, Broadcom, Cisco, Dell EMC, HPE, Huawei, II-VI Inc, Intel, Juniper Networks, Lumentum, Molex, Nvidia and TE Connectivity. Contributors include Accelink, Amphenol, AOI, Eoptolink, FIT, Fourte, Genesis, Hisense, Infinera, Innolight, Maxim Integrated, Multilane, Nokia, Oclaro, Senko, Source Photonics, US Conec and ZTE.

www.sfp-dd.com

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NeoPhotonics assessing US tightening of Huawei restrictions beyond Q3/2020

Non-Huawei growth expected to drive return to profit by end 2021

NeoPhotonics Corp of San Jose, CA, USA — a vertically integrated designer and manufacturer of silicon photonics and hybrid photonic integrated circuit (PIC)-based lasers, modules and subsystems for high-speed communications — has provided a business update following the updated actions of 17 August by the US Department of Commerce's Bureau of Industry and Security (BIS).

Recent actions by the BIS have increased restrictions on China-based Huawei Technologies and its affiliates on the Entity List related to items produced domestically and abroad that use US technology or software and have imposed new license requirements for items subject to Department of Commerce export control. NeoPhotonics currently targets achieving its third-quarter 2020 outlook provided on 4 August (with shipments to Huawei contributing about $40m of revenue) but, beyond Q3, it is still assessing the full impact of the current BIS restrictions. Given the uncertainty, NeoPhotonics will manage the business without relying on revenue contributions from Huawei.

"Despite the near-term revenue impact resulting from the recent BIS restrictions, demand for our products broadly remains strong, driven by expanding high-speed capacities, hyper-scale data-center interconnects, network edge provisioning for increased cloud service usage and remote working," says chairman & CEO Tim Jenks. "Our highest-speed-over-distance products for 400G-and-above applications continue to gain traction with leading network equipment manufacturers and are expected to represent more than 20% of total revenue in 2020, after only two years in the market. Of note, revenue from customers beyond Huawei is expected to grow 40-50% over the next year, independent of potential customer share shifts. Coupled with the upcoming 400ZR and 400ZR+ high-speed module opportunity, which is expected to begin volume production in second-half 2021, the end market for these products, as defined by high-speed ports, is forecasted to increase at an 80% five-year compounded annual growth rate (CAGR) through 2024," he adds.

"Beyond topline growth, we must also ensure our operations remain aligned with the demand outlook and pursue appropriate expense adjustments and structural actions to mitigate the impact of revenue declines," cautions Jenks. "We are fortunate to have entered this period with both a strong financial position and a management team with a demonstrated track record of taking the necessary actions to navigate uncertain times. Through the continued growth of our existing product lines and the ability to pull operational levers as needed, we feel confident in our ability to return to profitability by the end of 2021 with a greater level of diversity across our customer base," he concludes.

www.neophotonics.com

Emcore launches 1550nm high-power laser module for LiDAR and optical sensing

Custom version adopted by LiDAR system provider for AVs

Emcore Corp of Alhambra, CA, USA — which provides mixed-signal products for the aerospace & defense and broadband communications markets — has launched the Model 1790 1550nm-wavelength high-power laser module for light detection & ranging (LiDAR) and optical sensing applications.

The 1790 laser module was developed for use as a continuous-wavelength (CW) coherent optical source for next-generation frequency-modulation continuous wavelength (FMCW) LiDAR systems. A custom version of the new product has already been adopted by a major provider of LiDAR systems for its anticipated use in autonomous vehicles.

The underlying technology for the Model 1790 has been in development for over three years and was designed to address demanding applications in industrial sensing and measurement. The 1790 achieves extremely narrow linewidths combined with a high-efficiency coupling scheme to enable high optical output power of 18dBm, creating a compact, robust solution for FMCW sensing. Its monolithic design, combined with optimized coupling optics, makes it highly immune to the mode or optical frequency hopping typically found with single-isolator, external-cavity designs. Emcore says that its LiDAR laser technology maintains optical frequency stability over temperature, suppressing false readings caused by the mode or frequency hopping which is typical in conventional designs.

Emcore sees its laser technology for LiDAR and optical sensing supporting a broad array of industrial applications beyond autonomous vehicles, including materials characterization, strain measurement, terahertz spectroscopy, interferometry, position and interference measurement, and other applications. "Our vertical integration allows for different wavelengths to be available for custom applications and form factors, including packaged component or micro-optical subassembly," Gyo Shinozaki, VP & general manager of broadband.

The Model 1790 laser module is DC-coupled with a built-in thermoelectric cooler (TEC), thermistor and monitor photodiode. The device is packaged in a 14-pin, OC-48 pinout compatible hermetic butterfly form factor with double optical isolator mounted on the TEC. It has a wide operating temperature range from –10°C to +65°C and is Telcordia Technologies GR-468 and RoHS compliant.

www.emcore.com

Mitsubishi to ship samples of 1310nm 100Gbps EML CAN for 5G mobile base stations

On 1 October, Mitsubishi Electric Corp of Tokyo, Japan will begin shipping samples of its new 1310nm-wavelength (specifically, 1304.5–1317.5nm) ML770B64 100Gbps EML (electro-absorption modulator laser) CAN for high-speed, large-capacity optical data transmissions in 5G mobile base stations on radio access networks. It joins the existing 25Gbps ML760B54, launched at the 20th China International Optoelectronic Exposition (CIOE 2018) in Shenzhen, China that September.

Mobile communication systems worldwide are being required to handle increasing data communication volume due to the transition from 4G to 5G, the spread of mobile terminals including smartphones and tablets, and the shift of information to the cloud. The expansion of 5G mobile networks will require the transmission of huge volumes of data to/and from base stations in high-speed optical communication networks, which in turn will drive the demand for high-speed, low-power-consumption optical devices. Mitsubishi Electric says that its new 100Gbps EML CAN not only meets these requirements, it also contributes to greater efficiency in manufacturing optical transceivers.

The new ML770B64 achieves what is reckoned to be an industry-leading transmission speed of 100Gbps for an EML device in an industry-standard TO-56 CAN package, due to the broader frequency bandwidths of EML devices and 5.6mm-size packages, as well as and the adoption of 4-level pulse-amplitude modulation (PAM4).

Also, due to the downsized thermo-modules (which convert heat and power to keep EML device temperatures constant), the operating case temperature ranges between –40°C and 95°C. Compared with Mitsubishi Electric's existing FU402REA model for 100Gbps transmission, power consumption of the thermo-modules is therefore reduced by about 60%, to 0.4W (typical, at +95°C). Typically, optical output power is more than +10dBm, and the extinction ratio is more than 5dB.

In addition, simplified fabrication of the bi-directional optical modules improves productivity in the manufacturing of the optical transceivers.

www.mitsubishielectric.com/semiconductors/products/opt

Record 25.9% efficiency for III–V multi-junction solar cells on silicon

Aixtron working with Fraunhofer ISE, Technical University of Ilmenau and Philipps University of Marburg

As part of the funded MehrSi project, the Fraunhofer Institute for Solar Energy Systems ISE of Freiburg, Germany, in cooperation with the Technical University of Ilmenau, the Philipps University of Marburg and deposition equipment maker Aixtron SE of Herzogenrath, Germany, has achieved record efficiency of 25.9% for a multi-junction solar cell grown directly on a silicon substrate. This was done through optimizing the layer structure and technology.

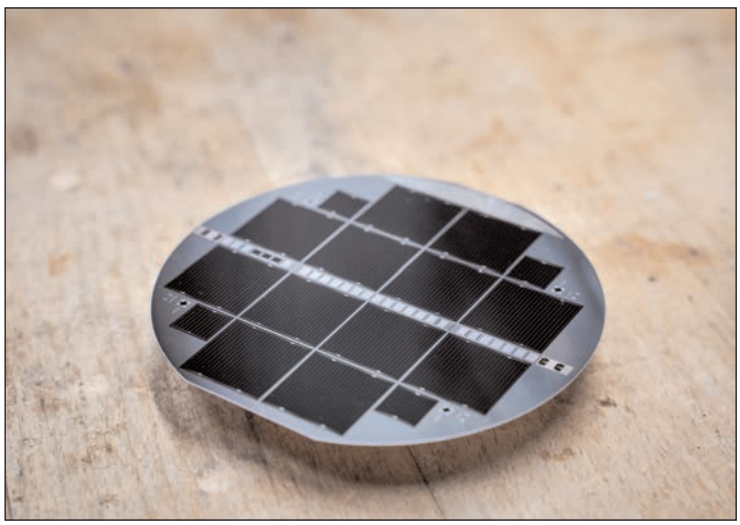
Tandem photovoltaics

"For the first time we have now been able to realize a tandem solar cell based on a silicon wafer with such high efficiency," says Dietmar Schmitz, Aixtron's vice president corporate technology transfer. Until now, the production of III-V multi-junction solar cells has been based on more expensive compound semiconductor substrate material.

"The gallium and phosphorus atoms must occupy the correct lattice positions at the interface with silicon. To achieve this, we have to control the atomic structure very well. This requires exceptionally high precision," notes Schmitz. "In addition, to achieve the necessary high quality of the epiwafers, it is crucial that a high crystal quality of all layers is achieved during epitaxial growth," he adds. "This was achieved in the project thanks to the improved system technology developed by Aixtron and the good cooperation with the project partners."

High cost attractiveness of silicon wafers

In tandem photovoltaics, different combinations of high-performance solar cell materials are arranged in layers on top of each other in order to use the different wavelengths of sunlight more efficiently when converting light into electrical energy. Silicon is suitable for absorbing the infrared portion of the solar spectrum. Layers of different III–V semiconductor compounds, a few microns thick, are then applied to the silicon base to convert the ultraviolet, visible and near-infrared light more efficiently into electricity.



Several III-V tandem solar cells on a 10cm-diameter silicon substrate. (Copyright: Fraunhofer ISE / photo:

The project partners are now working to further increase efficiency and reduce manufacturing costs... Layer deposition is to be realized even faster, with higher throughput and thus more cost-optimization

Due to tandem photovoltaics using a silicon substrate, the multi-junction solar cells are more cost-effective than those based on other substrates.

Work on faster crystal growth to further reduce manufacturing costs

After establishing the technological base, the project partners are now working to further increase efficiency and reduce manufacturing costs. To this end, layer deposition is to be realized even faster, with higher throughput and thus more cost-optimization.

"Specifically, the dislocation density in the III–V solar cell layers is to be reduced from $10^8 cm^{-2}$ to the range of $1–5x10^6 cm^{-2}$ in order to increase the efficiencies to more than 30%," says professor Dr Michael Heuken, VP corporate R&D at Aixtron. "Last but not least, the cost-effectiveness of the epitaxy processes is to be further optimized," he adds.

By means of more cost-effective processes, in combination with silicon as the lowest sub-cell, tandem technology is to be made accessible for broad-based photovoltaics in the future. Aixtron says that it has already been working on such III–V multi-junction solar cells on silicon with several partners for many years.

The project SiTaSol for the joint development of layer packages that can be produced as quickly and cheaply as possible is funded by the European Union (EU). In SiTaSol, Aixtron has built and tested a specially optimized metal-organic vapor phase epitaxy (MOVPE) system in its own laboratory.

SiTaSol is funded by the EU (funding number: 727497) and MehrSi is funded by Germany's Federal Ministry of Education and Research BMBF (funding number: 03SF0525D).

www.ise.fraunhofer.de/en/research-projects/mehrsi.html

www.aixtron.com

US AFRL invests in NREL solar cell project

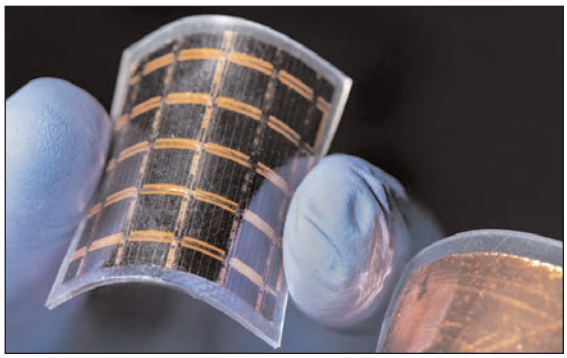
Installation of pilot-production D-HVPE reactor expected next July

The US Air Force Research Laboratory (AFRL) is investing in a technique developed at the National Renewable Energy Laboratory (NREL) to adapt space-based solar technology for terrestrial applications.

As III–V solar cell technology is extremely efficient, it is commonly used to power satellites in Earth's orbit and many of NASA's missions to Mars and other planets. However, it is expensive for terrestrial use. NREL has hence spent the last several years working on a way to make the cells cheaper to manufacture.

The method pioneered at NREL relies on dynamic hydride vapor phase epitaxy (D-HVPE). The earlier version of HVPE used a single chamber where a chemical was deposited, the substrate removed, the chemical swapped out for the next, and the substrate returned to the deposition chamber. D-HVPE uses a multi-chamber reactor, significantly speeding up the process.

"The investment here is specifically to make a pilot-production reactor," says Aaron Ptak, a senior scientist in the National Center for Photovoltaics at NREL. "This will enable us to prove that the D-HVPE technology can be scaled to meet the needs of Department of Defense customers."



NREL has pioneered a method of lower-cost manufacturing for extremely efficient III–V solar cells, such as flexible gallium arsenide solar cells. Photo by Dennis Schroeder, NREL.

Until now, the Department of Energy's Solar Energy Technologies Office and the Advanced Research Projects Agency–Energy have funded NREL's work on D-HVPE.

AFRL serves as the primary scientific R&D center for the United States Air Force. Last year it announced the creation of the Space Solar Power Incremental Demonstrations and Research project, which intends to capture solar energy using highly efficient solar cells and transmit the collected energy to Earth.

Using a laboratory-scale reactor, NREL researchers can make a III–V solar cell measuring 2-inches in diameter. The production-scale reactor will allow the manufacture of industry-standard cells 6-inches in diameter. The larger reactor is expected to be installed at NREL in July 2021.

Kyma Technologies Inc of Raleigh, NC, USA (which provides crystalline nitride materials, crystal growth and fabrication equipment, and devices) will work with NREL researchers to help design the reactor for the D-HVPE system. The firm specifically has expertise in HVPE equipment.

Ceres Technologies Inc (which provides process equipment for the semiconductor and solar industries) of Saugerties, NY, will manufacture the reactor for NREL. The two companies have previously partnered on other projects.

"Bringing Kyma in gives us some extra HVPE knowledge that's really useful here," Ptak says. "It was kind of natural to deal with Kyma because they understood the HVPE process and they already had an existing relationship with Ceres to help build semiconductor equipment to the specs that are required for industry and now for national labs."

www.kymatech.com
www.cerestechnologies.com
www.nrel.gov/solar

AZUR orders 3D-Micromac microPRO XS for processing GaAs solar cells

Laser system to be used for drilling, cutting and marking substrates

3D-Micromac AG of Chemnitz, Germany (which provides laser micromachining and roll-to-roll laser systems for semiconductor, photovoltaic, medical device and electronics applications) has received an order for a microPRO XS laser system from AZUR SPACE Solar Power GmbH of Heilbronn, Germany for processing III–V (GaAs-based) solar cells.

AZUR develops and produces III–V (GaAs-based) multi-junction solar cells for both satellites and terrestrial concentrative photovoltaic (CPV) solar systems. More than 550 satellites have so far been equipped with AZUR cells. To increase the production of such solar cells, AZUR has now ordered a microPRO XS. The main application for this system is laser drilling and laser cutting of germanium, semiconductor and glass substrates. The flexible system will also be used for laser marking.

"During the assessment of different laser systems for our solar cell production, 3D-Micromac's microPRO XS has convinced us with its smart machine concept, in combination with the achievable throughput rates," comments AZUR's CEO Jürgen Heizmann.

www.azurspace.com
https://3d-micromac.com/

First Solar modules for Europe's largest urban PV plant

JPee's 59MW$_{DC}$ facility built on disused landfill

First Solar Inc of Tempe, AZ, USA — which makes thin-film photovoltaic (PV) modules based on cadmium telluride (CdTe) as well as providing engineering, procurement & construction (EPC) services — says that JP Energie Environnement (JPee) is using its Series 6 photovoltaic (PV) solar modules to power the 59MW$_{DC}$ Labarde solar power plant.

Believed to be the largest urban solar PV power plant in Europe, the facility is being built on the site of a former open-air municipal landfill in Bordeaux, South West France. The land was designated as a wasteland, unfit for residential or commercial buildings, or agricultural use. However, JPee secured a 35-year lease for the 600,000m^2 site and began developing the Labarde solar project, which was selected under successive rounds of the PV tenders organized by France's Commission de Régulation De L'Énergie (CRE).

Based in Caen, France, JPee has over 15 years of experience developing, financing, constructing and operating renewable energy assets. The firm operates 263MW$_{DC}$ of wind and solar projects, generating enough energy to power 230,000 average homes, making it one of France's leading independent renewable energy producers.

JP Energie Environnement's 59MW$_{DC}$ Labarde solar power plant.

The Labarde project's role "goes beyond transforming sunlight into solar electricity and supporting France's decarbonization goals, as it helps heal a piece of land that has no other practical use," notes JPee's chairman Xavier Nass. "While solar is inherently sustainable, this project is powered by the lowest-carbon solar technology and sets new benchmarks for sustainability."

With over 1100MWs installed, First Solar's module thin-film technology forms the backbone of France's solar fleet. The firm's modules have been deployed across over 400 projects in France, ranging from large-scale ground-mounted plants to commercial and industrial (C&I) projects.

www.jpee.fr/construction-centrale-photovoltaique-de-labarde
www.firstsolar.com/en/Modules/Series-6

Goldman Sachs Renewable Power acquires 123MW project

First Solar says that Goldman Sachs Renewable Power LLC (GSRP), a private company managed by the Renewable Power Group of Goldman Sachs Asset Management (GSAM), has acquired the 123MW$_{AC}$ American Kings Solar project in a transaction that closed at the end of June.

Located in Kings County, California, the project is backed by a 15-year power purchase agreement (PPA) with Southern California Edison and is scheduled to be commissioned in fourth-quarter 2020.

GSRP partnered with M&T Bank in acquiring the American Kings Solar project. "This is a bankable power plant backed by a long-term PPA, that is responsibly developed, and will generate the lowest carbon electricity possible today," says Greg Roer, vice president, GSAM Renewable Power Group.

The facility will be powered by First Solar's Series 6 photovoltaic (PV) modules, designed and developed at its R&D centers in California and Ohio. With a carbon footprint that is up to six times lower than crystalline silicon PV panels manufactured using conventional, energy-intensive production methods, Series 6 delivers what is claimed to be a superior environmental profile and the lowest carbon solar electricity available today.

"This project will support California's efforts to decarbonize its electricity with technology developed in the state," says Richard Romero, vice president, project finance & treasury, First Solar.

"Partnering with GSRP on its acquisition of the American Kings solar project represents M&T's ongoing commitment to the renewable energy sector," says Eric Heintz, director of Energy Finance at M&T Bank, which will provide the tax equity financing for the project.

Once operational, American Kings will displace 78,000 metric tons of CO_2 annually (equivalent to taking 15,000 cars off the road every year and saving 79 million liters of water annually, based on California averages). The air quality benefits of the project will amount to more than $12m in avoided healthcare costs annually, it is reckoned.

First Solar plant first utility-scale facility to deliver ancillary grid services

Chile's ISO licenses Luz del Norte to supply ancillary services

First Solar Inc of Tempe, AZ, USA — which makes thin-film photovoltaic modules based on cadmium telluride (CdTe) as well as providing engineering, procurement & construction (EPC) services — says that its 141MW$_{AC}$ Luz del Norte photovoltaic (PV) power plant is the first known utility-scale solar facility licensed to deliver ancillary grid services commercially. Chile's independent system operator (ISO) Coordinador Eléctrico Nacional recently added Luz del Norte to its portfolio of large-scale power generators that are approved to deliver a range of grid services, including automatic generation control (AGC).

Located in Copiapó, Chile, the facility is now being used by the ISO to manage the frequency of the country's electricity system, helping to ensure the grid's reliability and stability, in addition to generating renewable energy. This follows an extensive audit, jointly conducted by Coordinador Eléctrico Nacional, Laborelec Latam and First Solar, to evaluate the plant's capabilities. Until now, grid operators around the world had to rely exclusively on thermoelectric or hydroelectric power plants to respond to changes in load by balancing generation.

"This increases the spectrum of technologies capable of providing the services needed to maintain a safe and reliable operation of the electrical system," says Carlos Barria, head of the Forecast and Regulatory Analysis, and Environment and Climate Change at Chile's Ministry of Energy. "These demonstrated capabilities are in line with our plans in integrating higher levels of renewable energy in our grid, which will enable us to achieve our goal to phase out coal-fired power plants by 2040 and to be carbon neutral by 2050."

The Luz del Norte photovoltaic power plant.

Utility-scale solar's grid capabilities were previously proven as part of a 2016 demonstration project by the California Independent Systems Operator (CAISO), the US Department of Energy's National Renewable Energy Laboratory (NREL) and First Solar. The study examined a First Solar-designed power plant's ability to provide AGC, primary frequency control, ramp rate control, and voltage regulation. It found that the PV power plant performed better than fast gas turbine technologies, which are typically used by grid operators to respond to load changes.

The study examined a First Solar-designed power plant's ability to provide AGC, primary frequency control, ramp rate control, and voltage regulation

Significantly, utility-scale PV's ability to provide ancillary services was one of the solutions selected by the Mission Innovation program, for its potential to deliver close to 30 million metric tons of avoided emissions per year. The program, which is a global initiative of 24 countries, including the USA, and the European Commission, is working towards accelerating clean energy innovation.

"Chile's visionary approach to designing its future grid allowed us to take a proven concept and implement a commercially and technically viable solution," says Troy Lauterbach, senior VP, First Solar Energy Services. "As utility companies and ISOs around the world grapple with the challenge of decarbonizing their grids, Luz del Norte has come to represent the realizable potential of large-scale solar," he adds. "By delivering a combination of clean electricity and no-carbon grid services, it demonstrates the value of investing in large-scale solar."

Commissioned in 2016, Luz del Norte is one of the largest PV plants in Chile. Powered by First Solar's proprietary thin-film module technology, developed at its R&D centers in California and Ohio, the facility generates enough electricity to power 50,000 average Chilean homes with the lowest carbon footprint and no water use.

www.firstsolar.com
www.coordinador.cl

CW operation of semi-polar GaN-on-sapphire laser

Researchers claim a "significant breakthrough in substantially reducing the cost of semi-polar laser diodes" for future development and applications.

University of California Santa Barbara (UCSB) in the USA claims the first continuous-wave (CW) electrically driven semi-polar gallium nitride (GaN) blue laser diodes (LDs) at room temperature heteroepitaxially grown on 4-inch sapphire substrate [Haojun Zhang et al, ACS Photonics, vol7, p1662, 2020]. The researchers see their work as "a significant breakthrough in substantially reducing the cost of semi-polar laser diodes and expediting the development of future semi-polar GaN laser diodes and their applications".

The semi-polar GaN crystal orientation enables the growth of indium gallium nitride (InGaN) light-emitting layers with a more efficient recombination of electrons and holes into photons, compared with the conventional charge-polarized c-plane orientation.

Also, the hole mobility in semi-polar materials is higher, improving injection into light-emitting structures. Emissions also tend to be optically polarized — a property that could also be useful for device applications.

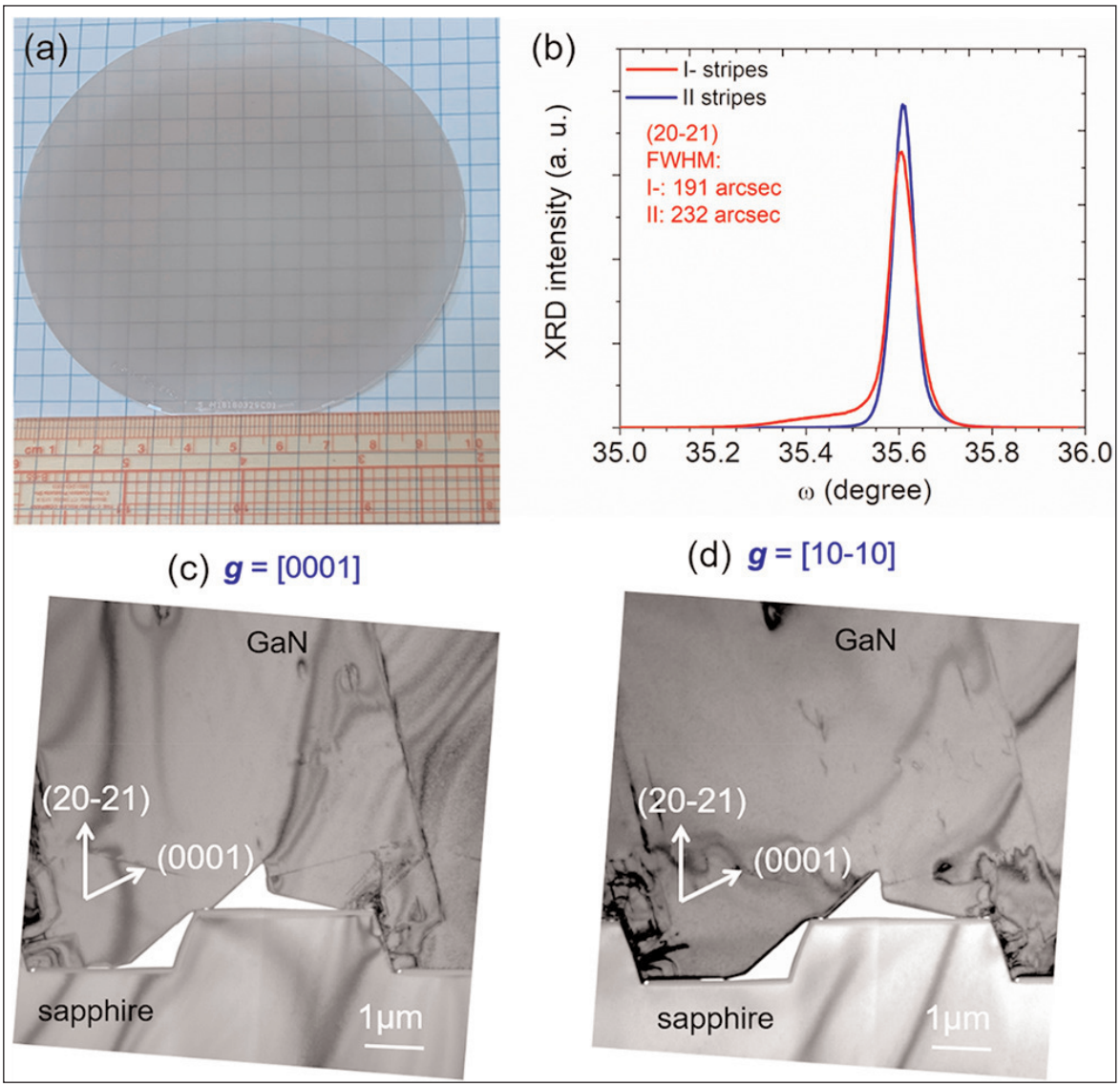


Figure 1. (a) Image of 4-inch (20$\bar{2}$1) GaN on sapphire substrate; (b) x-ray diffraction rocking curves of on-axis (20$\bar{2}$1) plane with axis perpendicular and parallel to patterned stripes; bright-field cross-sectional transmission electron microscope images under two-beam conditions along (c) g = [0001] and (d) g = [10$\bar{1}$0] diffraction vectors with [11$\bar{2}$0] zone axis.

The team sees potential benefits from semi-polar lasers for applications such as LiFi light communications, where very high data rates of 20Gb/s have been demonstrated, beyond the performance of 5G wireless.

Up to now semi-polar light-emitting devices have been realized mainly through homoepitaxy on very

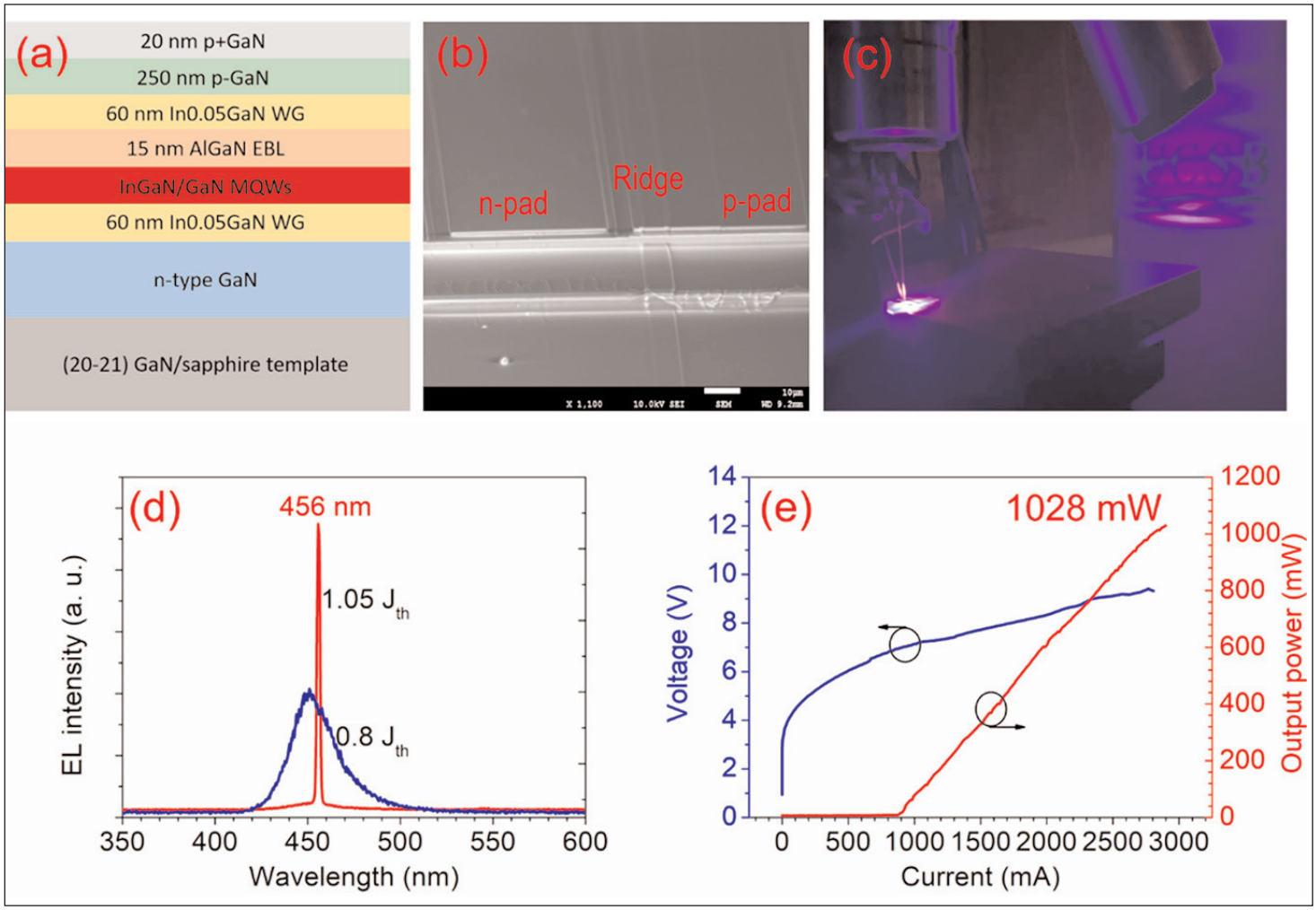


Figure 2. (a) Laser diode structure; (b) scanning electron micrograph of 1800µmx8µm laser diode; (c) electroluminescence (EL) and far-field image of laser diodes above lasing threshold; (d) EL spectra with injection current density of 0.8x and 1.05x threshold; (e) light output power and voltage versus current of 1800µmx8µm laser diode under pulsed operation at room temperature.

expensive freestanding GaN substrates. Heteroepitaxy on sapphire would be much more cost-effective, but semi-polar material on such substrates has previously been of very low quality, making useful devices almost impossible to fabricate.

The semi-polar (20$\bar{2}$1) GaN layers were grown on (22$\bar{4}$3) sapphire substrates using metal-organic chemical vapor deposition (MOCVD). The sapphire was patterned with 6µm trenches to expose the c-plane on the trench sidewalls before the GaN growth (Figure 1). The GaN/sapphire templates were supplied by Yale University spin-out company Saphlux Inc. On the basis of x-ray diffraction and transmission electron microscopy, the UCSB researchers estimate a threading dislocation density of ~1x10^8/cm^3.

The (2021) template surface was planarized using chemical mechanical polishing (CMP). The laser diode structure (Figure 2) used a design without aluminium gallium nitride (AlGaN) cladding layers. AlGaN is slow to grow and has a large lattice mismatch with the rest of the III–nitride structure. There was a thin AlGaN electron-blocking layer (EBL) in the laser diode design.

The epitaxial structure with InGaN multiple quantum well (MQW) active region was also grown by MOCVD. A thin p-GaN cladding component (250+20nm in this case) has been found previously by the UCSB group to enhance laser diode voltage performance and thermal management. The cladding was completed with indium tin (Sn) oxide (ITO), deposited at high temperature and low tin-doping concentration.

Ridge laser diodes were fabricated with silicon dioxide isolation. The 150nm ITO cladding was added by electron-beam evaporation at 650°C of a 90:10%wt In_2O_3/SnO_2 target. The n-type contact was titanium/aluminium/nickel/gold. The p-contact pads were titanium/gold. The devices used chemically assisted ion-beam etched facets.

For testing, the sapphire substrate was thinned to 50µm thickness, from ~650µm. Sapphire is thermally insulating, and thinning the material enables better heat dissipation, reducing self-heating from CW operation. The thinning process was in two steps: first polishing down to 90µm, followed by inductively coupled plasma etching to 50µm.

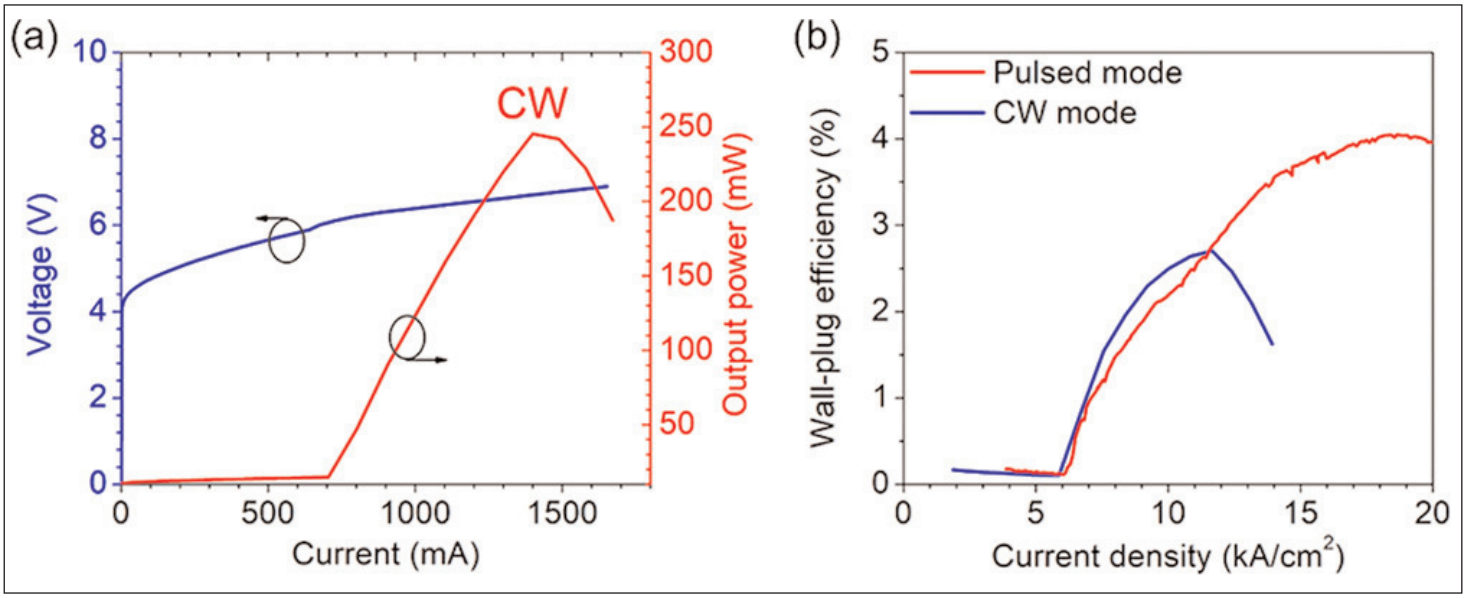


Figure 3. (a) Light output power and voltage versus current density for 1500µmx8µm laser diode under CW operation and (b) WPE performance for pulsed and CW modes.

The test set up found the individual laser bars mounted on a copper block with indium/lead solder. The block was put on an electrically and thermally controlled copper stage.

With 500ns pulse operation at 0.05% duty cycle, the threshold current density for a 1800µmx8µm device was 6kA/cm^2 (880mA).The forward voltage was 6.9V, and the wall-plug efficiency (WPE) reached 4.1% at 1100mA (1.1A).

The maximum light output power (P_0) achieved was 1028mW (1.028W) from a single facet with 2.8A current injection. The team claims this as the "best" performance reported so far for a semi-polar laser diode grown heteroepitaxially on a foreign substrate.

The researchers comment: "The P_0 over 1W of the semi-polar laser diodes grown on a sapphire substrate marks a significant breakthrough in exploring the low-cost and high-performance semi-polar laser diodes."

CW operation was, of course, more challenging (Figure 3). Even so, the achievement of CW lasing constitutes "the world's first report about hetero-epitaxially grown CW semi-polar blue laser diodes on foreign substrates," according to the researchers. The threshold of a smaller 1500µmx8µm laser diodes was 720mA (6kA/cm^2). The WPE peaked at 2.5%. The P_0 value was 243mW at 1.4A injection. The device was operated for an hour under CW conditions without noticeable performance degradation.

The team believes that topside flip-chip bonding to a high thermally conductive substrate such as silicon carbide could significantly improve laser diode performance and WPE under CW operation.

Study of the optical polarization of the emissions showed it to be almost 100% transverse electric (TE), as opposed to transverse magnetic (TM), at 1100mA injection. This was expected behavior. ■

https://dx.doi.org/10.1021/acsphotonics.0c00766

www.saphlux.com

Author: Mike Cooke

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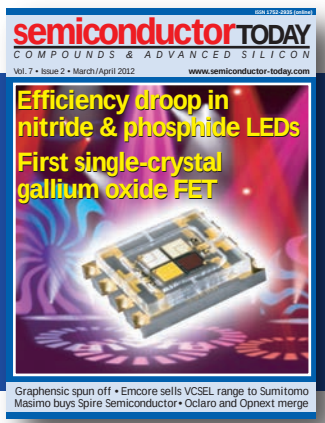

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First claim of nitrogen-polar III–nitride tunnel-junction light-emitting diodes

Light intensity enhanced by 70% over non-tunnel-junction reference, and efficiency by 1.7x, at 20A/cm².

Researchers based in China and Saudi Arabia claim the first demonstration of nitrogen-polar tunnel-junction (TJ) indium gallium nitride (InGaN) light-emitting diodes (LEDs) [Yuantao Zhang et al, ACS Photonics (2020)volume 7, issue 7, p1723]. N-polar tunnel junctions with good performance have previously been reported, but up to now only III-polar III–nitride TJ-LEDs have been achieved, according to the researchers.

The team from Jilin University in Changchun, China, King Abdullah University of Science and Technology (KAUST) in Saudi Arabia, China's Institute of Semiconductors, and Zhengzhou University used polarization-doped aluminium gallium nitride (AlGaN) to enhance the performance of the TJ, giving a higher hole concentration and boosting lateral current spreading from the electrodes.

Despite being the first N-polar TJ-LED report, the researchers admit: "The current density of the tunnel junction in this work is still lower than those of the reported N-polar GaN/InGaN/GaN TJs, which may be caused by the use of Al-rich AlGaN for the tunnel junction, though it could be improved by further optimization."

The team adds: "It is worth mentioning that the proposed tunnel junction in this work can be applied to other spectral ranges, not only UVB and UVC, but also longer-wavelength yellow and red with modifications of material and structural parameters."

(a)

TJ	n-GaN	1080°C	150nm
TJ	$Al_{0.4}Ga_{0.6}N$		5nm
TJ	p-$Al_xGa_{1-x}N$	x graded 0-0.3	75nm
MQW	5x(InGaN/GaN)	775°C/950°C	3nm/14nm
Cladding	n-GaN		500nm
Buffer	u-GaN		2μm
Substrate	c-plane sapphire		

(b)

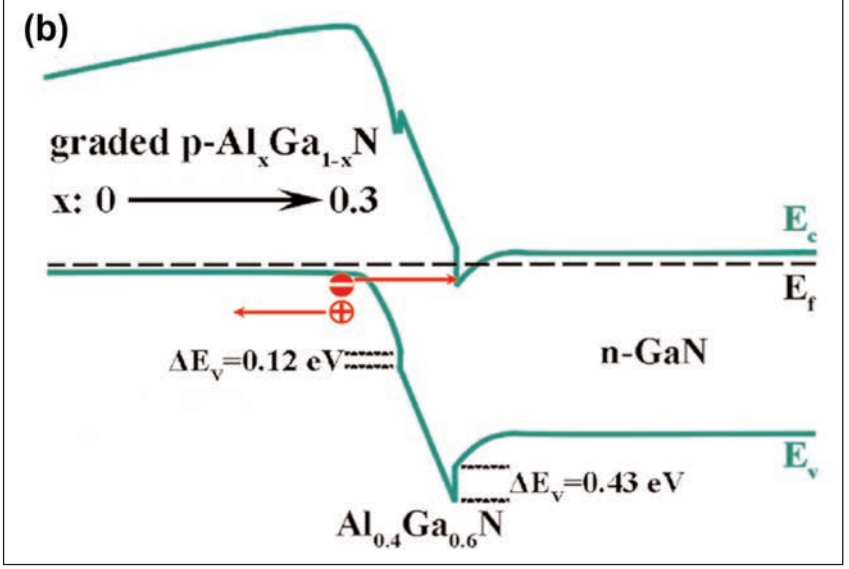


Figure 1. (a) Epitaxial layers of TJ-LED, and (b) sketch of expected energy-band diagram in tunnel-junction region.

The N-polar III–nitride material (Figure 1) was grown by metal-organic vapor phase epitaxy on c-plane sapphire.

The top n-GaN layer of the tunnel junction was optimized using periodic delta-doping with silicon sourced from silane (SiH_4). This avoided the appearance of 'dots' on the surface of the material, as occurred when the silane was supplied continuously. Also, in continuous growth, undulations were seen, attributed to step-bunched growth. Closer study of the dots showed them to be V-pits, which degrade device performance by offering current leakage paths.

The periodic doping was carried out with continuous ammonia (NH_3) flow and alternate bursts of silane and trimethyl-gallium (TMG). Each period was preceded by a 5-second purge without silane or TMG. The

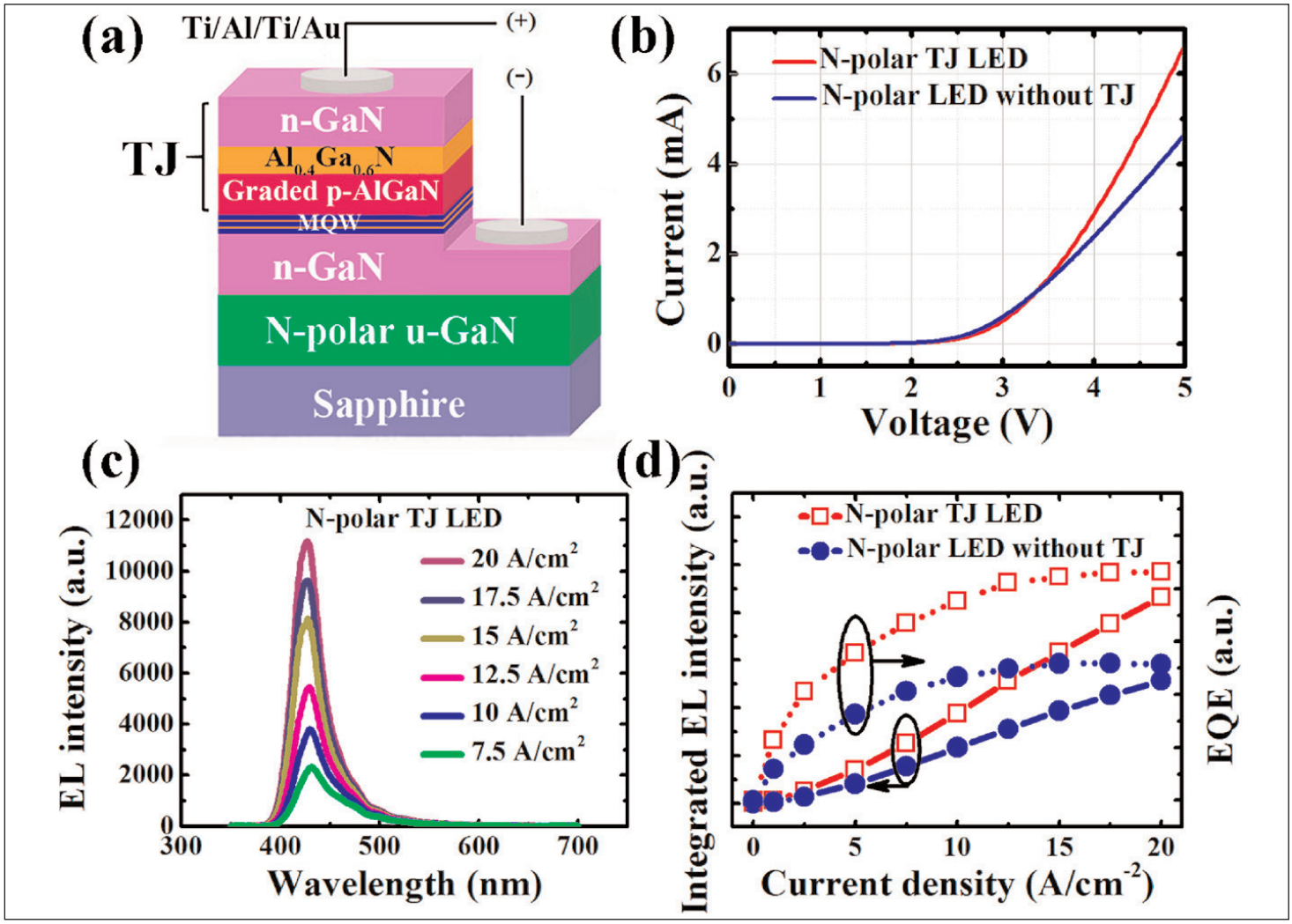


Figure 2. (a) Schematic diagram of TJ LED under electroluminescence (EL) operation. (b) Current–voltage curves of tunnel-junction and reference LEDs. (c) EL spectra of TJ LED under varying current density. (d) Integrated EL intensity and relative EQE of tunnel-junction and reference LEDs versus current density.

researchers describe the resulting material as being effectively a "periodic superlattice comprising unintentionally doped u-GaN and SiN_x layers".

The team comments: "We speculate that the suppressed formation of V-pits may be related to the reduced tensile stress amid the periodic Si-delta doping as compared to the conventional continuous Si doping in N-polar GaN."

The researchers optimized the period thickness and silane flow rate. With 20nm thickness and 16nmol/min flow, the n-GaN layer was found to have an electron concentration and mobility of $2x10^{18}/cm^3$ and $329cm^2/V\text{-}s$, respectively.

The other component of the tunnel junction — the underlying p-AlGaN layer – was kept to a relatively thin 75nm in order to optimize the polarization-doping effect of the graded composition. The magnesium p-type dopant was supplied by bis-cyclopentadienyl magnesium (Cp_2Mg). The hole concentration and mobility were $9x10^{17}/cm^3$ and $7.5cm^2/V\text{-}s$, respectively. A thin $Al_{0.4}Ga_{0.6}N$ interlayer was placed between the p- and n-type layers of the tunnel junction.

The material was fabricated into 250µmx250µm mesa-type LEDs. The contact metal to the n-GaN of the tunnel junction and the n-side of the device consisted of titanium/aluminium/titanium/gold. A reference LED, with the top n-GaN layer of the tunnel junction replaced by 3nm p-$Al_{0.3}Ga_{0.7}N$, used a nickel/gold p-contact.

The tunnel junction enabled a higher current for a given forward voltage to be achieved (Figure 2). The turn-on voltage of both devices was about 2.5V. In the linear region, the total resistance was 264Ω with the tunnel junction and 439Ω in the reference device. The peak wavelength of both devices was ~430nm.

In terms of light output, the TJ-LED delivers increasing intensity over the reference above $2A/cm^2$ injection current density. By $20A/cm^2$ injection, the TJ-LED's light output was 70% more intense. The external quantum efficiency (EQE) was also higher — 1.7x at $20A/cm^2$. The researchers attribute the improved performance to the lower total resistance of the TJ-LED. ■

https://dx.doi.org/10.1021/acsphotonics.0c00269

Author: Mike Cooke

Improving MOCVD tunnel junctions for gallium nitride micro-light emitting diodes

Researchers enhance performance with selective-area growth of perforated layers, reducing forward voltage and increasing light output power.

University of California Santa Barbara (UCSB) in the USA claims the lowest forward voltage for gallium nitride (GaN)-based micro-sized light-emitting diodes (μLEDs) with epitaxial tunnel junctions (TJs) grown by metal-organic chemical vapor deposition (MOCVD) [Panpan Li et al, Optics Express, vol28, p18707, 2020]. The voltage was only marginally higher than that achieved with indium-tin oxide (ITO) transparent conductive electrodes.

The UCSB team used a selective-area growth (SAG) technique to create a tunnel junction layer with perforations. The perforated holes in the TJ were used to enable escape of hydrogen during annealing aimed at activating the underlying p-GaN layer of the junction. Hydrogen passivates the magnesium acceptor levels of the p-GaN, inhibiting their ability capture electrons and create holes in the valence band. Although molecular beam epitaxy (MBE) can be used to avoid hydrogen in GaN TJ structures, MOCVD is preferred for manufacturing.

Industry is looking to use μLEDs in a range of applications: "wearable devices, large-area displays, augmented reality (AR) and virtual reality (VR), and high-speed visible light communications (VLC)," are mentioned in the paper. The potential advantages of μLEDs over liquid crystal displays (LCDs) or organic LEDs include ultra-high resolution and lower power consumption.

Hoped for benefits of using TJ structures over conventional p-electrodes include simpler fabrication, improved current spreading, and lower photon absorption. New device architectures could be enabled with direct integration of blue/green/red μLEDs in cascade structures connected with TJs.

The UCSB researchers used standard industry blue indium gallium nitride (InGaN) LED epitaxial wafers grown on patterned sapphire substrate (PSS) with a

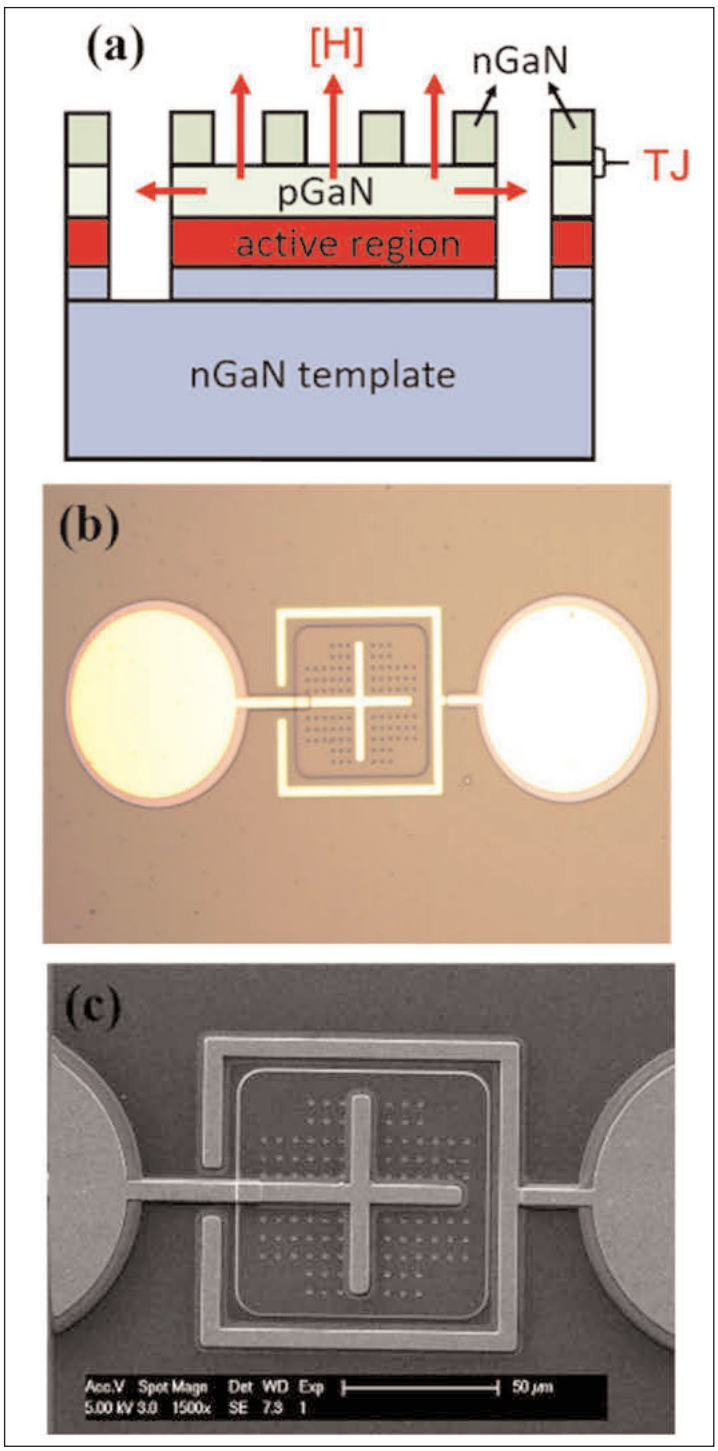


Figure 1. (a) Schematic structure of GaN TJ μLEDs through SAG; (b) microscope and (c) scanning electron microscope images of fabricated 80μmx80μm device.

target emission wavelength around 440nm. Silicon-doped n^+-/n-GaN layers were added selectively to provide the perforated tunnel junction. (Figure 1).

In fact, the MOCVD process was preceded by growth and patterning of silicon dioxide into pillars on the p-GaN surface, which provided sacrificial structures for the hole perforations. The n^+- and n-GaN layers were then grown at 1000°C with target silicon doping concentrations of $1.5x10^{20}/cm^3$ and $3x10^{18}/cm^3$, respectively.

The LED fabrication consisted of mesa etch with silicon tetrafluoride reactive ions, removal of the silicon dioxide pillars using buffered hydrofluoric acid, 700°C annealing in nitrogen to drive out hydrogen from the p-GaN, the formation of an omni-directional reflector from 7-pairs of silicon dioxide and tantalum pentoxide layers, and the deposition of aluminium/nickel/gold for the contacts and metal pads.

Testing was carried out with diced devices mounted on silver headers and encapsulated in silicone. It was found that the emitted radiation was much more uniform across the device, compared with similar reference MOCVD TJ-µLEDs without the perforations of the n^+-/n-GaN layers. In fact, the emissions were greater at the edges of the reference devices, most likely due to the sidewall out-diffusion of hydrogen during annealing.

The electrical performance of the TJ-µLEDs with perforations was also superior, giving much tighter and lower forward voltage for a given injection current density. By contrast, the reference devices showed increased forward voltage for larger areas, indicating the reduced effectiveness of sidewall out-diffusion of hydrogen during annealing in these cases.

The forward voltage for $20A/cm^2$ injection decreased approximately linearly with area in the reference devices: 3.7V at $100µm^2$ and 4.6V at $10000µm^2$. By contrast, the performance of similarly sized perforated TJ-µLEDs at $20A/cm^2$ varied only between 3.24V and 3.31V.

The team points out that the forward voltages in the perforated TJ-µLEDs were only 0.2–0.3V higher than in conventional µLEDs with ITO electrodes on the p-GaN. The researchers comment: "To the best of our knowledge, these forward voltages are the lowest for the GaN LEDs with TJs grown by MOCVD, and comparable to the lowest for GaN LEDs with TJs grown by MBE."

In fact, the perforated TJ-µLEDs showed improved performance over ITO-based devices in terms of light output power at higher injection currents (Figure 2).

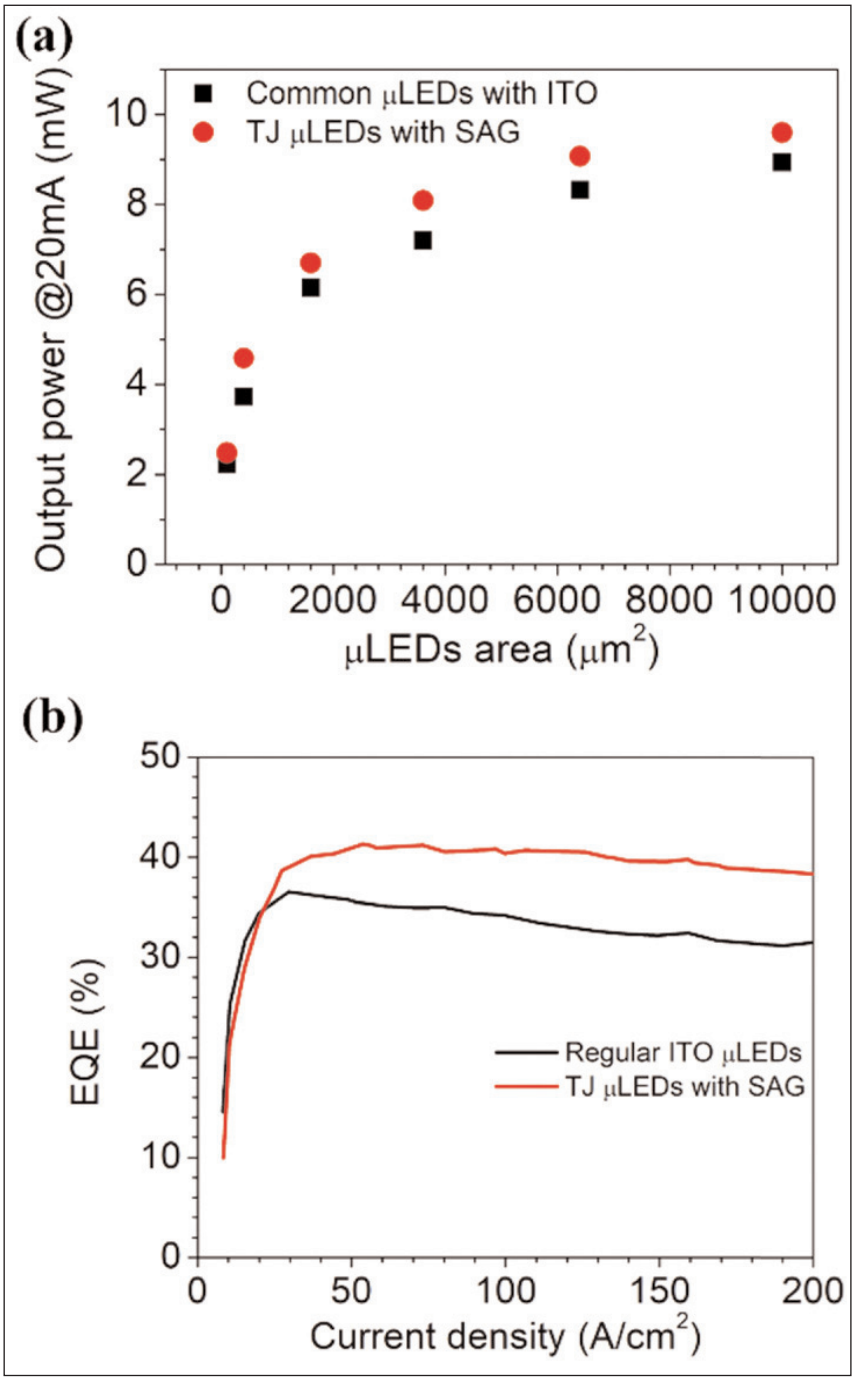


Figure 2. (a) Output power at 20mA versus various sizes in TJ µLEDs with SAG and ITO µLEDs; (b) EQE versus current density for 40µmx40µm devices.

At 20mA, the increase in output power was of the order of 10% at all device sizes.

The external quantum efficiency (EQE) was 40% at $100A/cm^2$ injection for a 40µmx40µm TJ-µLED, compared with 35% for a similar-sized reference device. The researchers credit the improved EQE on improved light extraction of the perforated TJ layer. Further positive factors could be "improved current spreading and reduced light absorption of the TJs", according to the team. ■

https://doi.org/10.1364/OE.394664

Author: Mike Cooke

Wafer-scale micro-LEDs transferred onto adhesive film for planar and flexible displays

A new tape-assisted laser lift-off transfer technique is targeting fast assembly of micro-LEDs with high yield and placement accuracy.

Researchers at the Guangdong Institute of Semiconductor Industrial Technology (GISIT), the University of Tokyo, and Foshan Debao Display Technology Co Ltd have recently developed a tape-assisted laser lift-off transfer (TALT) technique, addressing the industry's problems of massive chip transfer and heterogeneous integration of micro-LED for high-resolution display purposes [Zhangxu Pan et al, 'Wafer-Scale Micro-LEDs Transferred onto an Adhesive Film for Planar and Flexible Displays', Advanced Material Technology, https://doi.org/10.1002/admt.202000549].

Recognized as a next-generation display technology in the display industry, micro-LEDs have many advantages such as higher brightness, lower power consumption, longer lifetime, higher resolution and faster response speed compared with conventional liquid crystal display (LCD) and organic light-emitting diode (OLED) display technologies. They are therefore expected to have very good application prospects in wearable electronic devices, outdoor displays and augmented reality/virtual reality (AR/VR) head-mounted displays.

However, the volume production of high-resolution micro-LED display devices currently faces many challenges. Among them, how to quickly and accurately transfer and integrate millions of micro-LED chips onto the drive circuit is a major hurdle to be overcome. Although a variety of transfer technologies for micro-LEDs have been proposed, there is still ample room for improvement in their transfer speed and placement accuracy. In addition, most of these transfer technologies are focused on the optimization of the chip transfer technology itself, but less attention is paid to their compatibility with subsequent bonding processes.

The joint teams have exploited the merits of both laser lift-off and tape transfer to fabricate wafer-level thin-film micro-LEDs. The novel TALT technique for fabricating thin-film micro-LEDs transferred to a temporary adhesive substrate is shown in Figure 1. An adhesive tape is laminated onto the micro-LED arrays on a sapphire substrate [Figure 1(a)]. The sapphire substrate is then taken off by laser lift-off (LLO). As a result, wafer-scale micro-LED arrays are then released to the first adhesive tape [Figure 1(b)]. Before flip-chip

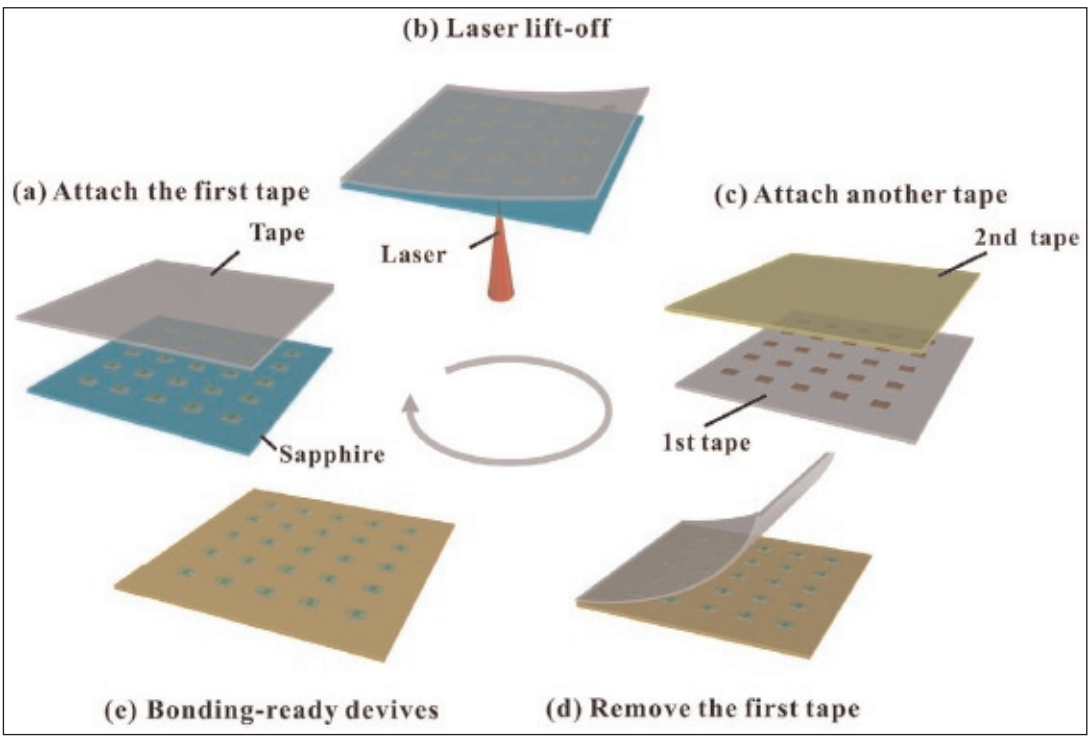


Figure 1. Working procedure of TALT technique for wafer-level micro-LED transfer.

bonding to a driver board, micro-LEDs must be turned upside down. This is achieved by attaching another tape with stronger adhesion to the full LED arrays on the first tape [Figure 1(c)]. Because of the stronger adhesion, micro-LEDs can be released to the second tape. This is achieved by simply peeling away the first tape [Figure 1(d)]. Now, transferrable thin-film micro-LEDs, which are particularly suited to flip-chip bonding, are ready [Figure 1(e)].

The resulting wafer-level μLED thin film is shown in Figure 2. The results in Figures 2(a) and (b) clearly show that a very high yield of μLED lift off (up to 99.9%) can be achieved under optimized LLO conditions. Both the optical and electrical tests suggest that the device before transfer and after transfer shows minimal degraded device performance [Figures 2(c) and (d)]. The researchers believe that this method has the potential for wafer-scale production, and can even be scaled up to larger-size wafers.

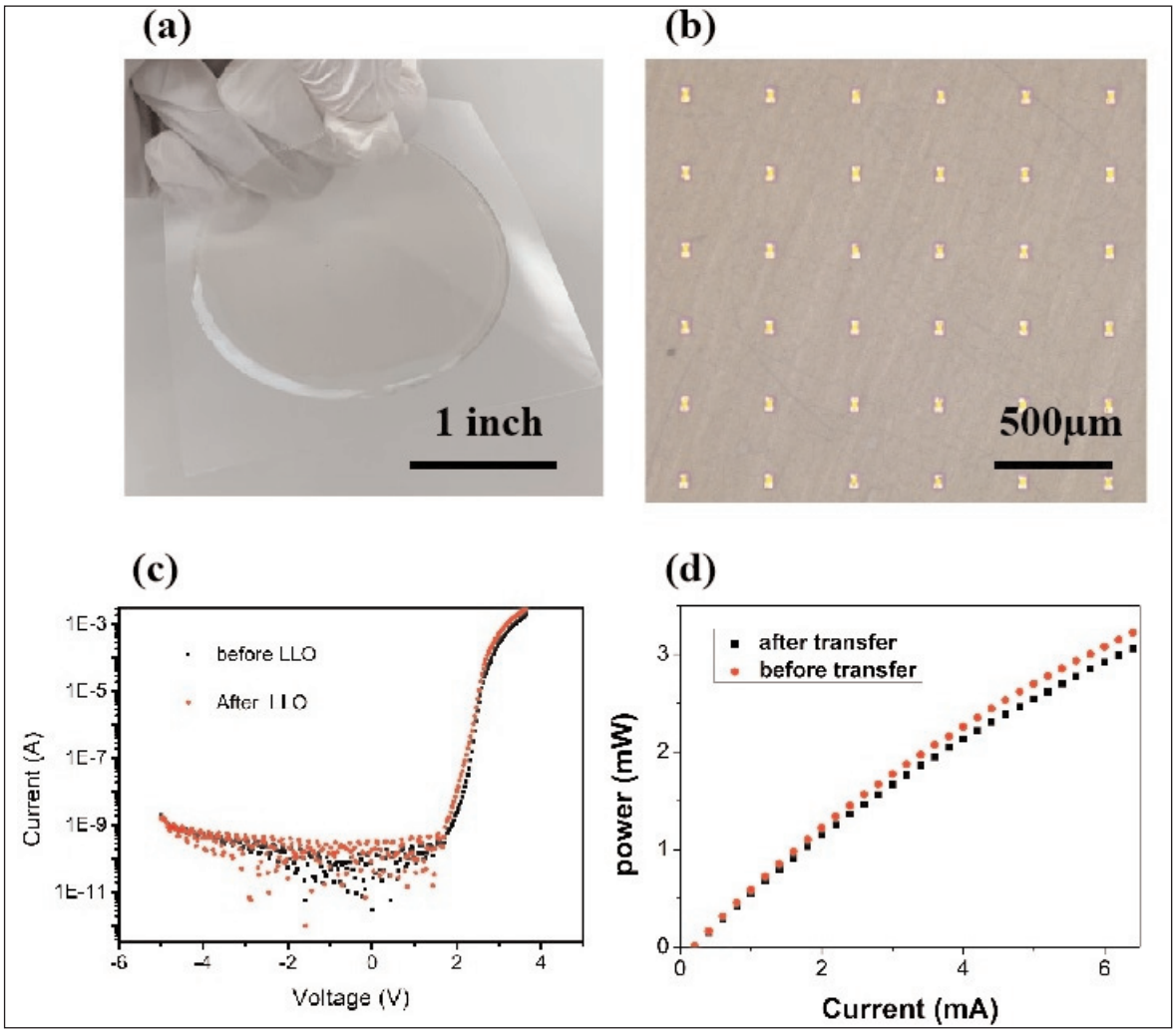


Figure 2. Wafer-level μLEDs transferred to adhesive tape; electrical & optical performance.

The researchers also particularly emphasize that the TALT technology is suitable not only for wafer-level transfer of micro-LEDs but also for flip-chip bonding for good electrical connection. Indeed, the researchers have further demonstrated both rigid and flexible micro-LED prototypes with convincing device performances, based on the TALT technique and the bump-less bonding process that the same joint team has developed. Representative flexible micro-LED devices are shown in Figure 3.

The researchers reckon that this technique paves the way for fast assembly of micro-LEDs with high yield and excellent placement accuracy. The method is also promising for fabricating high-resolution micro-display devices for potential applications in areas such as VR/AR headsets, wearables and mini-projectors. ■

https://onlinelibrary.wiley.com/doi/10.1002/admt.202000549

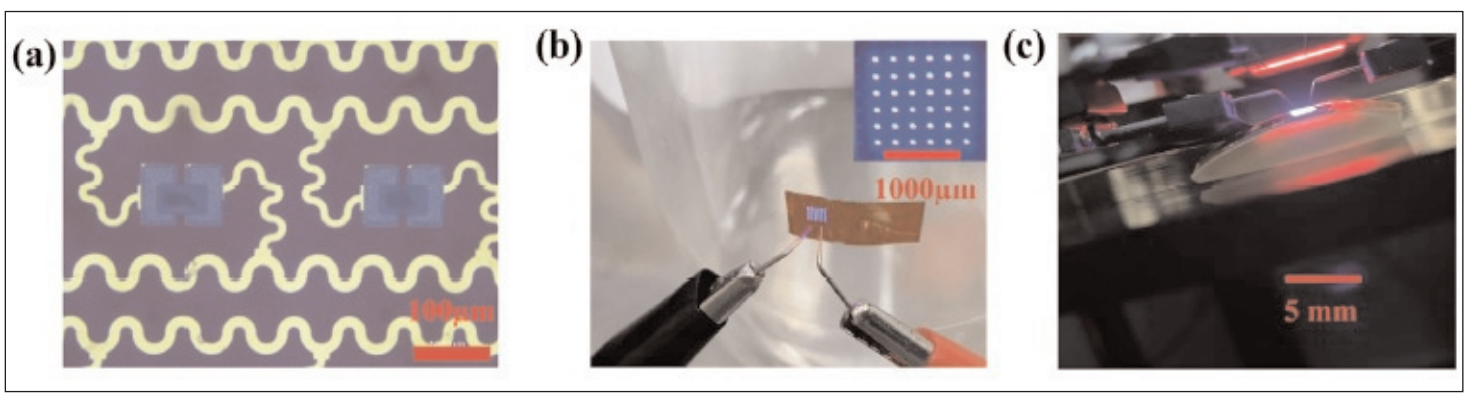


Figure 3. Flexible micro-LED display prototypes.

Aledia benefits from strong patent portfolio in GaN-on-Si nanowire LEDs

CEA-Leti spin-off Aledia is building its first manufacturing facility to address the display market, outlines Knowmade.

Aledia S.A. of Sophia Antipolis, France was spun off from Grenoble-based micro/nanotechnology R&D center CEA-Leti in 2011 to develop a disruptive 3D LED technology based on the standard 200mm silicon platform, which would shrink the cost per chip in comparison with the conventional 2D LED technology.

Now, to address a market estimated to be worth about $120m related to displays for computers, tablets, smartphones and augmented reality (AR) glasses, earlier this year the startup announced plans to build a first manufacturing facility in the Grenoble area. Aledia plans to enter mass production of micro-displays by 2022.

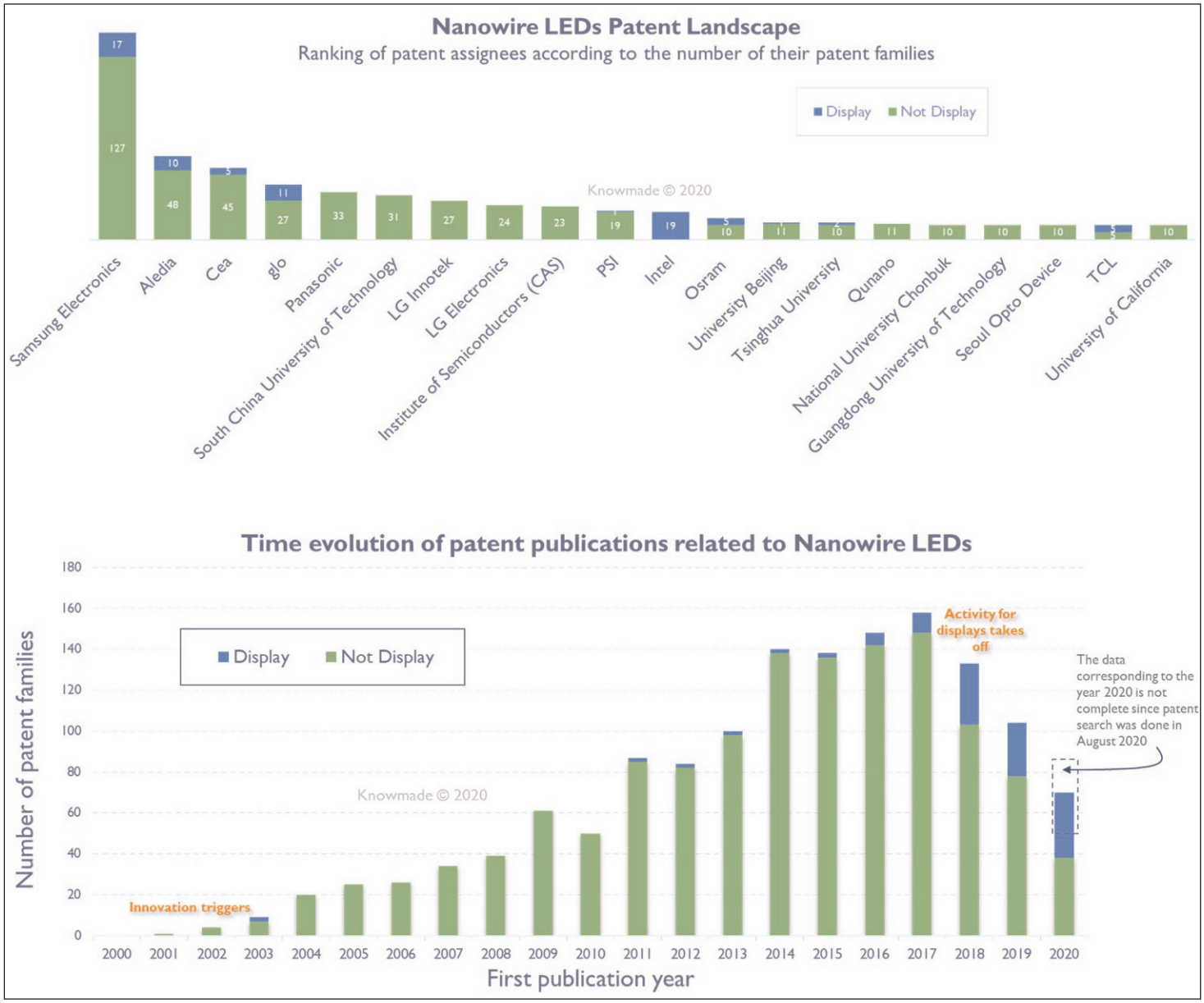
Jointly with Cea-Leti, Aledia has developed the fabrication of 3D LEDs based on GaN nanowires grown on large-area silicon substrates, leading to the filing of more than 100 patent families (single inventions filed in multiple countries) since 2012, grouping more than 440 patents and pending patent applications worldwide. "Interestingly, more than 180 patent applications have already been granted, putting the emphasis on Europe (90+ patents) and the USA (50+ patents), although a significant number of patents were also granted in Asia (China: 19, Japan: 10, South Korea: 4 and Taiwan: 4)," notes Remi Comyn PhD, technology & patent analyst Compound Semiconductors and Electronics at IP strategy consulting company Knowmade. "Importantly, 29 patent families have not got a granted member yet; mostly inventions filed in the last three years and related to display applications (21)," he adds.

As of September, Aledia owns 58 patent families focused on nanowire LEDs (see Figure, top). The startup first considered residential lighting and automotive lighting as the most promising markets for its technology, explaining the presence of companies such as Ikea and Valeo among its investors. However, it eventually decided to target display applications, which translated into more than 40 additional patent families related to displays in Aledia's portfolio, with more than 30 patent applications filed in the last three years.
In the nanowire LED patent landscape, several players such as Samsung and glo are following a similar trend. As a result, patenting activity related to nanowire-based micro-displays took off in 2016/2017 and is expected to accelerate in 2020/2021 as more players race towards micro-LED commercialization (Figure, bottom).

Another component of Aledia's strategic move towards display applications is that Intel joined the rank of investors in 2018. At the same time, the US company was identified by Knowmade as a new entrant in the nanowire LED patent landscape, with a relatively similar approach to Aledia and a strong focus on micro-LED displays (Figure, top). "Intel is developing manufacturing approaches for micro-LED structures and displays based on the assembly of nanowires, including GaN nanowires, on silicon substrates," says Comyn. Indeed, Knowmade has identified 19 inventions from Intel in the nanowire LED patent landscape, mostly filed in the USA. As of September, 5 US patents have already been granted to Intel.

In 2020, Knowmade investigated the GaN-on-silicon patent landscape, in which Aledia owns 30 patent families. "Aledia's inventions included in the GaN-on-silicon patent landscape are mainly related to the growth of

The startup first considered residential lighting and automotive lighting as the most promising markets for its technology, explaining the presence of companies such as Ikea and Valeo among its investors. However, it eventually decided to target display applications, which translated into more than 40 additional patent families related to displays in Aledia's portfolio, with more than 30 patent applications filed in the last three years. In the nanowire LED patent landscape, several players such as Samsung and glo are following a similar trend



(top) Aledia's main competitors in the nanowire LED patent landscape. (bottom) Timeline of publications in the nanowire LED patent landscape.

the nanowire emitters in large quantities with a high degree of precision and control," says Comyn. Additional inventions concern the fabrication of electrical contacts on GaN nanostructures (US9991342, US10340138), and device manufacturing issues (e.g. dry etching US20190172970), the removal of defective nanowires (US9299882), the monolithic integration of LEDs with devices such as transistors to control the nanowire LEDs (US10050080) or to detect the LED temperature (US20160197064). In addition, more and more display-related inventions have been identified in GaN-on-silicon lately (e.g. US10734442).

Furthermore, Aledia can rely on additional patents from its R&D partner CEA-Leti, which is well established in nanowire LEDs and GaN-on-Si for optoelectronics. The institute owns 50 patent families related to nanowire LEDs with more than 170 patents granted in the US (40+), Europe (30+), China (15) and Japan (15). Interestingly, at least five inventions focus on displays (e.g. US8890111). Also, 19 belong to the GaN-on-Si for optoelectronics patent landscape, where CEA is a well-established player (30+ inventions).

Overall, between its own patents and IP agreements with partners, Aledia benefits from a strong patent portfolio of more than 170 patent families to protect the features of its technology in view of commercialization.

In conclusion, major endeavors in R&D over the last three years to improve the nanowire LED technology for displays, together with its global IP strategy, have put Aledia in a good position to face the tough competition in an emerging micro-LED display market, reckons Knowmade. ■

www.aledia.com
www.knowmade.com/downloads/gan-on-silicon-patent-landscape

Transfer printing and self-aligned etching for E-mode GaN transistors

First realization of monolithic Si / III–nitride cascode structure using the technique.

China's Xidian University has claimed the first wafer-scale monolithic realization of normally-off, enhancement-mode (E-mode) cascode field-effect transistors (FETs) constructed from silicon (Si) and gallium nitride (GaN) components assembled through a low-cost transfer printing and self-aligned etching process [Jiaqi Zhang et al, IEEE Transactions on Electron Devices (2020), vol 67, issue 8, p3304].

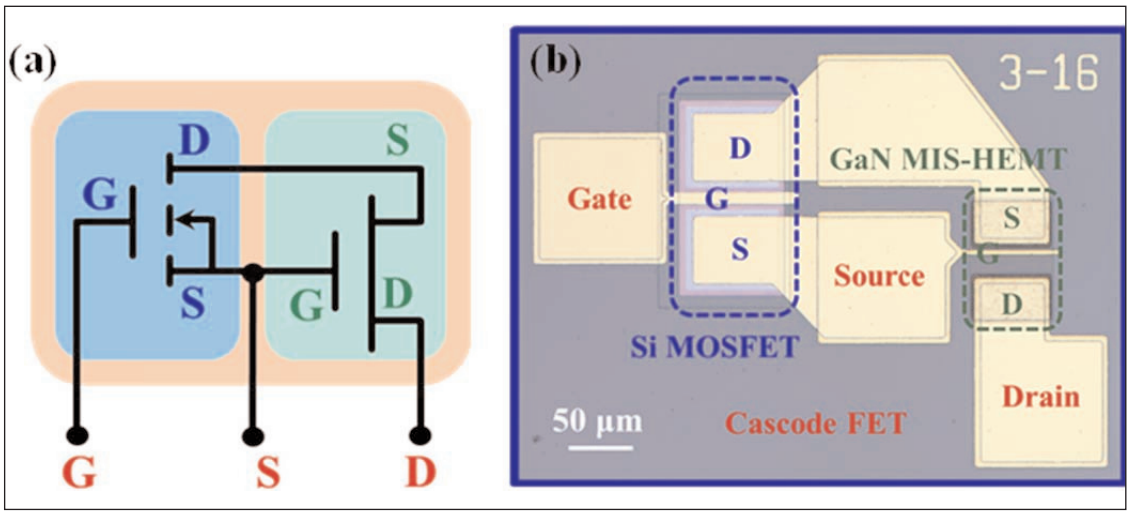


Figure 1. (a) E-mode cascode FET circuit diagram. (b) Optical photograph of fabricated device.

The researchers hope their technique will lead to large-scale integration and wide-spread functional-diversification of devices and circuits combining Si, GaN and other materials. The methodology avoids expensive and complex metal-organic chemical vapor deposition (MOCVD) or wafer bonding steps.

The cascode structure (Figure 1) increases the threshold of the normally-on, depletion-mode (D-mode) GaN high-electron-mobility transistor (HEMT) by connecting it with an E-mode silicon metal-oxide-semiconductor field-effect transistor (MOSFET).

While GaN-based devices have great potential for high-breakdown-voltage power switching, the HEMT structure tends to result in D-mode performance, while normally-off operation is mandated for low power consumption/waste, along with fail-safe behavior.

The source materials for the cascode device (see Figure 2) consisted of silicon-on-insulator (SOI) and silicon nitride/aluminium gallium nitride/GaN/sapphire (SiN/AlGaN/GaN/sapphire) wafers. The III–nitride substrate was 2-inch diameter. The 200nm-thick Si layer was boron-doped at $1x10^{14}/cm^3$ concentration.

The SiN cap layer electrically isolated the Si-based transistor from the underlying AlGaN/GaN material in the final cascode device. The SiN reduced leakage currents by some nine orders of magnitude.

The SOI wafer was used as donor for the Si part of the device. The silicon and silicon dioxide (SiO_2) layers were etched into an array of 155µmx85µm rectangles, which the researchers refer to as 'false inks' (FI). The Si parts were anchored in place by photoresist, before the SiO_2 was dissolved underneath, using buffered oxide etching and hydrofluoric acid.

The 'false ink' rectangles were transferred to the SiN/AlGaN/GaN/sapphire receiver wafer on acetone soluble tape (AST). The tape, as its name suggests, was removed by acetone, followed by ashing. The bond between the silicon and receiver wafer was strengthened by a rapid thermal anneal (RTA) at 500°C in nitrogen for five minutes.

A self-aligned reactive-ion etch (RIE) process was then performed, forming the device mesas, and reducing the bonding Si rectangles to 150µmx80µm rectangles, which the researchers then refer to as the 'true inks' (TI). The reduction in size takes account of the potential for the rectangles to shift around 2µm from the desired position in the AST transfer.

The Si rectangles were fabricated into MOSFETs with phosphorus implanted source/drain regions. The GaN HEMT was formed by exposing the source/drain

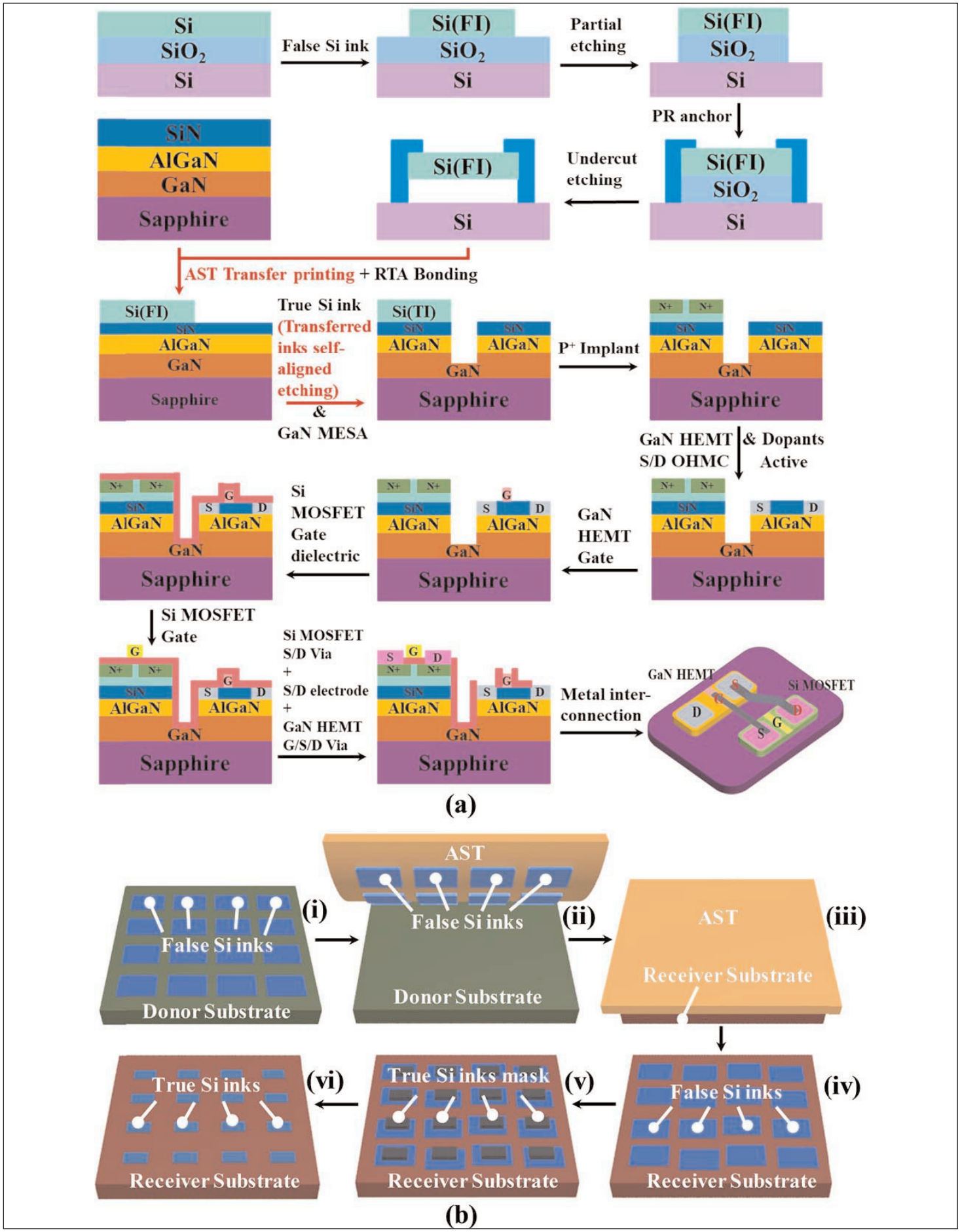


Figure 2. (a) Fabrication process flow of monolithic Si–GaN cascode FET. (b) Key steps of transfer printing and self-aligned etching technology.

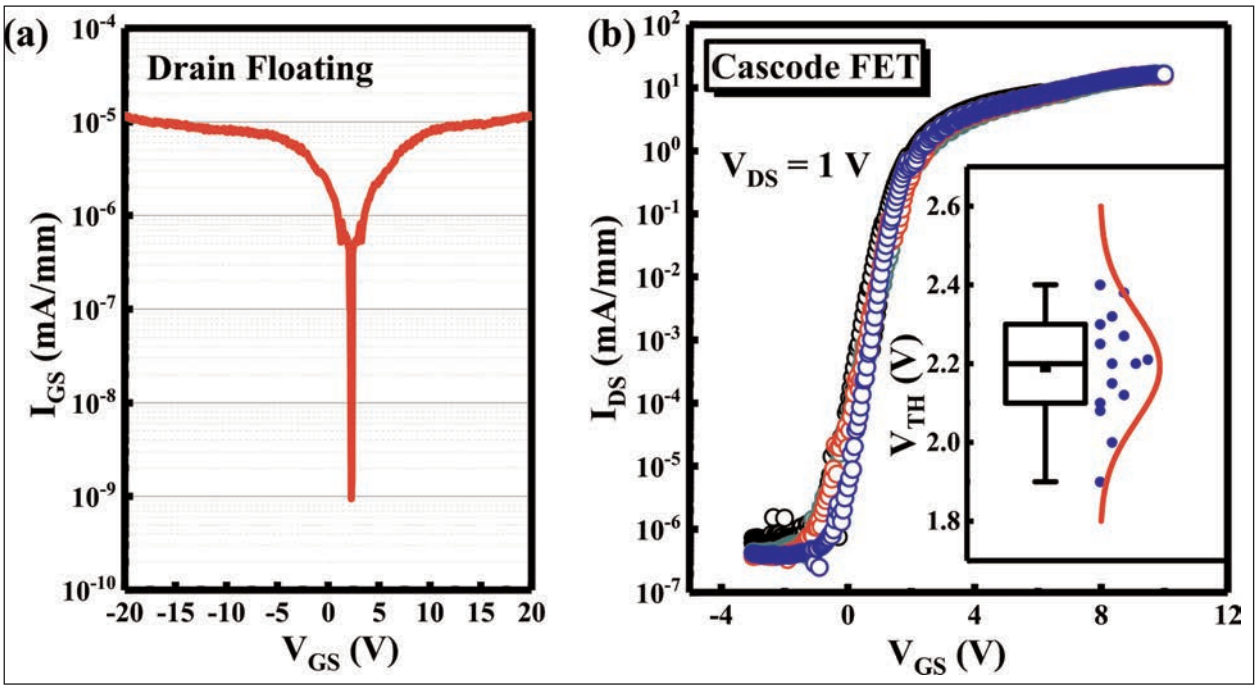


Figure 3. (a) Gate swing graph of E-mode cascode FET with drain electrode floating. (b) Transfer characteristics for series of devices.

regions and depositing and annealing titanium/aluminium/nickel/gold electrodes. The 857°C annealing process also activated the phosphorus doping.

The GaN HEMT gate consisted of nickel/gold. The Si MOSFET gate consisted of atom layer deposition (ALD) aluminium oxide and titanium/gold electrode. The source/drain contacts of the Si MOSFET were created from nickel. Nickel/gold was used for device interconnection.

The researchers have been developing AST transfer techniques for a while. This latest methodology, with a thicker AST than before, has estimated yields for the various steps: 98.25% for transfer efficiency, 93.78% for then achieving rectangles without wrinkles or cracks on the receiver substrate ('yield'), and 96.86% for completely removing the tape ('cleanliness').

The transfer process enabled the researchers to reduce the interconnection distance between the E-mode silicon MOSFET and D-mode GaN HEMT to the order of 100µm. Typically, chip-to-chip connections measure about 2mm. Reducing such distances are key to avoiding parasitic inductances, which introduce instability ringing effects, and increased switching losses that must be tackled in power circuits.

The researchers report: "It is estimated that the parasitic inductance can be reduced by 98.59% in monolithic integrated Si–GaN cascode FETs when compared with the conventional chip-to-chip packaged devices."

The GaN HEMT had a gate threshold of –7.9V for a drain current of 1mA/mm at 1V drain bias. The negative threshold put the operation in the normally-on, depletion-mode category. The on/off current ratio was of the order 10^7. The sub-threshold swing was 96mV/decade. The gate leakage was about 10^{-4}mA/mm. The maximum drain current was 700mA/mm with the drain bias above 8V.

The cascode circuit increased the threshold to +2.1V. The on/off current ratio continued at 10^7. The sub-threshold swing was somewhat negatively impacted, increasing to 141mV/decade. The gate leakage was reduced to around 10^{-5}mA/mm. The maximum drain current was around 90mA/mm. The reduction reflected an increase in on-resistance: 31Ω-mm for the cascode FET, compared with 6.5Ω-mm for the GaN HEMT alone.

The researchers comment: "The ON-resistance or drive current of cascode FET depends on many factors, such as the interconnection distance between Si device and GaN device, the thickness of interconnection metal, the dimension of devices, and the threshold voltage of GaN HEMT. The large ON-resistance of cascode FET can be reduced by optimizing the V_{TH} of D-mode GaN HEMT, matching the dimensions of Si–GaN devices, thickening the metal interconnects, and reducing the distance between Si–GaN devices."

With a gate swing between +18V and –18V, the gate leakage remained below 10^{-5}mA/mm (Figure 3). The researchers say that this swing is greater than for competitor structures such as p-GaN gate GaN HEMTs and recess-gate GaN HEMTs. The researchers also found good uniformity of behavior over a range of separate cascode FETs.

The team found a relatively low off-state breakdown voltage of 40V, which the researchers attribute to the floating body effect of the Si MOSFET on insulating SiN structure. It is thought that the floating body Si MOSFET accumulates holes, negatively impacting the breakdown capability. This effect could be tackled by either grounding the Si MOSFET body, or implanting germanium to create a narrow-gap source region for removing the holes more effectively through recombination. ■

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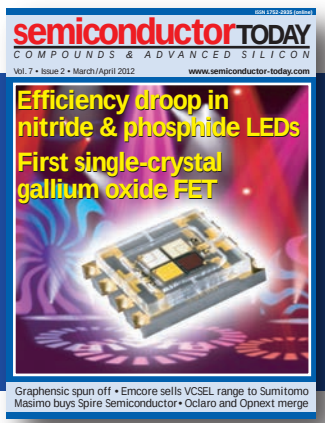

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Improving aluminium nitride nucleation and regrowth on sapphire

Researchers use ultra-high-temperature annealing to boost crystal quality with a view to power switching electronics.

Researchers in China and Taiwan have been seeking ways to improve the growth quality of aluminium nitride (AlN) on sapphire with a view to power electronics applications [Xianfeng Ni et al, IEEE Transactions on Electron Devices, vol 67, issue 10, p3988].

To take advantage of the enhanced critical electrical field of ultra-wide-bandgap AlN, it is vital to reduce potential leakage through crystal defects. Presently, the quality of AlN templates is relatively poor, with threading dislocation densities of the order 10^8–10^{10}/cm^2.

The team from Southeast University Suzhou Campus in China, Suzhou Hanhua Semiconductor Inc in China, and Lextar Electronics Corp in Taiwan used ~1700°C high-temperature annealing after nucleation growth to significantly improve crystal quality of AlN/sapphire templates.

"The demonstrated method paves a way for producing high-quality low-cost AlN templates for use of power electronics production," the researchers write.

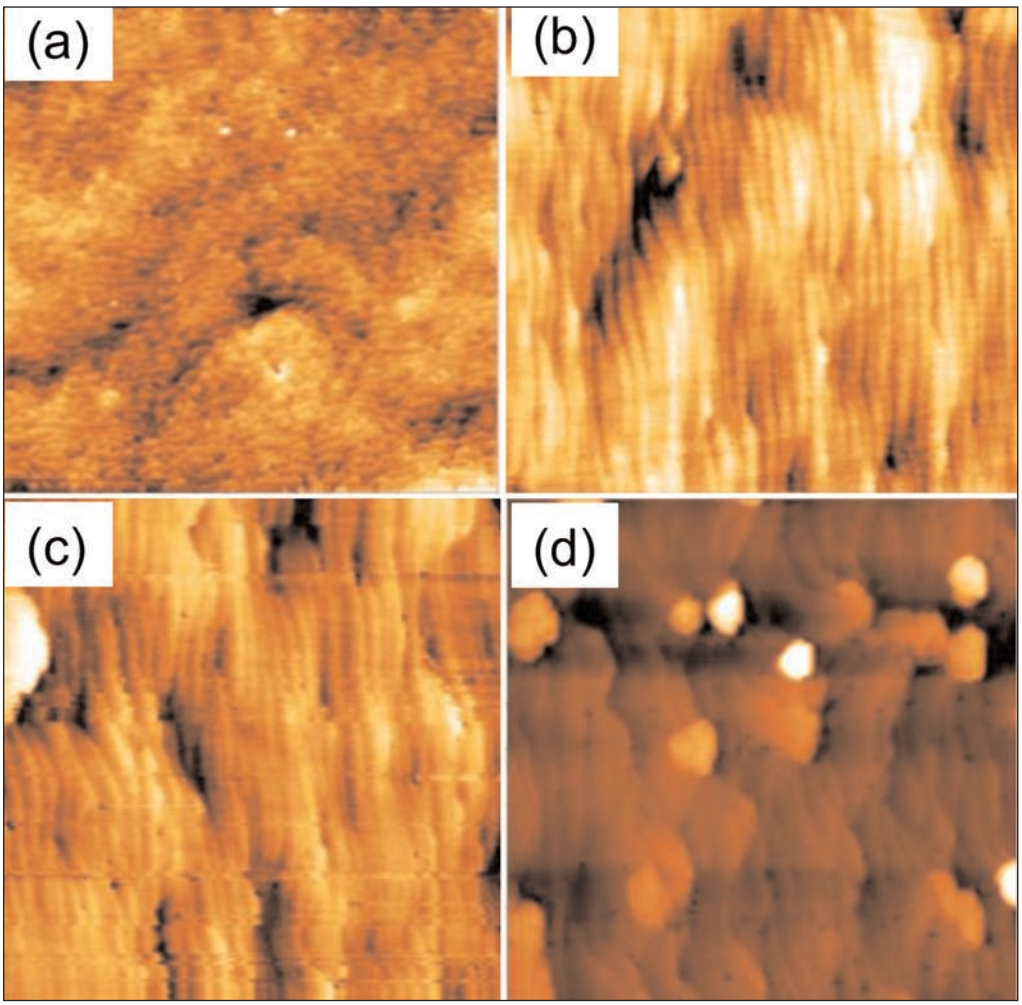

Figure 1. 5μmx5μm AFM images for as-grown (a) and annealed AlN at 1670°C (b), 1700°C (c) and 1730°C (d).

Apart from the high critical field before electrical breakdown, AlN also has a high thermal conductivity, which would enable improved thermal management in power diodes, transistors and more complex integrated circuits.

The high critical field could lead to much faster, more energy-efficient and more compact power switching devices, compared with devices based on silicon, gallium nitride or silicon carbide.

AlN is also an attractive substrate for aluminium gallium nitride structures needed for deep-ultraviolet-emitting devices, with applications such as sterilization and water purification.

The researchers grew 300nm AlN nucleation layers on 2inch-diameter sapphire substrates, using metal-organic chemical vapor deposition (MOCVD). The precursors for the Al and N components were trimethyl-aluminium and ammonia (NH_3), respectively. The samples were loaded into an annealing furnace in

pairs, with the AlN surfaces facing each other. The annealing temperature was variously in the range 1670–1730°C. The treatment was carried out in a nitrogen atmosphere at 500Torr pressure.

The annealing process halved the full-width at half maximum (FWHM) of the (002) x-ray diffraction peak from 130arcsec down to 61.9 arcsec for the 1700°C treatment. The results for 1670° and 1730°C were 64.2arcsec and 62.5arcsec, respectively.

The reduction of the (102) peak was even more dramatic: 1610.5arcsec, as-grown (i.e. without annealing), down to 383.1arcsec, 350.7arcsec and 344.8arcsec for 1670°C, 1700°C and 1730°C annealing, respectively. The (102) peak is seen as being sensitive to mixed or edge-type crystal fault structures such as threading dislocations.

After the annealing, the samples were subjected to further 1200°C AlN regrowth, resulting in 1–2µm layers. The nitrogen/aluminium ratio during the regrowth process was 150, i.e. nitrogen-rich.

The (002) x-ray diffraction peak was increased by regrowth in all the samples. The as-grown sample FWHM for the peak after 2µm regrowth was 174arcsec. By contrast, the (102) peak FWHM tended to decrease with regrowth, most noticeably with the as-grown sample reducing to around 534arcsec. The 1730°C annealing resulted in a (102) peak FWHM of 255arcsec after regrowth.

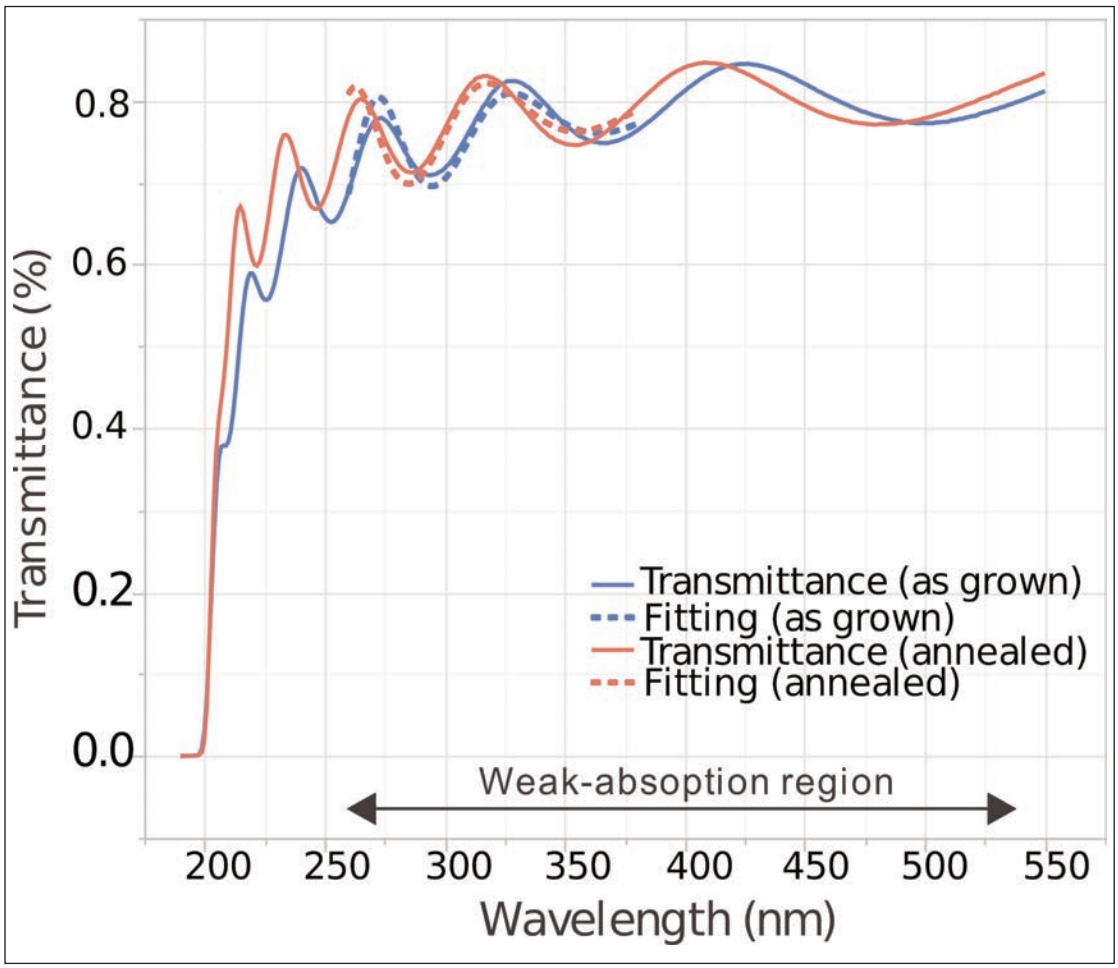

Figure 2. Transmittance data for as-grown and 1700°C annealed AlN nucleation samples.

In the 260–270nm deep-UV portion, the annealed samples demonstrated 3–4% more transmission than the as-grown samples. The team comments: "The slight improvement could be due to the recrystallization of AlN upon annealing, leading to better transmittance.

The demonstrated method paves a way for producing high-quality low-cost AlN templates for use of power electronics production

Surface inspection using atomic force microscopy (AFM) showed the annealed samples having more pronounced atomic steps (Figure 1). Such steps can improve regrowth processes. The root mean square (RMS) roughness values for as-grown and 1670–1730°C annealing were, in order of increasing temperature, 0.74nm, 0.27nm, 0.32nm and 1.4nm.

The transmission of electromagnetic radiation by the samples was measured in the wavelength range 200–550nm, covering from the deep-ultraviolet (UV) and visible light out to the green part of the spectrum (Figure 2).

In the 260–270nm deep-UV portion, the annealed samples demonstrated 3–4% more transmission than the as-grown samples. The team comments: "The slight improvement could be due to the recrystallization of AlN upon annealing, leading to better transmittance."

The undulation of the curves is attributed to interference fringes from the multiple reflections/transmissions of the interfaces in the samples. ■

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Author: Mike Cooke

Gallium nitride & silicon carbide power semiconductor market evolving

Major power semiconductor suppliers are now taking the lead in the GaN and SiC power semiconductor sector following a startup-dominated period, says Omdia.

The emerging market for silicon carbide (SiC) and gallium nitride (GaN) power semiconductors is rapidly evolving from a startup-dominated business to one led by large-established power semiconductor manufacturers, notes Omdia in its 'SiC & GaN Power Semiconductors Report — 2020'.

The transition comes as the market reaches a critical size, with revenue forecast to grow to $854m by the end of 2020 (up from just $571m in 2018) then surpass $1bn in 2021, reckons the firm, energized by demand from hybrid & electric vehicles, power supplies, and photovoltaic (PV) inverters.

"The origins of the SiC and the GaN power semiconductor industry were all about enthusiastic little start-up companies, many of which have now been swallowed up by large, established silicon power semiconductor manufacturers," says Richard Eden, senior principal analyst for power semiconductors.

During 2016–2019 established player Littelfuse acquired SiC start-up Monolith Semiconductor, and then bought established company IXYS Semiconductor. ON Semiconductor merged with Fairchild, which had previously bought Swedish start-up TranSiC, to enter the SiC market. Later, Microchip Corp acquired Microsemi, giving it a range of SiC products. Also, during this period, several manufacturers entered the SiC market, such as ABB Semiconductors, CRRC Times Semiconductors, PanJit International, Toshiba and WeEn Semiconductor.

Early players among the GaN market startups — such as EPC, GaN Systems, Transphorm and VisIC — are still going, with some forming alliances with established silicon power semiconductor manufacturers, such as the linkages between Transphorm and Fujitsu, and GaN Systems and ROHM Semiconductor. One reason why few of the original startups have been acquired by the silicon power semiconductor manufacturers may be the emergence of the foundry service providers perfecting the production of GaN-on-Si epiwafers and devices, establishing a viable fabless GaN manufacturer market.

There have been fewer mergers and acquisitions (M&A) during the last 12 months. Two M&As have occurred in the SiC power semiconductor industry, both concerning SiC wafer suppliers: STMicroelectronics' purchase of Norstel Sweden and SK Siltron's purchase of DuPont's SiC Wafer business (formerly Dow Chemicals). Also, Global Power Technologies Group changed its name to SemiQ in late 2019.

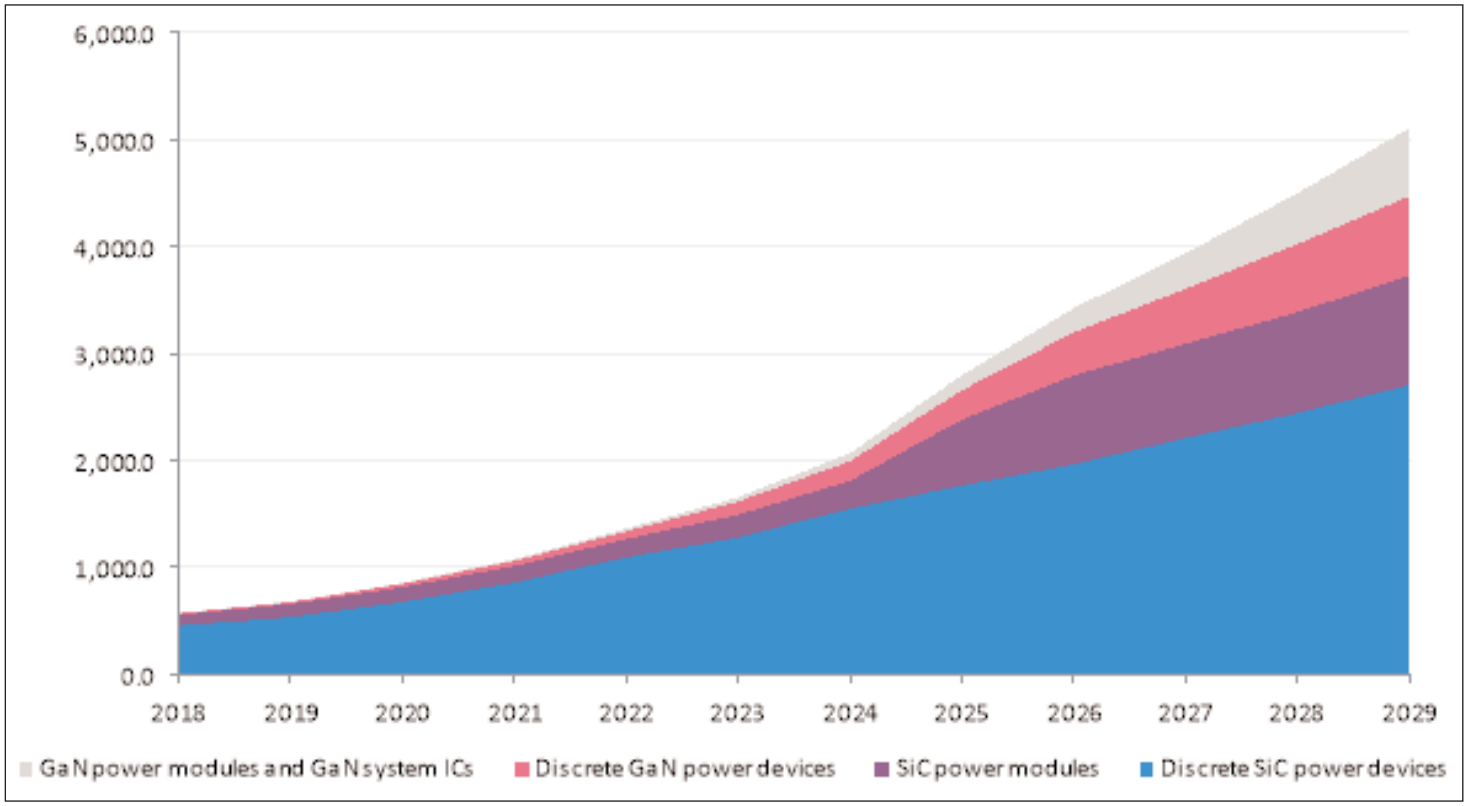
In the GaN power semiconductor industry, STMicroelectronics acquired a majority shareholding in Exagan earlier this year, with the intention of completing a full acquisition at some point in the future. The new entrants into the GaN power semiconductor industry included Power Integrations (which was already in production while in stealth mode), NexGen Power Systems, Odyssey Semiconductor and Tagore Technology.

Infineon Technologies has been joined by Alpha & Omega Semiconductor in offering silicon, SiC and GaN power semiconductors in mass production. ON Semiconductor is very close to joining this exclusive club, as its GaN product development approaches completion. Renesas Electronics, ROHM Semiconductor, STMicroelectronics and Toshiba Electronics are all thought to be joining this exclusive club too.

Substrate wafer market

The SiC substrate wafer supply market is expanding slowly, with many leading players announcing production capacity expansion plans, but wafer prices are not falling fast enough. However, there is not enough competition to the market leader: Cree (Wolfspeed) has announced several long-term supply agreements with device producers such as Infineon Technologies, STMicroelectronics and ON Semiconductor as well as with automotive suppliers like Delphi Technologies, Volkswagen Group and ZF Friedrichshafen AG. As well as its agreement with Cree (Wolfspeed), STMicroelectronics also revealed a long-term supply agreement with SiCrystal (which is owned by ROHM Semiconductor) as well as buying wafer supplier Norstel Sweden outright.

Within the GaN substrate wafer supply market, the biggest surprise of 2019 was that Power Integrations was producing GaN system ICs on GaN-on-sapphire substrates while still in stealth mode. Power Integrations acquired Velox Semiconductor in 2010 and used its GaN-on-sapphire research and know-how to create its 'PowiGaN' technology. Compared with its competitors,



Silicon carbide and gallium nitride power semiconductor market, by technology (in millions of dollars).

the company has taken a different approach by co-packaging GaN switches with silicon driver and protection ICs in its third generation of integrated InnoSwitch devices.

Bulk GaN (or freestanding GaN or GaN-on-GaN) wafers are small and very expensive, but prices are falling as new Chinese suppliers appear, including ETA Research, Sino Nitride and Nanowin. New developers of trench devices on freestanding GaN wafers, like NexGen Power Systems and Odyssey Semiconductor, have appeared, but it will take many years before devices become prevalent, Omdia concludes. ■

https://technology.informa.com/624431/sic-gan-power-semiconductors-report-2020

Smartphone production falls a record 16.7% year-on-year in Q2/2020

A rebound of 17.2% is expected from Q2 to Q3, but 2020 will still be down 11.3% on 2019, reckons TrendForce.

Global smartphone production reached 286 million units in second-quarter 2020, a slight quarter-to-quarter rebound of 2.2% but a record 16.7% decrease year-on-year, according to TrendForce. The COVID-19 pandemic has compelled governments worldwide to impose border closures and regional lockdowns, which led to significant declines in various countries' GDPs this year as economic and social activities around the world have stagnated, notes the market research firm.

Governments in many countries have now started to ease some of the restrictive measures for containing COVID-19 and launched economic stimulus policies to generate consumer demand, TrendForce adds. These developments will be beneficial for the smartphone market's potential rebound going into second-half 2020. Smartphone production in Q3/2020 is expected to amount to 335 million units, down by 10.1% year-on-year but up 17.2% on Q2.

Samsung the only top-six manufacturer to see market share fall; Huawei's share in China may be cannibalized by competitors

In the course of the COVID-19 pandemic since March, the situation has become worse for most countries. By region, the major markets for Samsung smartphones are Europe, the USA and India. Their outbreaks were very severe during Q2/2020, and this affected Samsung more than the other brands in the top six. Samsung led the industry in terms of smartphone production with 55 million units in Q2, but it is also the only top-six brand that posted a quarter-to-quarter decline, approaching 16%. In Q3, as China–US tensions intensify due to the latter's sanctions against Huawei, and China–India relations continue to destabilize, Samsung has been building up its inventories as it targets the entry-level and mid-range segments in order to compensate for its poor performances in the previous quarter. Samsung's production volume is likely to increase in Q3.

Placing second in the production ranking, Huawei, which continues to rely heavily on the Chinese market, raised its smartphone production by 13% quarter-to-quarter to about 52 million units in Q2. Competition in this market is expected to intensify in Q3 as brands release their new flagship models in second-half 2020. Huawei's smartphone sales in overseas markets have been falling sharply since the end of 2019 as the effect of the trade actions by the US government began to take its toll. These measures will make R&D on in-house mobile processors and the sourcing of components much more difficult for this Chinese smartphone brand. Given that Huawei depends on China for smartphone sales, other Chinese brands — including Xiaomi, OPPO and Vivo — are expected to cut into Huawei's market share.

Apple's iPhone production in Q2/2020 rose by 8% quarter-to-quarter to 41 million units due to above-expected sales of the iPhone SE and iPhone 11, giving the brand third place in the ranking. In Q3, demand for the iPhone SE and iPhone 11 is expected to remain strong. At the same time, Apple will begin mass producing the four new models in the (tentatively named) iPhone 12 series, which are equipped with 5G capabilities, raising its quarterly smartphone production. The bill-of-materials (BOM) costs of the iPhone 12 models are significantly higher compared with the models in the previous series because of the 5G support. To cut costs and stabilize retail pricing, Apple is selling the upcoming iPhones without accessories such as wired earphones, power adapter, etc. This is expected to help with sales performance. However, recent orders by the Trump administration barring US businesses from carrying out transactions with TikTok, WeChat and their respective parent companies ByteDance and Tencent may have an impact on Apple's sales performances in the Chinese market going forward, reckons TrendForce.

Xiaomi is fourth in the production ranking for Q2/2020 with 29.5 million units, OPPO (including OPPO, OnePlus, and realme) is fifth with 27.5 million, and Vivo is sixth with 26.5 million. The three Chinese brands benefitted from the recent recovery of their home market. Furthermore, they also took advantage of the precautionary inventory building in the overseas retail channels dur-

ing first-half 2020. Retailers stocked up aggressively during that time in fear of pandemic-related disruptions. They hence all posted a rise of more than 10% quarter-to-quarter for Q2.

Recent border tensions between India and China have placed considerable pressure on the three brands' sales efforts, since they all count on India as one of their major foreign markets. On the other hand, they have been cultivating their presence in the country for a long time. This, combined with their products' price competitiveness, may be enough to get them through this difficult period with their market shares relatively intact, predicts TrendForce. Nevertheless, Chinese smartphone brands will be very constrained in terms of growth if the relationship between their home country and India remains tense.

Xiaomi, OPPO and Vivo will continue to prioritize the entry-level and mid-range segments in their overseas expansion strategies (which include regions such as Europe, India, Southeast Asia and Russia) over the long term. In China, the three brands will capitalize on the Chinese government's push to commercialize 5G services by being more proactive in the development and pricing of 5G smartphones.

Company	2Q20		3Q20E	
	Ranking	Market Share	Ranking	Market Share
Samsung	1	19.2%	1	23.5%
Huawei	2	18.2%	2	14.0%
Apple	3	14.3%	3	13.3%
Xiaomi	4	10.3%	5	11.5%
OPPO	5	9.6%	4	11.8%
Vivo	6	9.3%	6	8.2%
Total Production Volume (Unit: M)		286.1		335.2

Ranking of global top-six smartphone brands by production for Q2/2020.

Rebound in production and sharp rise in 5G penetration expected in 2021

TrendForce forecasts annual smartphone production of 1.24 billion units for 2020, down 11.3% year-on-year. However, assuming that the pandemic can be brought under control in 2021, total smartphone production is likely to rebound next year.

In addition, to maintain their market shares in the face of the recent demand slump, smartphone brands are pushing out 5G models from this year.

Since mobile system-on-chip (SoC) suppliers such as Qualcomm and MediaTek are also starting to provide 5G solutions for mid-range and high-end smartphones, the share of 5G models in total smartphone production is projected to grow rapidly to 19.2% for 2020 (a penetration rate equivalent to about 238 million units). ■

www.trendforce.com

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6 Deposition equipment

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7 Wafer processing materials

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8 Wafer processing equipment

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event calendar

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12–15 October 2020
SCTE-ISBE Cable-Tec Expo 2020
Virtual Experience
E-mail: expo@scte.org
https://expo.scte.org

8–11 November 2020
2020 IEEE BiCMOS and Compound Semiconductor Integrated Circuits and Technology Symposium (BCICTS) — virtual conference
Monterey Marriott, Monterey, CA, USA
E-mail: cs@cshawevent.com
www.bcicts.org

10–13 November 2020
SEMICON Europa 2020
Munich, Germany
E-mail: SEMICONEuropa@semi.org
www.semiconeuropa.org

16–18 November 2020
PCIM (Power Conversion, Intelligent Motion) Asia 2020
Shanghai World Expo Exhibition and Convention Center, Shanghai, China
E-mail: pcimasia@china.messefrankfurt.com
www.pcimasia-expo.com

6–8 December 2020
2020 IEEE 51st Semiconductor Interface Specialists Conference (SISC)
San Diego, CA, USA
E-mail: mpasslack@ieeesisc.org
www.ieeesisc.org

6–10 December 2020
(postponed from 20–24 September)
46th European Conference on Optical Communication (ECOC 2020)
Brussels Expo, Brussels, Belgium
E-mail: info@ecoc2020.org
www.ecoco2020.org

12–16 December 2020
IEEE International Electron Devices Meeting (IEDM 2020) — now a virtual, online event
~~Hilton San Francisco and Towers, San Francisco, CA, USA~~
E-mail: info@ieee-iedm.org
www.ieee-iedm.org

17–19 December 2020
SEMICON Japan 2020
Tokyo Big Sight, Tokyo, Japan
E-mail: semicon@sakurain.co.jp
www.semiconjapan.org/en

10–15 January 2021
(postponed from 13–18 September 2020)
23rd European Microwave Week (EuMW 2020)
Utrecht, The Netherlands
E-mail: eumwreg@itnint.com
www.eumweek.com

14–18 February 2021
IEEE International Solid- State Circuits Conference (ISSCC 2021)
San Francisco, CA, USA
E-mail: Issccinfo@yesevents.com
www.isscc.org

advertisers' index

12–15 March 2021
(postponed from 22–25 July 2020)
International Congress on Advanced Materials Sciences & Engineering (AMSE)
Vienna, Austria
E-mail: eve@istci.org
www.istci.org/amse2021

17–19 March 2021
LASER World of PHOTONICS CHINA 2021
Shanghai, China
E-mail: info@world-of-photonics-china.com
www.world-of-photonics-china.com/en

21–25 March 2021
IEEE Applied Power Electronics Conference and Exposition (APEC 2021)
Phoenix, AZ USA
E-mail: registration@apec-conf.org
www.apec-conf.org

25–27 March 2021
International Conference on Nano Research and Development (ICNRD-2021) — Breakthrough and Innovation in Nano Science and Technology
Grand Copthorne Waterfront Hotel, Singapore
E-mail: laura@icnrd.com
www.istci.org/icnrd2021

28 March – 1 April 2021
Optical Networking and Communication Conference & Exhibition (OFC 2021)
Moscone Center, San Francisco, CA, USA
E-mail: OFC@csreg.zohodesk.com
www.ofcconference.org

15–16 April 2021
EPIC Annual General Meeting 2021
Radisson Blu Hotel Lietuva, Vilnius, Lithuania
E-mail: neringa.norbutaite@epic-assoc.com
www.epic-assoc.com/epic-annual-general-meeting-2020

18–21 April 2021
(postponed from 26–29 April 2020)
2nd International Conference on UV LED Technologies & Applications (ICULTA 2021)
Berlin, Germany
E-mail: contact@iculta.com
www.ICULTA.com

20–22 April 2021
(postponed from 21–23 April 2020)
24th Annual Components for Military & Space Electronics Conference & Exhibition (CMSE 2021)
Four Points by Sheraton (LAX) Los Angeles, CA, USA
E-mail: info@tjgreenllc.com
www.tjgreenllc.com/cmse

9–14 May 2021
2021 Conference on Lasers & Electro-Optics (CLEO)
San Jose Convention Center, San Jose, CA, USA
E-mail: CLEO@compusystems.com
www.cleoconference.org

11–14 May 2021
10th World Congress of Nano S&T 2021
Venetian Macao Resort Hotel, Macao, China
E-mail: esther@bitcongress.com
www.bitcongress.com/nano2021-macao

20–24 June 2021
International Congress on Photonics in Europe — co-located with LASER World of PHOTONICS
ICM – Internationales Congress Center München, Munich, Germany
E-mail: info@photonics-congress.com
www.photonics-congress.com/en

21–24 June 2021
LASER World of PHOTONICS 2021
Messe München, Munich, Germany
E-mail: info@world-of-photonics.com
www.world-of-photonics.com/en

22–24 June 2021 (postponed from 9–11 Feb 2021)
Strategies in Light 2021
Santa Clara Convention Center, Santa Clara, CA, USA
E-mail: registration@endeavorb2b.com
www.strategiesinlight.com

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

12–17 September 2021 (postponed to 2022)
19th International Conference on Silicon Carbide and Related Materials (ICSCRM 2021-2022)
Davos, Switzerland
E-mail: info@icscrm2021.org
www.icscrm2021.org

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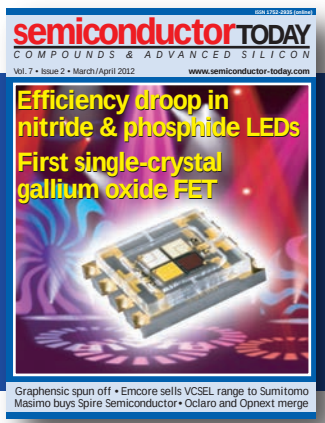

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