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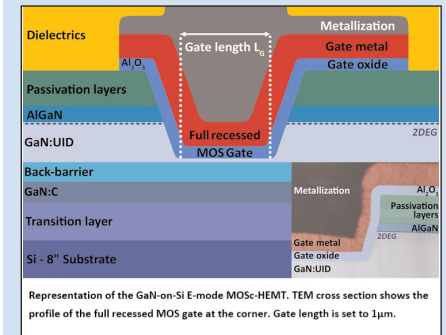
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p12 The new building at ROHM Apollo's plant, which will boost SiC power device production capacity, starting in 2022.



p18 France's CEA-Leti presented papers at IEDM on progress in GaN power electronics devices.



p30 The new EVG Academy will provide customers with technical training on all classes of EVG equipment and on the firm's CIM Framework software platform.



p38 Cover: ams has announced the pre-release of the TARA2000-AUT family of VCSEL flood illuminators for automotive applications — claimed to be first to be qualified to the AEC-Q102 automotive quality standard and ISO 26262 functional safety standard.

SiC powering ahead, despite COVID

The power silicon carbide (SiC) device market has been driven by power supply applications, but the automotive segment is becoming the killer application after SiC's adoption for Tesla's main inverters in 2018. Due to the COVID-19 pandemic, SiC device and materials market growth in the electric vehicle/hybrid electric vehicle (EV/HEV) sector slowed in first-half 2020 due to lockdown restrictions and lower production at both OEMs and SiC suppliers. Nevertheless, many car makers continue qualifying SiC discrete devices or modules in the inverter, on-board chargers (OBCs) and DC/DC converters for their next-generation models, and design wins for SiC devices have recently multiplied. Automotive is hence expected to remain one of the main applications. The SiC device market will still exceed \$2.5bn by 2025, reckons market research firm Yole Développement (see page 70).

Correspondingly, SiC device makers are continuing to invest in capacity expansion, with Japan's ROHM having just opened a new five-storey building at its Apollo plant (to enter operation in 2022) — see page 12. Meanwhile, US-based Cree has decided to skip 150mm SiC wafers for the start-up of its Mohawk Valley fab in first-half 2022, making it the world's first 200mm SiC fab (to be reported in detail next issue). It has also just announced that, once it has completed the divestiture of the Cree LED business (which follows its sale of Cree Lighting in May 2019), within the next few quarters it will change its name to that of its Wolfspeed business, which makes silicon carbide and gallium nitride power & RF devices (and SiC wafers), signifying Cree's full pivot away from its original LED focus.

The GaN power device market will exceed \$680m by 2025, forecasts Yole. The adoption of GaN HEMTs for Oppo's in-box fast charger at the end of 2019 boosted penetration, but GaN is now making visible inroads into the end-consumer mass market. This was highlighted at January's Consumer Electronics Show (CES) by GaN power device makers (and their customers) such as EPC and Navitas (which has just shipped its 13 millionth GaNFast power IC, with zero failures in the field, courtesy of the GaN-on-Si platform of Taiwanese foundry manufacturing partner TSMC).

Yole estimates that the GaN RF device market is rising at a CAGR of 12% from 2019 to beyond \$2bn in 2025, driven by telecom and defense applications (although GaN RF devices for military use are expected to grow rapidly, to over \$1bn by 2025).

In the optoelectronics sector, automotive applications — such as advanced driver assistance systems (ADAS) and autonomous vehicles (AVs) — are also driving the light detection & ranging (LiDAR) market, which will grow at a 34% CAGR from \$682m in 2020 to \$2.932bn in 2025, forecasts TrendForce (see page 9). LiDAR uses vertical-cavity-surface-emitting lasers (VCSELs), which are also used for in-cabin sensing (driver monitoring etc), for which Austria-based ams has unveiled the first AEC-Q102- and ISO 26262-compliant VCSEL flood illuminator (see pages 38). The firm has also launched VCSEL IR flood illuminators for industrial applications such as not only autonomous guided vehicles (AGVs) but also robots and cobots (collaborative robots), e.g. in factories and warehouses. The latter may be even more important post-COVID, to minimize unnecessary human-human proximity in the workplace.

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LED revenue falls 10% in 2020 to \$15.127bn Rebound to \$15.7bn in 2021 expected as COVID vaccines distributed

The COVID-19 pandemic has had a substantial impact on the LED industry in 2020, resulting in a considerable drop in market demand and projected annual revenue down 10.21% year-on-year to just \$15.127bn, according to market research firm TrendForce.

Although the magnitude of the decline in 2020 is of historic proportions, as COVID vaccines become more widely available in 2021 it is likely that long-term pent-up market demand will rebound from rock-bottom levels, resulting in annual LED revenue growing by 3.82% year-on-year to \$15.7bn in 2021, it is forecasted.

TrendForce indicates that, due to the wide variety of LED applications, the degree of recovery in each application-specific industry varies too.

With regard to traditional backlighting applications, demand for consumer electronics (such as tablets and notebook computers) has skyrocketed on the back of the 'new normal' brought about by the pandemic, which involves the proliferation of work-from-home (WFH) and distance education. Given the resultant high demand for display panels, LED backlighting suppliers have seen remarkable performances across the board this year. However, in light of the possibility that most consumers have already purchased the needed electronics products ahead of time in 2020, TrendForce therefore maintains a conservative attitude towards whether the strong market demand in 2020 will persist in 2021.

On the other hand, with regard to the long-anticipated mini-LED backlights, various new products are expected to be released in 2021, spearheaded by major brands including Apple and Samsung. As such, mini-LED backlighting demand will see substantial growth, with annual revenue forecasted to rise by 900% year-on-year to \$131m in 2021.

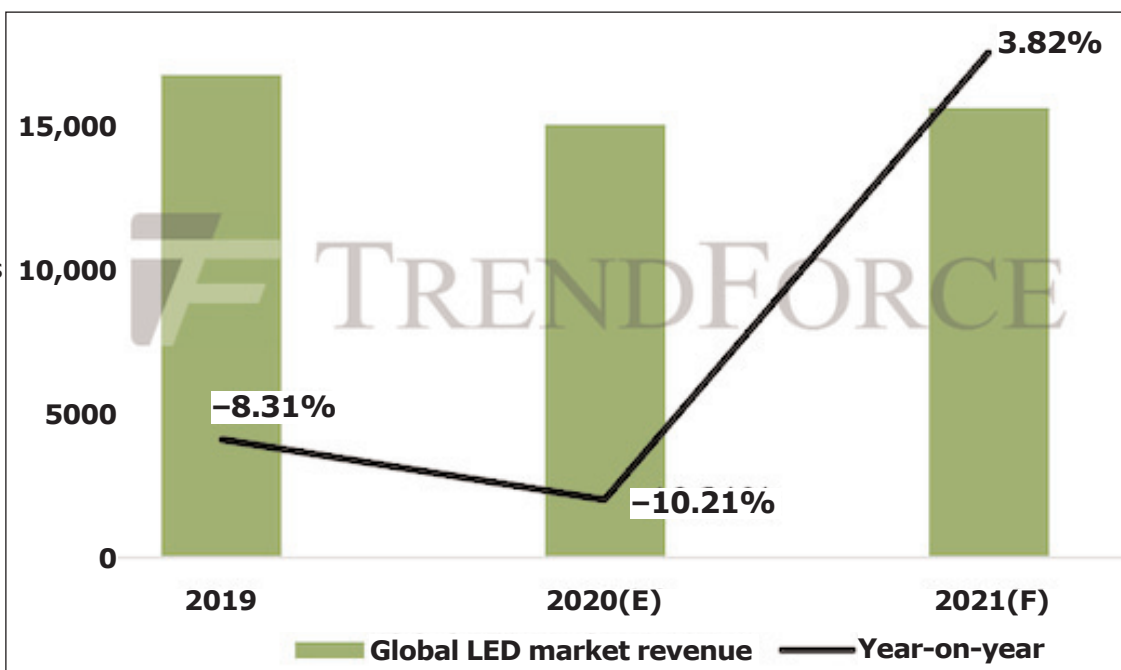
With regard to display applications, LED displays are primarily used within the commercial space. Similar to general lighting applications, the cutbacks in live performances this year caused a corresponding 9.3% decline year-on-year in LED display revenue. However, looking ahead to 2021, TrendForce expects LED display revenue to return to the pre-pandemic level of about \$1.48bn due to the gradual recovery of live performances and the rising demand for high-resolution, small-pixel-pitch LED displays.

With regard to general-use lighting, LED lighting applications have suffered massive declines due to the

pandemic's impacts. As commercial activities dwindled this year, the declines in commercial lighting and outdoor landscape lighting have been the most noticeable among the various LED lighting applications. Conversely, the gradual legalization of marijuana and the pandemic-generated skyrocketing market for medical and recreational marijuana in North America have galvanized a substantial increase in horticultural LED demand. Furthermore, the pandemic has also gradually affected the food supply chain, in turn leading to resurging capital expenditure (CapEx) for indoor agricultural infrastructure. As a result, certain LED lighting applications will see recovery in 2021.

Finally, with regards to automotive lighting, the decline in auto sales in 2020 has also stagnated the automotive lighting market. However, automotive LED lighting revenue is expected to return to the level of \$2.6bn as the pandemic slows down in 2021, concludes TrendForce.

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Global LED revenue (in US\$m) and year-on-year change, 2019–2021.

LED chip prices raised by 5–10%

Shortage caused by explosive growth in mini-LED demand

While major OEMs such as Apple and Samsung prepare to release their new notebook computers, tablets and TVs fully equipped with mini-LED backlights this year, various companies in the LED supply chain began procuring mini-LED chips ahead of time in fourth-quarter 2020, leading to explosive growth in demand for these chips, which in turn crowded out LED suppliers' production capacities for other mainstream LED chips, according to the latest investigations by market research firm TrendForce. Given this industry-wide shortage of LED chips, certain suppliers have been raising their quoted price by about 5–10%, it is estimated, for chips supplied to non-core clients and chips with relatively low gross margins.

TrendForce further indicates that companies in the downstream LED supply chain have started to aggressively procure components in order to mitigate the impending price hike on raw materials and shortage of components due to manufacturers' tight production capacities after the Chinese New Year. However, products of certain serial numbers or specifications are already in short supply at the moment, prompting these downstream companies to raise quotes first for small- and medium-size clients who place relatively low-volume orders. As for tier-one

clients who have relatively higher bargaining power, should they reject such a price hike they would then need to wait for more than two months in lead times (significantly longer than the average of two weeks), says TrendForce.

Taiwan-based Epistar is currently shipping about 150,000 mini-LED wafers (4-inch equivalent) per month. As mini-LED chips yield far higher gross margins than traditional LEDs, Epistar has reallocated some of its production capacities from the latter, less profitable products to mini-LED chip manufacturing instead. On the other hand, China-based San'an and HC SemiTek are directly benefitting from Epistar's order transfers. In addition to persistently growing demand for traditional LED backlights and RGB LED chips for video walls, San'an and HC SemiTek are also shipping several tens of thousands of mini-LED wafers per month (4-inch equivalent) due to the skyrocketing mini-LED demand.

HC SemiTek's product strategy of focusing on LED chips for display applications is paying off noticeably, says TrendForce. By leveraging its competitive advantage of highly cost-effective products, HC SemiTek's capacity utilization rates have been fully loaded for two consecutive quarters since Q3/2020. On the other hand, about 400,000 wafers in patterned sapphire sub-

strate (PSS) production capacity was suspended last month due to the fire at the fab of supplier Xuzhou GAPSS OE Technology Co Ltd. This incident led to a 5–10% price hike in key upstream LED chip materials including sapphire wafers and PSS, which will likely further exacerbate the price hike and shortage of LED chips.

TrendForce believes that the structural shortage in the LED industry, which led to a price hike for LED chips, can be attributed primarily to the fact the industry underestimated the production capacity needed for key parts of the supply chain during the infancy of pandemic-related emerging applications, in addition to the corresponding production capacity squeeze. However, these issues are expected to be resolved within half a year. Also, the downturn experienced by the LED industry in the past few years led to a clearance of excess capacity and subsequently the highly concentrated supply of key materials in the upstream LED supply chain, including sapphire wafers and PSS. As a result, suppliers of these key materials now enjoy increased bargaining power in price negotiations. Given the simultaneous increase in material costs and limited material supplies, TrendForce therefore forecasts a price hike for LED chips.

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Mini-LED chip revenue to reach \$270m in 2021 amid battle over backlight TV specifications

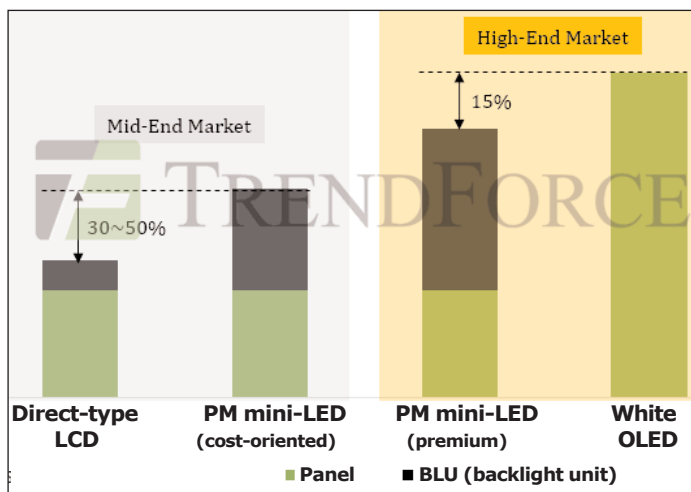
Backlight profitability to depend on optimization of mini-LED chips, backplanes and driver ICs

As various TV manufacturers such as Samsung, LG and TCL announced their new models equipped with mini-LED backlights at the All-Digital Consumer Electronics Show (CES) on 11–14 January, TrendForce's '2021 Mini LED New Backlight Display Trend Analysis' report shows that total mini-LED chip revenue from mini-LED backlight TVs could reach \$270m in 2021, as manufacturers gradually overcome technological bottlenecks and lower their overall manufacturing costs.

Mini-LED backlight costs for entry-level just 50% higher than LCD equivalents

Regarding TV backlight technologies, the cost of mini-LED solutions is 2–3 times lower than that of white organic light-emitting diode (OLED) and entry-level direct-lit LCD solutions, reckons TrendForce. This cost difference therefore serves as mini-LED technology's competitive advantage over its competitors in display backlight adoption.

High-end TVs currently contain about 16,000 mini-LED chips per TV, divided into 2000 local dimming zones. In this market segment, passive-matrix (PM) mini-LED TV panels with a BLU (backlight unit) still cost about 15% less than OLED TV panels and therefore hold a cost advantage. On the other hand, in the mid-range TV segment, each TV contains 10,000–12,000 mini-LED chips and 500 local dimming zones, so the cost of mini-LED backlight integration in this market segment is approximately just 50% more than entry-level direct-lit LCD backlight units, making mini-LEDs a viable alternative to traditional LCD solutions in this segment too. Given the high cost-effectiveness of mini-LED backlight units, TV makers are therefore likely to adopt them as a viable technology and initiate an industry-wide competition over



Cost comparison between direct-type LCD/white OLED and passive-matrix mini-LED solutions.

mini-LED TV specs this year, forecasts TrendForce.

HDR and 8K resolution will be the two mainstream features of high-end TVs this year. Regarding Korean brands, Samsung's Neo QLED mini-LED TV and LG's QNED mini-LED TV, both unveiled at CES 2021, are equipped with mini-LED backlights as a performance-enhancing technical feature. These TVs feature not only 8K resolution but also mini-LED backlight units, which require more than 20,000 mini-LED chips (divided across more than 1000 local dimming zones, with more than 1000 nits in peak brightness), in addition to passive-matrix FALD technology, which allows for contrast ratios of 1,000,000:1, which is a significant improvement that puts these TVs on almost equal footing with OLED TVs in terms of image quality. At the same time, China-based TCL is also set to release its OD Zero mini-LED TV, which has comparable specs with Korean offerings and is also equipped with mini-LED backlight units. Going forward, more TV makers, such as Hisense and Xiaomi, are expected to participate in the burgeoning mini-LED backlight TV market.

market: Chip suppliers include firms in Taiwan (Epistar and Lextar), China (San'an and HC SemiTek) and Korea (Seoul Semiconductor). Testing and sorting companies include FitTech, Saultech and YTEC. SMT companies include Taiwan-based Lextar and China-based Hongli Zhihui. Driver IC suppliers include Taiwanese (Macroblock, Elan, Parade, Himax, and Novatek) and Chinese (Chipone). Backplane suppliers include companies in Taiwan (Apex and Zhen Ding Tech) and Korea (Young Poong Group). Panel suppliers include SDC, LGD, AUO, Innolux, BOE and CSOT.

TrendForce believes that mini-LED backlight displays currently possess a competitive advantage over OLED displays due to the former's 15% lower cost, comparatively. Ultimately, the future development and profitability of the mini-LED backlight market in the long run will depend on the continued optimization of components that account for a relatively higher allocation of backlight costs, including mini-LED chips, mini-LED backplanes, and driver ICs, concludes TrendForce.

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Pace of optimizing mini-LED chips, backplanes and driver ICs key to rapid growth

As various manufacturers successively release their mini-LED backlight TVs this year, related companies in the supply chain are expected to benefit as a result. Currently, there are multiple major suppliers of mini-LED components on the

LiDAR market growing at 34% CAGR from \$682m in 2020 to \$2.9bn in 2025

ADAS/autonomous vehicles are primary applications

Driven by applications such as advanced driver assistance systems (ADAS), autonomous vehicles (AVs), industry, deliveries and smart cities, the light detection & ranging (LiDAR) market is rising at a compound annual growth rate (CAGR) of 34% from \$682m in 2020 to \$2.932bn in 2025, forecasts market analyst firm TrendForce.

Regarding automotive LiDAR applications (ADAS and AVs), automakers have continued to release NEVs (new energy vehicles, or plug-in electric vehicles) despite the COVID-19 pandemic's negative impact on the global automotive industry in 2020, says TrendForce. Furthermore, these automakers are also adding ADAS to high-end conventional gasoline vehicles and NEVs alike. As an essential component in SAE levels 4–5 autonomous vehicles, LiDAR systems are used by automakers to both build their databases and increase vehicle location accuracy. In addition, automotive LiDAR is also featured in autonomous buses, robo-taxis, and self-driving trucks. Total automotive LiDAR revenue is expected to reach \$2.434bn in 2025. At the moment, major automotive LiDAR suppliers

include Velodyne, Valeo, Quanergy Systems Inc, ibeo, Continental, LeddarTech, INNOVIZ, HESAI, LeiShen, and Luminar, while major LiDAR laser suppliers include Osram, Laser Components, Excelitas, and Hamamatsu.

LiDAR Market	2020	2025	CAGR
ADAS and Autonomous Vehicles	409	2,434	43%
Industry and Delivery	259	469	13%
Smart City	14	29	17%
Total	682	2,932	34%

Regarding delivery and logistics, the rising popularity of e-commerce has prompted online vendors and delivery companies to lower their last-mile delivery costs by performing deliveries with autonomous delivery robots, bicycle couriers and self-driving trucks, leading to increased demand for delivery robots with self-navigation and autonomous decision-making capabilities, notes TrendForce. Major e-commerce companies that have been promoting these delivery methods include Alibaba, Amazon, FedEx and Jingdong (also known as JD.com).

Likewise, growth in the industrial automation market has been lackluster due to the pandemic, with most companies having deferred their previous expansion plans in consideration of budgets, although certain companies wary of potential

future shortages in human labor are investing additional capital into industrial automation development against the market downtrend. Having seen various deferred developments throughout 2020, the European and North American markets are expected to see surging demand for industrial automation applications starting in third-quarter 2021. On the whole, TrendForce forecasts \$469m in revenue for the industry and delivery LiDAR markets in 2025. Major LiDAR suppliers in these markets currently include SICK, Hokuyo, OMRON and Velodyne.

With increasing demand for ADAS, AVs and industrial automation, LiDAR market value will be boosted by rising LiDAR usage volumes, concludes TrendForce.

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Table 2: LiDAR Market Supply Chain (Upstream/Downstream Connections)

LiDAR Laser (Upstream)	Automotive LiDAR (ADAS / AV) (Midstream)	Car Maker / Robocars (Downstream)
Pulsed Laser Diodes • OSRAM • Excelitas • Laser Components • Hamamatsu VCSEL • OSRAM Fiber Laser DPSS Laser	• Velodyne LiDAR • Vales • ibeo • Continental • Quanergy • LeddarTech • Innoviz • InnoLuce • Luminar • Hesai • Leishen Robosense • OMRON	• BMW • General Motors • Daimler • Volkswagen Volvo • Toyota • Ford • Audi • Nissan • Chery • Great Wall • Geely • SAIC Motor • BAIC Group • FAW • Hyundai • Google Waymo • Uber • Cruise • Argo AI • Aurora • Baidu • MILLA • ...
Photodetector (Upstream)	Industry and Delivery LiDAR (Midstream)	AGV and AMR (Downstream)
APD • Hamamatsu • First Sensor • Laser Components • Excelitas SPAD • Hamamatsu • Laser Components	• SICK • Hokuyo • OMRON • Velodyne LiDAR • Konica Minolta • ...	• MiR • KUKA • HIKROBOT • Amazonrobotics • ...

Skyworks ships over 1 million units of the first small-cell base-station 5G power amplifiers

5G small-cell carrier roll-outs accelerate infrastructure upgrade cycle

Skyworks Solutions Inc of Woburn, MA, USA (which manufactures analog and mixed-signal semiconductors) says that it has now shipped more than 1 million units of its SKY66318-21 power amplifier (PA), which is claimed to be the first high-efficiency small-cell PA with a bandwidth of 200MHz at +28dBm. Skyworks says that the milestone highlights it accelerating the adoption of 5G by enabling enhanced 5G connections and powering more efficient range extension for small cells.

To demonstrate the benefits of the new technology, for its virtual booth at the All-Digital Consumer Electronics Show (CES 2021) on 11-14 January, Skyworks collaborated with Xilinx Inc to showcase the spectral and power efficiency achievable using the SKY66318-21 PA in 5G infrastructure applications.

The demonstration included Skyworks' SKY66318-21 high-efficiency PA, Xilinx's Crest Factor Reduction (CFR) and Digital Pre-Distortion IP along with an RF transceiver from Texas Instruments. Featuring a highly efficient, wide instantaneous bandwidth, fully input/output-matched PA with high gain and linearity, the SKY66318-21 enables newly auctioned operation

in both the Citizens Broadband Radio Service (CBRS) and the 5G C-band, making it well positioned for 'carrier sharing' where multiple operators can take advantage of the opportunity to share the same equipment says Skyworks.

According to a report 'Small-cell 5G network market outlook, November 2020' from Allied Market Research, the small-cell 5G network industry is rising at a compound annual growth rate of 43% from 2020 to \$8.32bn in 2027. The report also notes that the rise in network densification, increase in mobile data traffic, advent of the CBRS band, and growth in investment in 5G infrastructure by several economies have driven growth in the global small-cell 5G network market.

"For emerging 5G environments, it is critical that the PA can deliver increased efficiency

For emerging 5G environments, it is critical that the PA can deliver increased efficiency while meeting challenging out-of-band emissions and EVM requirements

while meeting challenging out-of-band emissions and EVM requirements," says Dan Mansur, VP of marketing, Wired and Wireless Group at Xilinx. "We are delighted to collaborate with Skyworks and TI to provide our highly adaptable CFR and DPD IP, which offers a scalable digital front-end solution to address future RF PA efficiency needs," he adds.

"As 5G is being deployed globally and with the mid-band serving as the sweet spot thanks to its speed, capacity and range, the SKY66318-21 is a robust addition to Skyworks' broad portfolio of complete connectivity solutions," says David Stasey, VP & general manager of diversified analog solutions at Skyworks.

"Regardless of band, Skyworks is poised to meet the need for densification in the rapidly expanding small-cell market."

The SKY66318-21 PA has a compact design, making it suitable for 5G NR and 4G LTE systems operating at 3300-3700MHz. Active biasing circuitry is integrated to compensate for temperature, voltage and process variation. The SKY66318-21 is part of a family of high-efficiency, pin-to-pin compatible PAs supporting major 3GPP bands.

Skyworks launches mid- and high-band FEM for 3G/4G/5G mobile applications

Front-end module builds on Sky5 portfolio for 5G

Building on its Sky5 portfolio of products for 5G applications, Skyworks has launched the SKY58085-11, a mid- and high-band front-end module (FEM) that supports 3G/4G/5G mobile devices and operates efficiently in 3G/4G/5G modes.

The module meets 5G NR and LTE Advanced requirements where

wider bandwidth (100MHz) and carrier aggregation are used for higher data rates.

The highly integrated solution includes power amplifier blocks operating in the mid and high bands, a silicon controller containing the MIPI RFFE interface, RF band switches, mid- and high-band antenna switches,

bi-directional couplers, and integrated filters to support Bands 1, 2, 3, 7, 34, 39, 40 and 41.

Packaged in a 62-pad LGA assembly, it offers a highly manufacturable and low-cost solution, says Skyworks.

www.skyworksinc.com/en/Products/Front-end-Modules/SKY58085-11

Skyworks partners with ASUS to launch first ultra-fast Wi-Fi 6E extended-band router

Wi-Fi 6E front-end modules featured in ROG Rapture AXE11000 gaming router

Skyworks Solutions Inc of Woburn, MA, USA (which manufactures analog and mixed-signal semiconductors) says that its high-performance Wi-Fi 6E front-end modules are featured on the first ultra-fast Wi-Fi 6E gaming router from ASUS.

Utilizing the FCC's newly allocated 6~7GHz extended band to double the capacity of traditional Wi-Fi, the Wi-Fi 6E standard enables faster connectivity and supports an increased number of connected users, meeting the unprecedented demand for increased video conferencing, online gaming, streaming TV, augmented/virtual reality (AR/VR), home security cameras and online exercise apps. ASUS is said to be first to deliver the increased and wider-bandwidth 160MHz channels of Wi-Fi 6E with its ROG Rapture GT-AXE11000 gaming router.

The report '6GHz Wi-Fi opportunities and challenges' (15 September 2020) from ABI Research forecasts 1.4 billion Wi-Fi 6E chipset shipments by 2025, while noting that the addition of the 6GHz band is coming at a critical time as home Wi-Fi communications faces increased data demand, with operators worldwide having reported major surges in Wi-Fi traffic. The addition of the 6GHz band will help to provide faster Wi-Fi with less interference, ensuring that this increased use of home Wi-Fi can be supported with high-quality connectivity.

Skyworks says that its Wi-Fi 6E solutions expedite time-to-market by incorporating all the required functionality to deliver the maximum allowed performance and contain a logarithmic power detector to support wide dynamic ranges, low power consumption and improved thermal management. It adds that its Wi-Fi 6E wireless products are

enabling faster download and upload speeds along with enhanced coverage, highly reliable connectivity in dense traffic areas and improved power efficiency.

Designed with three concurrent frequency bands of operation and 802.11ax Wi-Fi 6E connectivity, the ROG Rapture GT-AXE11000 (said to be the first Wi-Fi 6E router) supports speeds of up to 11Gb/s and features WAN aggregation for wired connectivity up to 2Gb/s. With 4x4 Wi-Fi 6 and a 2.5Gb/s wired LAN port, both wired and wireless networks can achieve sustained speeds of more than 1Gb/s, yielding true multi-gigabit performance. The GT-AXE11000 leverages Skyworks' latest 6GHz front-end modules to maximize RF performance in signal coverage, quality and power efficiency.

"This year people have been spending more time than ever at home working, learning and playing, and for gamers this has also meant seeking out the latest and greatest gear to level up their play," says Ten-Long Deng, corporate VP at ASUS.

"Leveraging Skyworks' vast experience developing cutting-edge technologies has enabled

us to bring true multi-gigabit performance to life for those looking to gain an advantage while upgrading their gaming experiences with the new ASUS ROG Rapture GT-AXE11000," he adds.

"Faster, highly reliable and efficient Wi-Fi coverage has never been more important as more and more devices and users have shifted to virtually connecting while staying safe at home," says Dave Stasey, VP & general manager of diversified analog solutions at Skyworks. "Through our portfolio of high-performance solutions, Skyworks is proud to continue our partnership with an industry leader like ASUS by providing functionality to optimize Wi-Fi coverage and speeds to address the insatiable demand for always-on connectivity."

Wi-Fi 6E technology takes advantage of the newly available radio spectrum in the 6GHz band, which offers three times more bandwidth than the 5GHz band. It also adds seven new 160MHz channels to the current Wi-Fi 6 standard, provides lower latency, and will be dedicated to Wi-Fi 6E devices for maintaining high speeds that will not be affected by legacy devices.

Part of Skyworks' portfolio of Wi-Fi 6E products, SKY85780-11 and SKY85784-11 are highly integrated, front-end modules (FEM) incorporating a single-pole, double-throw (SPDT) transmit/receive (T/R) switch, a high-gain low-noise amplifier (LNA) with bypass, and a power amplifier (PA) intended for high-power Wi-Fi 6E applications and systems. Housed in a compact, 24-pin 3mm x 5mm package, the FEMs can reduce front-end board space by more than 50%, it is reckoned, making them suitable for routers, gateways and wireless audio/video applications.

www.skyworksinc.com

ABI Research forecasts 1.4 billion Wi-Fi 6E chipset shipments by 2025, while noting that the addition of the 6GHz band is coming at a critical time as home Wi-Fi communications faces increased data demand, with operators worldwide having reported major surges in Wi-Fi traffic

ROHM completes new building at Apollo plant in Chikugo

Power semiconductor maker ROHM of Kyoto, Japan has held an opening ceremony announcing the completion (in December) of its new five-storey building at ROHM Apollo's plant in Chikugo, Fukuoka, which will boost the firm's silicon carbide (SiC) power device production capacity (after it enters operation in 2022).

The new building introduces a number of energy-saving technologies to its production facilities, with 100% of its electricity coming from renewable energy sources.

In addition, ROHM has strengthened its BCM (business continuity management) system by introducing various disaster counter-measures. Also, from January ROHM will begin installing production equipment



and build a manufacturing system that can meet the medium- to long-term increases in demand for SiC power devices.

ROHM has been mass producing SiC power devices including Schottky barrier diodes (SBDs) and metal-oxide-semiconductor field-effect transistors (MOSFETs) since 2010. At the same time, with its integrated production system,

the firm says that it is continuously improving its production efficiency by increasing wafer diameter and utilizing the latest equipment while also reducing the environmental impact of manufacturing.

In addition to the new building, SiCrystal GmbH in Erlangen, Germany (a ROHM Group company that manufactures SiC wafers) is scheduled to start operating with 100% renewable energy from the next fiscal year, reducing CO₂ emissions from purchased power at the plant to zero. As a result, all of ROHM's major production processes for SiC wafers will use environmentally friendly renewable energy.

www.rohm.com

Infineon's CoolSiC used in Fronius' solar inverter

Fronius International GmbH of Wels, Austria has launched the Symo GEN24 Plus solar inverter, whose Multiflow technology makes it suitable for a wide range of applications supporting energy self-sufficiency. As well as providing power for direct use in the household it also has an interface for energy storage systems. In addition, the hybrid inverter is designed for water heating and the charging of electric cars, and can be connected to external systems.

The new solar inverter uses silicon carbide CoolSiC MOSFETs from Infineon Technologies AG of Munich, Germany with an efficiency of over 98%. In combination with the high-voltage storage system from BYD, the Symo GEN24 Plus has achieved a record value in the System Performance Index (SPI) of 94% in the 10kW class, it is claimed (the only one in this combination to achieve Class A energy efficiency).

"SiC modules can be used to build very energy-efficient, robust, and reliable inverters. This technology enables a significant increase in switching frequency," says Andreas Luger, head of R&D Power Electronics

in the Solar Energy business unit of Fronius. "Compared to the previous generation, the functionality is significantly improved, while its size remains comparable. Each device now also has an output for a secure power supply, and backup power, in addition to the standard connection options for a hybrid inverter," he adds.

"To maximize the advantages of SiC, engineers from Fronius and Infineon have jointly optimized the layout and chip assembly of the modules," says Peter Wawer, president of Infineon's Industrial Power Control Division. "Ultimately, the close communication between the development teams enabled system advantages that correspond to customer needs. Based on our tried and tested Easy module, the inverter's booster stages now use 1200V CoolSiC MOSFETs in combination with CoolSiC diodes. This full-SiC solution thus ensures maximum efficiency."

Full-SiC is also used for the battery stage. One Easy 1B 1200V with an on-resistance ($R_{DS(on)}$) of 45m Ω is used in the bidirectional DC/DC converter. The inverter stage implements a SiC hybrid solution in an Easy 2B module, which has also

been tailored to the needs of Fronius. The NPC1 topology combines silicon-based 650V TRENCHSTOP 5 insulated-gate bipolar transistors (IGBTs) and rapid diodes with CoolSiC Schottky diodes. The modules are controlled in all stages with an EiceDriver IC gate driver.

The combination of SiC MOSFET modules in the booster and battery input with hybrid modules in the inverter stage ensures the best possible ratio of efficiency and cost, it is reckoned. As Infineon's SiC power semiconductors have a high power density, the Fronius Symo GEN24 Plus offers many functions such as backup power, storage connection, multi-MPP tracker and energy management. The inverter weighs only 24kg and has a small volume (594mm x 527mm x 180mm). Its active air-cooling can reduce the temperature of the power electronics parts, and thus extend service life.

The inverter is available in the power classes 6, 8 and 10kW. Fronius supplies this inverter primarily in Europe, South America and Australia.

www.fronius.com

www.infineon.com/cool-sic-mosfet

SUNY Poly students receive Cree|Wolfspeed Scholarships

State University of New York Polytechnic Institute (SUNY Poly) has joined Cree Inc of Durham, NC, USA in congratulating 11 SUNY Poly students who were announced as recipients of the newly established, merit-based 'Cree|Wolfspeed Scholarship' program. The scholarships aim to ensure that students from historically underserved or marginalized communities, as well as those with significant financial need, will have critical access to the educational opportunities that can pave the way toward successful careers in the high-tech workforce.

"Cree is committed to providing students in our communities with the opportunity to excel through STEM education initiatives," said Cree|Wolfspeed chief technology officer John Palmour.

"This scholarship not only highlights Cree's commitment to innovation-based education but it also further facilitates these students' academic careers as they pursue their educational dreams and the growing opportunities in the Mohawk Valley and beyond," said SUNY Poly acting president Dr Tod Laursen.

The commitment from Cree includes a \$2m scholarship program over 10

years, with this cohort of awardees receiving a total of \$46,000. Students receiving the scholarship must be interested in pursuing a position in the semiconductor industry upon graduation. They must be committed to working hard, willing to collaborate, have a passion for innovation, and reflect the Cree values of integrity and respect, ownership and accountability, and ingenuity and passion, states the firm.

The students must also be enrolled in one of the following SUNY Poly academic programs: Computer Engineering Technology; Electrical & Computer Engineering; Electrical Engineering Technology; Mechanical Engineering; Mechanical Engineering Technology; Nanoscale Engineering; or Network & Computer Security.

As part of the scholarship, the recipients, first-year and sophomore students may be offered paid internships and will be assigned a Cree|Wolfspeed mentor, in addition to being able to attend the annual SUNY Poly and Cree|Wolfspeed Scholarship Mixer.

The initiative is also complementary to the recent announcement of the Dr John Edmond and Dr John Palmour

SUNY Polytechnic Institute Endowed Faculty Chairs. The five-year, \$1.5m funding underpins the continued expansion of science, technology, engineering and mathematics (STEM) opportunities for students at SUNY Poly.

As announced in September 2019, Cree is developing the world's largest 200mm-capable silicon carbide (SiC) fabrication facility (the Mohawk Valley Fab) in Marcy, New York, and has committed to creating more than 600 new jobs within eight years as well as providing internships for SUNY students as part of its presence. The efforts aim to develop an advanced manufacturing-oriented workforce development initiative across the SUNY system to prepare a 21st century workforce for the long-term, high-quality employment and advancement opportunities that the new facility will present.

Eight students from SUNY Poly recently took part in internships with Cree. The firm also donated \$25,000 to the SUNY Poly Foundation in November 2019 to invest in and expand SUNY Poly's STEM programs.

www.sunypoly.edu

www.cree.com

Wolfspeed WolfPACK SiC-based power module family

Cree has launched its Wolfspeed WolfPACK family of power modules, extending its range of solutions for a diverse range of industrial power markets, including electric vehicle (EV) fast charging, renewable energy and energy storage, and industrial power applications. Using 1200V Wolfspeed MOSFET technology, the new modules deliver maximum efficiency in easy-to-use packages that allow designers to significantly increase efficiency and performance with smaller, more scalable power systems, Cree claims.

The new silicon carbide modules are said to maximize power density while simplifying designs in a standard form factor to significantly

accelerate the production and roll-out of next-generation technology for a wide range of rapidly growing industrial markets, including off-board charging and solar energy solutions. The new family bridges the gap between single-die discrete components and high-ampacity module solutions, giving design engineers a breadth of portfolio options for design requirements using Wolfspeed silicon carbide.

"The introduction of the Wolfspeed WolfPACK power modules extends our power portfolio to cover the broad spectrum of high-voltage power applications, which will help an array of high-growth industries transform as the global transition from silicon

to silicon carbide continues to accelerate," says Jay Cameron, senior VP & general manager, Wolfspeed Power. "Maximizing power density while minimizing design complexity is essential for engineers working in the mid-power range, and the new modules simplify layouts to help accelerate production of EV fast charging and solar infrastructures."

WolfPACK power modules are said to deliver the highest rated current topologies commercially available, while offering compact footprints that cut system size, complexity and costs. The modules are available in half-bridge and six-pack configurations with various on-resistances.

www.wolfspeed.com/power/products

STMicroelectronics extends MasterGaN family

MasterGaN2 optimized for asymmetrical topologies

STMicroelectronics of Geneva, Switzerland says that, building on its MasterGaN platform, MasterGaN2 is the first in the new family to contain two asymmetric gallium nitride (GaN) transistors, delivering an integrated GaN solution suited to soft-switching and active-rectification converter topologies.

The 650V normally-off GaN transistors have on-resistance ($R_{DS(on)}$) of $150m\Omega$ and $225m\Omega$. Each is combined with an optimized gate driver, making GaN technology as easy to use as ordinary silicon devices, says ST. By combining advanced integration with GaN's inherent performance advantages, MasterGaN2 further extends the efficiency gains, size reduction and weight savings of topologies such as active clamp flyback, the firm adds.

The MasterGaN power system-in-package (SiP) family combines the two GaN high-electron-mobility



transistors (HEMTs) and associated high-voltage gate drivers in the same package with all necessary protection mechanisms built-in. The designer can connect external devices including Hall sensors and a controller such as a DSP, FPGA or microcontroller directly to the MasterGaN device. The inputs are compatible with logic signals from 3.3V to 15V, which helps to simplify the circuit design and bill of materials, permits a smaller footprint, and streamlines assembly, says ST. This integration helps to raise the

power density of adapters and fast chargers.

GaN technology is driving the evolution toward fast USB-PD adapters and smartphone chargers. ST reckons that MasterGaN devices enable these to become up to 80% smaller and 70% lighter, while charging three times faster compared with ordinary silicon-based solutions.

The built-in protection comprises low-side and high-side under-voltage lockout (UVLO), gate-driver interlocks, a dedicated shutdown pin, and over-temperature protection. The 9mm x 9mm x 1mm GQFN package is optimized for high-voltage applications, having over 2mm creepage distance between high-and low-voltage pads.

MasterGaN2 is in production now, priced from \$6.50 for orders of 1000 pieces.

www.st.com/en/power-management/mastergan2.html

CRADA to transfer AFRL's 0.14 μ m GaN-on-SiC process to MACOM

Microwave & millimetre-wave GaN MMIC product range to be expanded

MACOM Technology Solutions Inc of Lowell, MA, USA (which designs and makes semiconductors, components and subassemblies for analog RF, microwave, millimeter-wave and photonic applications) has entered into a Cooperative Research and Development Agreement (CRADA) with the United States Air Force Research Laboratory (AFRL) regarding gallium nitride-on-silicon carbide (GaN-on-SiC) technology.

AFRL and MACOM will work together to transfer AFRL's production-ready 0.14 μ m GaN-on-SiC process to MACOM's 'US Trusted Foundry' (a designation that it is a preferred facility for US defense business, as a registered ITAR facility).

Semiconductor experts from both parties will collaborate to support a rapid process transfer to MACOM.

The AFRL GaN-on-SiC process is suitable for monolithic microwave integrated circuit (MMIC) products and is capable of achieving what are claimed to be industry-leading frequency and power density performance. Once the process is transferred, MACOM anticipates that it will expand its standard and custom MMIC product offerings.

"This semiconductor process will enable us to enter the microwave and millimetre-wave GaN MMIC market with high-performance products," says MACOM's president & CEO Stephen G. Daly. "Our wafer fabrication facility is already well

equipped to support GaN, including installed electron-beam lithography capability, so we can bring the process online with minimal capital investment. We intend to service a wide range of commercial and US defense opportunities, including satellite communication systems, as well as land-, air- and sea-based radar systems," he adds.

"We look forward to MACOM supporting critical US Air Force and Department of Defense requirements with an industrialized and best-in-class GaN semiconductor process," says Dr Robert Fitch of AFRL Sensors Directorate. "Expanding domestic advanced semiconductor manufacturing is a national priority."

www.macom.com

Teledyne e2v HiRel adds high-power GaN HEMTs to 650V family

High-voltage GaN HEMTs for hi-rel available in lower-current 15A and 30A versions

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) is adding two new, ruggedized gallium nitride (GaN) power high-electron-mobility transistors (HEMTs) to its 650V high-power family of products based on GaN Systems' technology.

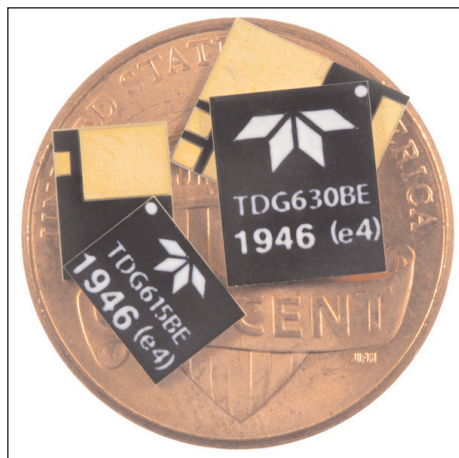
The TDG650E30B and TDG650E15B deliver lower-current performance of 30A and 15A respectively, while the original TDG650E60 650V (introduced a year ago) delivers 60A.

The 650V GaN HEMTs are claimed to be the highest-voltage GaN power devices on the market for demanding high-reliability military, avionics and space applications, providing a suitable fit for applications such as power supply, motor control, and half-bridge topologies.

The new devices come with a bottom-side-cooled configuration and feature ultra-low figure-of-merit (FOM) Island Technology die, low-inductance GaNPX packaging, very high-frequency switching of >100MHz, fast and controllable fall and rise times, and reverse current capability.

"We are pleased to continue the build-out of our 650V family of high-power GaN HEMTs for applications requiring the highest reliability such as space," says Mont Taylor, VP of business development. "We believe the smaller-sized packaging of these new devices will really benefit customers designing for the highest-power-density projects."

The TDG650E15B and TDG650E30B are both enhancement-mode GaN-on-silicon power transistors that allow for high current, high voltage breakdown and high switching frequency while



offering very low junction-to-case thermal resistance for high-power applications.

Gallium nitride devices have revolutionized power conversion in other industries and are now available in radiation-tolerant, plastic-encapsulated packaging that has undergone the stringent reliability and electrical testing to ensure mission-critical success, says Teledyne e2v HiRel. The release of the new GaN HEMTs delivers the efficiency, size and power-density benefits required in critical aerospace and defense power applications, it adds.

Teledyne e2v HiRel says that, for all product lines, it performs the most demanding qualification and testing tailored to the highest-reliability applications. For power devices, this regime includes sulfuric test, high-altitude simulation, dynamic burn-in, step stress up to 175°C ambient, 9V gate voltage, and full temperature testing. Unlike silicon carbide (SiC) devices, the two new devices can easily be implemented in parallel to increase the load current or lower the effective drain-source on-resistance ($R_{DS(on)}$).

Both of the new devices are now available for ordering and immediate purchase.

www.teledyne-e2v.com

www.gansystems.com

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GaN Systems' 650V E-mode power transistors used in Philips' 65W charger

New model smaller and faster than prior 18W 2C1A charger

GaN Systems Inc of Ottawa, Ontario, Canada (a fabless developer of gallium nitride-based power switching semiconductors for power conversion and control applications) says that its power transistors are featured in the new Philips SPS2316G/93, a 2C1A 65W GaN charger, which improves on the prior model (Philips 2C1A 18W) in size, power and charging time.

GaN Systems notes that GaN's growth in the consumer charger market is being driven by demand for smaller, faster charging, more energy-efficient devices. There are now more than 100 models of GaN chargers and adapters in the marketplace, including the small, light-weight and multi-functional Philips'

SPS2316G/93 2C1A 65W GaN charger.

The new charger includes three AC outlets and three USB ports, eliminating the need for multiple chargers. Performance tests show that it can charge three digital devices simultaneously while also supplying power to three 220V devices, such as speakers, TVs, fans and ultra-high-power chargers, suiting both home use and business travel.

The charger meets high-power needs of multiple device charging in a small form factor of 61mm x 65mm x 65mm (75% smaller than legacy solutions) with a maximum output power of 2500W. USB interfaces support a wide range of volt-

ages and 65W (USB-C) and 60W (USB-A) high-power fast charging protocols.

To achieve high performance and power density, the Philips charger uses GaN Systems' GS-065-011-1-L 650V E-mode GaN power transistor. The high-performance, low-cost FET is in a small 5mm x 6mm PDFN package and offers low junction-to-case thermal resistance, which results in ultra-high switching frequency and efficiency output. With the GaN Systems EZDrive implementation combined with the ON Semiconductor NCP1342 controller, the charger power design is simplified, a 'double-drive' is avoided, and low cost is achieved.

www.gansystems.com

MinDCet releases GaN-based half-bridge evaluation kit for 48V applications

MinDCet GaN gate driver used with GaN Systems E-mode HEMTs

Power semiconductor design house MinDCet of Leuven, Belgium has introduced the gallium nitride (GaN)-based MDC901-EVKHB half-bridge evaluation kit, which is based on the MinDCet MDC901 GaN gate driver and two GS61008P enhancement-mode (E-mode) GaN high-electron-mobility transistors (HEMTs) from GaN Systems Inc of Ottawa, Ontario, Canada (a fabless developer of gallium nitride-based power switching semiconductors for power conversion and control applications).

The high-end, high-performance solution has been developed to allow power electronics designers to easily design-in GaN for 48V market applications, including step-down converters, boost converters and class D audio applications.

The space-technology-based MDC901 is a non-isolated 200V

GaN gate driver with gate drive strength exceeding 9A, true floating programmable regulators, integrated charge pump, bootstrap diodes and extensive diagnostics. It is suitable for high-performance and high-reliability applications, where application diagnostics and GaN lifetime are key.

The MDC901-EVKHB evaluation kit features a 100V input step-down converter providing up to 30A of output current. The complete and compact power stage consists of the MDC901 in combination with two GS61008P E-mode GaN HEMTs. The evaluation board allows control of all MDC901 control IOs (internal/external dead-time control, programmable dead-time and programmable gate voltage) as well as verification of all diagnostic outputs (under-voltage detection, gate drive monitoring and temperature sensing).

The evaluation kit contains all hardware to reliably connect the board to an external power source, as well as the required fan, heat-sink, wiring and connectors to guarantee measurements under safe conditions. The evaluation kit is supported by GaN Systems and available for purchase through MinDCet.

MinDCet leverages expertise in high-voltage, power and mixed-signal ASIC design, delivering tailored integrated circuits. In-house production testing facilities allow medium-volume production of ASICs. The core development activities are focused on wide-bandgap gate drivers (GaN and SiC), high-voltage (>650V), radiation-hardened and high-temperature ASICs for power control, sensing and motor driving applications.

www.mindcet.com/asic-products/mdc901-evaluation-kit

Cup winners announced at China Power Supply Society awards ceremony

At an awards ceremony on 21 December at the China Power Supply Society (CPSS) conference, GaN Systems Inc of Ottawa, Canada (fabless developer of gallium nitride-based power switching semiconductors for power conversion and control applications) announced the winners of the sixth annual 'GaN Systems Cup' design competition.

The competition challenges top engineering teams from China's leading universities to design new or improved power electronics systems using GaN power transistors.

This year's challenge was to design a high-efficiency and high-power-density bidirectional AC/DC converter using GaN Systems' 650V GS66502B transistor. System technical requirements and parameters included:

- 400W rated output power;
- 220V_{AC} input voltage and 300–400V_{DC} output voltage;

- 94%+ efficiency in both directions at full load;
- no more than 30W/cm³ power density,;
- closed-loop control, over-current and over-voltage protection function; and
- run continuously for 30 minutes under natural cooling at 25°C.

Designs were judged on meeting the design criteria, functionality during the test day, ingenuity, and quality of presentation.

Thirty-five teams entered the competition and 14 got to the finals to compete in the final live round.

At the ceremony, six engineering teams were awarded for their GaN-based AC/DC converter designs.

A 20,000RMB prize was given to the grand-prize winner and 10,000RMB to the two first-prize winners, and 5000RMB to the three second-prize winners:

Grand prize: Heilongjiang University of Science & Technology (which presented the best-performance and highest-power-density design for the bidirectional AC/DC converter).

First prize:

- Shanghai Maritime University;
- Huazhong University of Science and Technology.

Second prize:

- Nanjing University of Science and Technology;
- Hangzhou University of Electronic Science and Technology;
- Beijing Jiaotong University.

The 2020 GaN Systems Cup is sponsored by GaN Systems, CPSS and its Science Popularization Working Committee, Ningbo Xici Electronic Technology Co Ltd and Itech Electronics Co Ltd and undertaken by Huazhong University of Science and Technology.

www.cps.org.cn



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Leti highlights progress in GaN power electronics

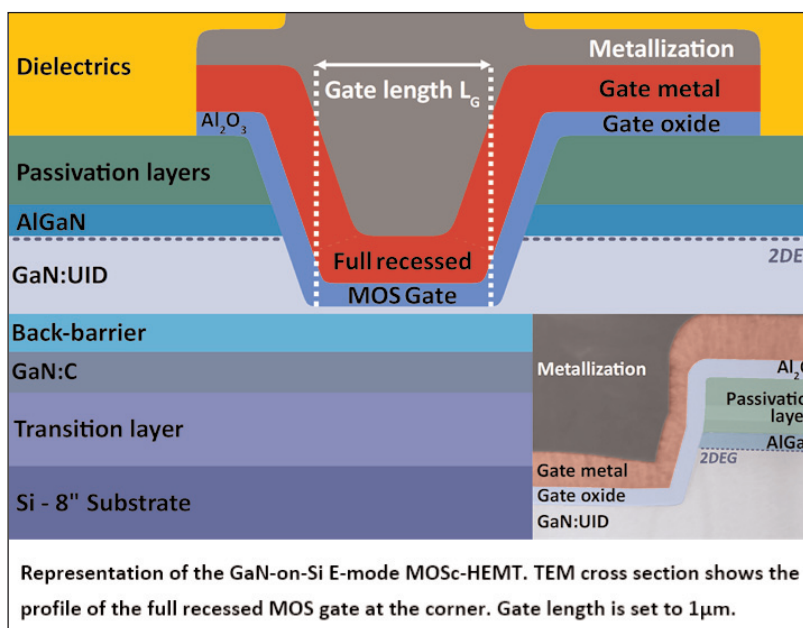
IEDM papers study degradation mechanisms and interface trap density

Micro/nanotechnology R&D center CEA-Leti of Grenoble, France says that two complementary research papers presented at the 66th IEEE International Electron Devices Meeting (IEDM 2020) confirm that its approach to gallium nitride (GaN) technologies is on track to overcome challenges in the architecture and performance of advanced GaN devices embedding a MOS gate, and targeting the fast-growing global market for power-conversion systems.

Researchers recounted experiments with variations of high-electron-mobility transistors (HEMTs) based on GaN-on-silicon (GaN-on-Si). Compared with silicon, GaN-based semiconductors improve both performance and reliability of increasingly compact power converters, and AlGaN/GaN HEMTs have shown the potential to replace power-conversion solutions based on silicon or silicon carbide (SiC) for high-frequency applications with high power and low noise. This technology is therefore expected to be a cost-effective power-conversion solution for many end-user applications, ranging from smartphones to kitchen appliances and e-vehicles and from battery loaders to DC/DC or AC/DC converters.

Considered together, the two papers provide a novel understanding of the gate stack of the GaN MOS-c HEMT developed at CEA-Leti in the IRT Nanoelec framework. They demonstrate the complexity of GaN MOS stack characterization as well as the requirement for deep expertise to report and analyze reliable parameter values.

The work presented in these papers will also help to solve detrimental effects occurring in GaN devices to improve reliability, which is one of CEA-Leti's key missions during an industrial trans-



'Carbon-Related pBTI Degradation Mechanisms in GaN-on-Si E-Mode MOSc-HEMT'

The paper 'Carbon-Related pBTI Degradation Mechanisms in GaN-on-Si E-Mode MOSc-HEMT' investigated the physics behind positive-bias temperature instability (pBTI) effects that occur when transistor gates are positively biased, to determine the root cause of this effect and to minimize it.

"We showed that the instabilities of voltage threshold (V_{th}) under positive gate stress were caused by two populations of traps," says paper author Aby-Gaël Viey.

"The first is related to defects in the gate oxide, which is a known effect, and the second to the presence of carbon atoms in nitrogen sites in GaN at the gate interface, which was a discovery, thus confirming the conclusions presented at IEDM."

Generally in MOS technology, where BTI is a common reliability test (e.g. Si/SiGe/Ge-based CMOS technologies), the root causes of V_{th} instabilities are related to oxide defects that can be charged or discharged by electrons or holes, depending on device type (n/p-MOS) and bias polarity. In the case of GaN MOS-c HEMTs, the epitaxial structure grown underneath the transistor is

extremely complex and far from homogeneous.

This study also confirmed the conclusions of the work that CEA-Leti reported in a paper at IEDM 2019 ('Investi-

gation of nBTI degradation on GaN-on-Si E-mode MOSc-HEMT') that showed that carbon in GaN-in-N [CN], which usually is introduced as a deep acceptor to create a semi-insulating GaN layer for breakdown-voltage management, is responsible for a part of the BTI instabilities along with the common oxide traps charging. The epitaxial structure is thus a great concern to reduce and minimize instabilities in GaN power devices.

"In addition, our more recent work demonstrated that it is possible to accurately model and predict these threshold voltage instabilities with great precision," Viey says.

"Indeed, the known model of capture emission time (CET) maps were used to confirm the presence of the two populations of traps and predict pBTI degradation (V_{th} shift) under a certain gate/temperature stress condition."

'A Novel Insight on Interface Traps Density (D_{it}) Extraction in GaN-on-Si MOS-c HEMT'

The study 'A Novel Insight on Interface Traps Density (D_{it}) Extraction in GaN-on-Si MOS-c HEMT' set out to characterize the oxide/GaN interface electrical quality to understand if the interface trap density of CEA-Leti's gate stack was the main

► threshold voltage (V_{th}) contributor in GaN-on-Si MOS-c HEMTs, and to confirm the performance of the institute's solution developed during 10 years of R&D.

Interface trap density (D_{it}) extraction extracts the density of interface defects that are electrically active at an oxide/semiconductor interface, as well as its distribution in terms of energy with the bandgap of the semiconductor. It is important because V_{th} is directly related to physical parameters such as metal-gate work function and doping of the semiconductor, which are easily adjustable, and to some defect-related parameters such as fixed or mobile charges in the oxide and interface state density. This density can dramatically influence

V_{th} if the interface is not correctly passivated and processed.

In the case of GaN MOS-c HEMTs, the GaN is dry-etched before oxide deposition, and this aggressive process step can have a tremendous impact on the future oxide/GaN interface. Thus, having an accurate and reliable characterization technique of this interface is a requirement for developing and optimizing MOS-based GaN power devices. "For other industries or researchers, this kind of approach would help to assess the interface trap density," says William Vandendaele, an author of the paper.

Vandendaele says that the next steps for CEA-Leti are to expand the teams' understanding of gate-stack optimization of GaN MOSc HEMTs

to minimize D_{it} values, and to transfer the best product, process and characterization methodology to the institute's industrial partners in the IRT PowerGan program.

CEA-Leti says that it will pursue its GaN roadmap with further research on epitaxy, devices, passive components, co-integration and system architectures to develop a GaN technology that allows switching frequencies in the MHz range and power densities 10 times those of silicon — all using standard CMOS processes to keep costs down.

Part of this work has been achieved in the frame of IRT Nanoelec.

www.leti.fr

www.irtnanoelec.fr/powergan

<https://ieeexplore.ieee.org/document/8993588>

US DoE announces project funding via BIRD Energy partnership with Israel

VisIC and Vepco to develop 80kW GaN-based dual motor drive power inverter for electric vehicles

In partnership with Israel's Ministry of Energy (MOE) and the Israel Innovation Authority as part of the Binational Industrial Research and Development (BIRD) Energy program, the US Department of Energy (DOE) has announced \$7.15m for eight newly selected R&D projects that will leverage \$10.25m in cost-share for a total project value of \$17.4m in the areas of electricity storage, eco-engineered concrete, sustainable transportation, and energy efficiency.

One of the projects involves VisIC Technologies Ltd of Nes Ziona, Israel — a fabless supplier of power conversion devices based on gallium nitride (GaN) transistor devices for automotive high-voltage applications — and engineering service company Vepco Technologies Inc of Chino, CA, USA, which will develop an 80kW gallium nitride (GaN)-based dual motor drive power inverter for both plug-in vehicles (PEVs) and battery electric vehicles (BEVs).

Projects that qualify for BIRD Energy funding must include one US and one Israeli company, or a company from one of the countries paired with a university or research institution from the other. The partners must present a project that involves innovation in the area of energy and is of mutual interest to both countries. BIRD Energy's review process selects the most technologically meritorious projects along with those that are most likely to commercialize and bring about a significant impact. Qualified projects must contribute at least 50% to project costs and commit to repayments if the project leads to commercial success.

"The BIRD Energy program fosters collaboration between US and Israeli companies that have produced real innovations in renewable energy and energy efficiency," says US Secretary of Energy Dan Brouillette. "This partnership continues to build bilateral relationships that will

benefit our economies and environment for years to come."

The announcement builds on the long history of cooperation between DOE and MOE, which brings together experts from both nations to drive innovation in renewable energy, energy storage, energy infrastructure cybersecurity, the energy-water nexus, and other areas.

"I hope that these R&D projects will bring us closer to an efficient and clean energy market," comments Israel's Minister of Energy Dr Yuval Steinitz. "Government investment in R&D is important to help reach these goals, and as a recovery tool from the Corona virus crisis we are experiencing now."

Since its inception, the BIRD Energy program has now funded 55 projects, involving total government investment of about \$42m in addition to about \$55m in funds matched by the private sector.

www.vepcotech.com

www.visic-tech.com

EPC issues its 12th reliability report

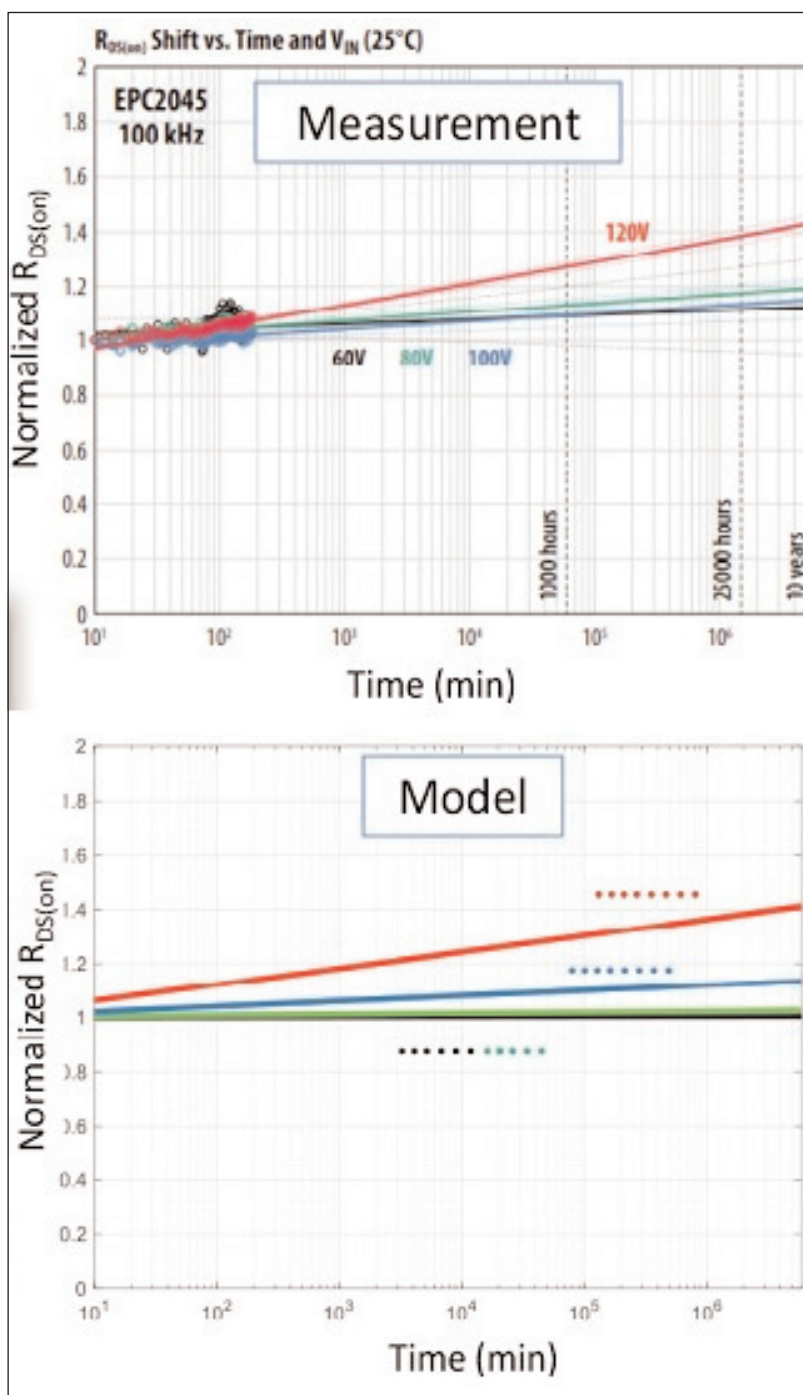
Physics-based models project eGaN device lifetime

Efficient Power Conversion Corp (EPC) of El Segundo, CA, USA — which makes enhancement-mode gallium nitride on silicon (eGaN) power field-effect transistors (FETs) and integrated circuits for power management applications — has released its Phase-12 Reliability Report, documenting the strategy used to achieve its field reliability record. eGaN devices have been in volume production for more than 11 years and have demonstrated very high reliability in over 226 billion hours of operation, most of which are in vehicles, LTE base stations, and satellites, to name just a few applications with rigorous operating conditions.

Testing eGaN devices to the point of failure provides the information to identify intrinsic failure mechanisms of the devices. Deep knowledge of the behavior of a device over time, temperature, electrical or mechanical stress can hence be developed and used to create physics-based models that accurately project the safe operating life of a product over a more general set of operating conditions.

The report is divided into nine sections, each dealing with a different failure mechanism:

- Section 1: Intrinsic failure mechanisms impacting the gate electrode of eGaN devices.
- Section 2: Intrinsic mechanisms underlying dynamic $R_{DS(on)}$.
- Section 3: Safe operating area (SOA).
- Section 4: Testing devices to destruction under short-circuit conditions.
- Section 5: Custom test to assess reliability over long-term light detection & ranging (LiDAR) pulse stress conditions.
- Section 6: Mechanical force stress testing.
- Section 7: Device solderability.
- Section 8: Thermo-mechanical stress.
- Section 9: Field reliability.



Physics-based models showing predicted eGaN device lifetime.

"The release of EPC's 12th reliability report represents the cumulative experience of millions of devices and five generations of technology," notes CEO & co-founder Dr Alex Lidow. "These reliability tests have been undertaken to continue our understanding of the behavior of GaN devices over a wide range of stress conditions," he adds.

record beyond what is achievable with traditional silicon MOSFET technology."

EPC is hosting a series of webinars highlighting the advances in modeling, predicting and measuring reliability in GaN devices that contribute to the major findings of the Phase-12 Reliability Report.

www.epc-co.com

"Standard power semiconductor qualification testing is inadequate since it only reports parts that pass a very specific test condition," Lidow continues. "By employing our test-to-fail methodology we have consistently produced more robust, higher-performance and lower-cost products for power conversion applications and have amassed a reliability track

EPC exhibits GaN-enabled consumer applications at CES eGaN FET and IC provider highlighting self-driving cars, eMobility, drones and robots

At this year's online All-Digital Consumer Electronics Show (CES 2021) on 11–14 January, Efficient Power Conversion Corp (EPC) of El Segundo, CA, USA – which makes enhancement-mode gallium nitride on silicon (eGaN) power field-effect transistors (FETs) and integrated circuits for power management applications – demonstrated the ability of eGaN technology to boost performance in consumer applications including self-driving cars, eMobility, drones, robots and 48V power conversion, as follows:

Self-driving cars

Light detection & ranging (LiDAR) technology has emerged as the leading technology to act as the 'eyes' for self-driving cars, as well as the time-of-flight systems used for autonomous mobile robotics and last-mile delivery. GaN enables these laser-based systems to see further, faster and with higher resolution.

eMobility

The rapid emergence of scooters and e-bikes has opened up new markets for chargers and compact motor drives. Due to their efficiency, small size and affordability,

eGaN FETs and ICs are ideal for these applications, says EPC.

Drones and robotics

eGaN FETs and ICs are said to provide the highest efficiency, lightest weight and most reliable solution for several systems within a drone, robot or collaborative robot (cobot). In these applications, GaN components contribute to smaller and lighter motors, higher-resolution time of flight, higher-efficiency 48V power conversion for longer battery life, and wireless power for increased operation, says EPC.

www.epc-co.com

EPC's eGaN FETs used in MPS' 48V–6V digital DC–DC power conversion modules

Monolithic Power Systems Inc (MPS) of Kirkland, WA, USA has launched a family of 48V–6V digital DC–DC power modules for 48V data center solutions that use eGaN power FETs from EPC. The power modules target applications for high-density computing and data centers, artificial intelligence (AI), machine learning, and multi-user gaming.

The MPC1100-54-0000 is the first in the new product family that will include modules in an LLC topology that utilize eGaN FETs to achieve an overall efficiency above 97% in a footprint of just 27mm x 18mm x 6mm for 48V–6V conversion. A key advantage of 48V–6V front-end conversion includes the enabling of a high-frequency secondary stage that is small enough to be placed much closer to the xPU/ASIC/GPU to reduce the power distribution loss by 4x compared with the commonly used STC topology for 48V–12V conversion.

For high-density server applications, record power density and efficiency can be achieved with



simple, low-cost topologies such as an LLC DC–DC converter. EPC says that eGaN FETs are well suited to LLC converters due to their combined low gate charge with 5V gate operation that yields very low gate power consumption, ultra-low on-resistance, and low output capacitance charge.

With power levels ranging from 300W to 1000W, the modules are scalable to accommodate a range of high-current and high-power applications. Customers can add up to three modules to address higher-power requirements, or scale down to one or two modules for lower-power requirements.

"The 48V–6V module family offers an extremely powerful and versatile solution set for high-performance computing, high-density data centers, and AI systems migrating to the 48V power distribution architecture," says Maurice Sciammas, senior VP marketing & sales,

MPS. "With the EPC devices inside our modules, we can increase power density significantly to meet the demanding requirements of these advanced applications," he adds.

"Advanced computing applications are putting higher demands on power converters, and silicon-based power conversion is not keeping pace," says EPC's CEO Alex Lidow. "We are delighted to work with MPS, a leader in this space, to implement GaN into their modules, allowing customers to increase the efficiency, shrink the size, and reduce system cost for 48V power conversion."

www.monolithicpower.com

Transphorm closes \$15m private placement Proceeds to ramp up volume shipments of GaN products, expand sampling and qualification of products for EVs, and grow epi business

Transphorm Inc of Goleta, near Santa Barbara, CA, USA — which designs and manufactures JEDEC- and AEC-Q101-qualified 650V and 900V gallium nitride (GaN) field-effect transistors (FETs) for high-voltage power conversion applications — has announced the closing of a common-stock-only private placement of 5,000,000 shares at a price of \$3.00 per share, resulting in gross proceeds of \$15m (before deducting placement agent commissions, financial advisor fees and other offering expenses).

“We are very pleased with the strong support from the financial community for Transphorm’s vision and the representative growth

opportunities for our high-voltage GaN power devices,” says CEO Mario Rivas. “In addition to strengthening Transphorm’s overall financial position, completion of this funding enables us to aggressively ramp production in support of secured design-ins for fast-charging power adapter applications, while simultaneously expanding the sampling and qualification of our Gen IV and Gen V SuperGaN products for electric vehicle (EV) automotive applications,” he adds. “Entering 2021, we are well positioned to benefit from industry megatrends, such as 5G communications and vehicle electrification, due to the increasing demand for high-reliability,

high-performance GaN power conversion devices that can deliver the features and functionality required by a growing cross-section of strategic partners and customers.”

Transphorm intends to utilize the net proceeds to scale volume shipments of GaN products for the fast-charging power adapter, server, communication and gaming power supply markets as well as converters/inverters for industrial and renewable applications, expanded sampling and qualification in EV automotive applications, growth of its epitaxial wafer business, as well as working capital to support general operations.

www.transphormusa.com

Bel Power launches Titanium efficiency AC-to-DC power supplies

Bel group company Bel Power Solutions says that six of its Titanium efficiency power supplies use Transphorm’s high-voltage GaN FETs, indicating the growing trend of high-performance, wide-bandgap power supply units (PSUs) deployed in data-center servers, routers and network switches.

The six GaN-based TET series PSUs are AC-to-DC front-end supplies. They include the TET3000 series, claimed to be the first AC-DC supplies to achieve Titanium efficiency with GaN being used in the AC-to-DC bridgeless totem-pole power factor correction (PFC) power stage — a product that has since been modified using the same circuitry with firmware improvements to become the TET3200 series based on customer interest in higher power output. The remaining four TET series range in power from 1.5kW to 2.5kW and are packaged in standard 1U or common redundant power supply (CRPS) rack-mount form factors. The entire family is said to deliver over 96% efficiency at high line with

a main output of 12V_{DC}, earning the PSUs an 80 Plus Titanium rating.

GaN for data-center power
GaN power converters offer fundamental advantages compared to silicon in power applications. Specifically, Transphorm’s GaN FETs are proven to increase the efficiency of the AC-to-DC PFC stage to over 99%, increasing power density while reducing overall system cost — all with a published field reliability of <1.0 FIT.

The use of GaN power transistors is hence expected to increase rapidly over the next few years. In fact, market research firm Omdia recently forecasted that the compound annual growth rate (CAGR) of GaN power transistors used in data-center power supplies will be 66.5% from 2019 to 2024.

“Our legacy is working with large data centers, creating a catalog of targeted power solutions that service the wide scope of applications used by our customers by leveraging cutting-edge technologies for the best possible performance results,” says Bel

Power Solutions’ business development manager Ian Warner. “We’ve been designing with Transphorm’s GaN for more than six years now. The efficiency and reliability we’ve been able to achieve to date has helped us create the TET family of supplies that are exceeding customer expectations with an unparalleled solution,” he adds. “We’re changing what’s possible in data centers and Transphorm is a contributor to that movement.”

“We’ve seen high-voltage GaN positively disrupt industries over the past few years,” says Philip Zuk, Transphorm’s VP of worldwide technical marketing & NA sales. “The data-center market is next. Transphorm’s technology performance is proven in excess of 10kW in various applications. Our device cost is driving down closer to silicon with each generation. And, we set the industry benchmarks for quality and reliability. We’re unsurpassed in that area, making our GaN devices an optimal choice for data-center solutions,” he reckons.

www.belfuse.com/power-solutions

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JEDEC WBG Power Semiconductor Committee publishes 'Test Method for Continuous-Switching Evaluation of GaN Power Conversion Devices' JC-70 Committee's JEP182 document complements JEP180 on how to use circuits for evaluating switching reliability

The JEDEC Solid State Technology Association (which develops standards for the microelectronics industry) has published 'JEP182: Test Method for Continuous-Switching Evaluation of Gallium Nitride Power Conversion Devices'. Developed by JEDEC's JC-70 Committee for Wide Bandgap Power Electronic Conversion Semiconductors, JEP182 is available for free download from the JEDEC website.

To enable the successful adoption of GaN power transistors, both reliable operation in power conversion applications and switching lifetime need to be demonstrated. JEP182, along with guidelines previously published by JC-70, helps to address that need by expanding the ecosystem of JEDEC guidelines for reliability evaluation, test and characterization of GaN power transistors under continuous switching conditions in power conversion applications.

Existing test methods for the Safe Operating Area (SOA) of silicon power transistors are not sufficient for full characterization of GaN

power transistors, notes JEDEC. GaN devices switch very rapidly and experience simultaneous voltage and current stresses during multiple switching events. Therefore, in addition to conventional SOA, it is necessary to test GaN power transistors under continuous switching conditions.

The JEP182 document describes test methods and suggests test circuits for continuous switching of GaN power transistors. JEP180, previously published by JC-70 and also available on the JEDEC website, describes how to use these circuits to evaluate switching reliability.

"As a much anticipated complement to the previously published JEP180, JEP182 will further help facilitate industry-wide adoption of GaN power devices for a broad range of applications and industries such as automotive and data centers," says JC-70 chair Dr Stephanie Watts Butler, technology innovation architect at Texas Instruments.

Formed in October 2017 with 23

member companies, JC-70 now has over 60 member companies, underscoring industry commitment to the development of universal standards to help to advance the adoption of wide-bandgap (WBG) power technologies. Global multinational corporations and technology startups from the USA, Europe, Middle East and Asia are working together to bring to the industry a set of standards for reliability, testing and parametrics of WBG power semiconductors. Committee members include industry leaders in power GaN and SiC semiconductors, as well as users of wide-bandgap power devices, and test & measurement equipment suppliers. Technical experts from universities and national labs also provide input.

JEDEC says that interested companies worldwide are welcome to join it to participate in this standardization effort. The next JC-70 committee meeting will be held on 16 February on a virtual platform.

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AXT's second-tranche private equity investment in China largely complete

Seven firms invest \$25m, with further \$1.5m to follow by end-January

AXT Inc of Fremont, CA, USA — which makes gallium arsenide (GaAs), indium phosphide (InP) and germanium (Ge) substrates and raw materials — says that the second tranche of the private equity investment in its China-based wafer manufacturing company Beijing Tongmei Xtal Technology Co Ltd was largely completed in December. The second tranche was originally scheduled to fund in January.

In December, seven private equity firms invested about \$25m in the second tranche. An additional \$1.5m is expected to be invested in January, closing the second tranche at about \$26.5m. The first tranche, totaling \$22.5m, funded in November. Upon completion of the final \$1.5m

investment, the capital raise will total about \$49m in exchange for a 7.28% minority interest in Tongmei.

Previously, on 16 November, AXT announced a strategic plan to access China's capital markets and progress to an initial public offering by Tongmei on the Shanghai Stock Exchange's Sci-Tech innovAtion boARd (the STAR Market). To qualify for a STAR Market listing, Tongmei is required to have multiple independent shareholders. The first major step in this process is engaging reputable private equity firms in China to invest funds in Tongmei.

"We are pleased that the second tranche participants accelerated the investment schedule," says CEO Morris Young. "Their strong support and enthusiasm underscore the

exciting applications and customer opportunities for which we are preparing this year, and their investment is an important milestone in Tongmei's progress toward a STAR Market IPO in 2022," he adds.

The process of going public on the STAR Market includes several periods of review and is therefore a lengthy process. Tongmei does not expect to accomplish this goal until mid-2022. AXT has posted a brief summary of the plan and the process on its website. The listing of Tongmei on China's STAR Market will not change the status of AXT Inc as a US public company, which will continue to be listed on the Nasdaq Global Select Market under the symbol AXTI.

www.axt.com

IQE's revenue grows 25% in 2020, exceeding 20% guidance

Net debt eliminated, due to strong trading, continued reduction in capital investment, and focus on cash management

In a pre-close trading update for 2020 (subject to external audit review), epiwafer foundry and substrate maker IQE plc of Cardiff, Wales, UK is expecting record full-year revenue of about £178m, up 25% on 2019's £140m, and consistent with guidance of at least £170m (up 20%).

IQE also highlights a net cash position of about £2m at the end of 2020 (compared with net debt of

£16m at the end of 2019), which it attributes to the strong trading performance, continued reduction in capital investment, and a focus on cash management.

Trading remained favourable in fourth-quarter 2020, and IQE enters 2021 with positive momentum in both the Wireless and Photonics business units, the firm notes.

"IQE has achieved real strategic progress over the past year with

excellent results," comments CEO Dr Drew Nelson. "We also demonstrated strong free cash flow of close to £18m, facilitating the transition to a net cash positive position at year end," he adds. "The whole IQE team contributed to this result and they have demonstrated outstanding resilience throughout what was a hugely challenging year globally."

www.iqep.com

Riber receives order from Asia for research MBE system

Projects to investigate 1.55µm lasers and properties of As/P thin films

Riber S.A. of Bezons, France — which manufactures molecular beam epitaxy (MBE) systems as well as evaporation sources and effusion cells — says that it recently received an order from a sciences and technology university

in Asia for a model C21 DZ research system, scheduled for delivery in 2021.

The university has several research projects planned for investigating the fundamental properties of arsenide/phosphide

thin films grown by molecular beam epitaxy, and a more applied program focused on telecom lasers operating around the 1.55µm wavelength for fiber-optic networks.

www.riber.com

AKHAN awarded further patents in Taiwan and Korea

Diamond semiconductor firm gains fourth patent in Taiwan and third in South Korea

AKHAN Semiconductor Inc of Gurnee, IL, USA — which was founded in 2013 and specializes in the fabrication and application of lab-grown, electronics-grade diamond as functional semiconductors — has been issued further patents for invention by the Taiwan and Korean Intellectual Property Offices. The patents cover additional claims for AKHAN's next-generation N-type diamond semiconductor electronics materials and devices. Applications for this technology platform span control & guidance electronics in military & space, power inverter for automotive, to FPGA and logic integrated circuits for the global semiconductor industry.

The Taiwanese-issued patent I711153 and South Korea-issued patent 10-2195950 are key additions to AKHAN's Miraj Diamond


intellectual property portfolio. It is the company's fourth issued patent from Taiwan and third issued patent from South Korea. The technology enables what is claimed to be breakthrough performance in semiconductor electronics. Through the integration of high-quality doped diamond in semiconductor electronics applications, the novel systems allow for next-generation electronics performance, including higher power & frequency capability, higher voltages of operation, higher current density, higher thermal conductivity/reduced thermal budget amongst other favorable attributes.

"Taiwan and South Korea both represent the global leadership when it comes to semiconductor foundries and production and are home to several of the largest chip foundries, including TSMC, SMIC

and Samsung, so it's important that AKHAN has an established presence in these countries, as well as the proper intellectual property protections in place," says CEO Adam Khan. "These patents will be critically important in advancing AKHAN's partnerships and relationships with companies throughout Taiwan, South Korea, and the world."

AKHAN's Miraj Diamond Electronics portfolio is at the center of the company's ability to manufacture next-generation diamond semiconductor technology. The platform enables fabrication of devices such as high-speed/power transistors, RF and microwave electronics. Fabricated devices have been shown to be faster, more efficient and >1000x thinner than the state of the art in both diamond and silicon.

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NCTU using Veeco's Propel MOCVD platform for GaN power and 5G device production

Veeco joins Taiwan consortium developing next-generation advanced power, communication and AI technologies

Epitaxial deposition and process equipment maker Veeco Instruments Inc of Plainview, NY, USA says that Taiwan's National Chiao Tung University (NCTU) in Hsinchu has selected it to be an essential collaborator in its initiative to drive Taiwan's semiconductor production through 2035. The collaboration consortium comprises leading universities and semiconductor manufacturers with the goal of developing the next generation of advanced power, communication and artificial intelligence (AI) technologies. Veeco says that its single-wafer Propel metal-organic chemical vapor deposition (MOCVD) platform serves a critical role in driving the consortium.

"The National Chiao Tung University and the Taiwan semiconductor industry have a long history of enabling global technology mega-

trends," states Edward Yi Chang Ph.D., senior vice president, dean of R&D and chair professor, NCTU. "Veeco brings world-class technologies and process know-how, and we have seen tremendous contributions from their single-wafer Propel platform, with its excellent performance and consistent results, while enabling scalability for the advanced development of GaN power and RF devices," he comments.

According to Allied Market Research, the GaN power device market size will rise at compound annual growth rate (CAGR) of 35% to \$1.24bn in 2027. Market analyst firm Yole Développement estimates that the total GaN RF market will grow at a CAGR of 12% from \$740m to more than \$2bn by 2025, driven largely by telecom and defense applications.

"We are proud to be a key contributor to the exceptional work of Dr Chang and the consortium he has assembled, and we are convinced this collaboration will result in game-changing contributions to the global semiconductor industry," comments Veeco's chief marketing officer Scott Kroeger. "Veeco's technology portfolio is focused on bringing unique value to semi and compound semi customers, and we are committed to driving exceptional progress in the fields of advanced power, communications, artificial intelligence and more," he adds. "We look forward to expanding our participation and driving the next generation of experience age technologies," Kroeger concludes.

www.veeco.com
www.nctu.edu.tw

Taiyo Nippon Sanso MOCVD equipment division wins industry award

Japan Society recognizes contribution to surface and vacuum science-related industries

Taiyo Nippon Sanso Corp (TNSC) of Tokyo, Japan says that its metal-organic chemical vapor deposition (MOCVD) equipment division for gallium nitride (GaN) and aluminium nitride (AlN) devices has received the 2020 Industry Award from The Japan Society of Vacuum and Surface Science.

The award is presented annually by The Japan Society of Vacuum and Surface Science to recognize significant contributions to the advancement and development of the surface and vacuum science-related industries.

TNSC has been developing MOCVD compound semiconductor

production equipment since 1983, and has delivered more than 500 MOCVD equipment systems to manufacturers and research institutions in Japan and abroad.

In 2015, TNSC developed the SR4000HT reactor model for high-Al-content aluminium gallium nitride (AlGaIn) ultraviolet (UV) light-emitting devices. The SR4000HT allows AlGaIn film to be deposited at a high temperature (greater than 1300°C). Processes for UV LED epitaxial wafers with high luminous efficiency have been demonstrated.

In 2012, TNSC introduced the UR26K reactor model, a large-scale

mass-production platform that can process 8-inch substrates. High-performance mass production of GaN high-electron-mobility transistors (HEMTs) on 8-inch silicon substrates has been demonstrated. The UR series reactors optimize film properties and productivity by reducing the operating time and supporting cleaning technology for reactor components.

TNSC says that it aims to continue to promote environmental and energy conservation initiatives in the industry by introducing new technologies and products.

www.tn-sanso.co.jp/en
www.mocvd.jp

Aixtron CVD system begins production of large-area graphene layers

GIMMIK project targets industrial application of graphene and hBN

As part of the research project GIMMIK (Graphene processing on 200mm wafers for microelectronic applications), a new industrial-grade chemical vapor deposition (CVD) reactor for processing graphene and hexagonal boron nitride (hBN) — developed, built and installed by Aixtron SE of Herzogenrath, near Aachen, Germany — has gone into operation for the production of large-area graphene layers.

Building on the existing knowledge of showerhead-based CVD systems, the reactor specially developed for this application can achieve the tight product specification needed for industrial application of these materials.

The GIMMIK project should lead to the industrial application of graphene and hBN, so the production of graphene layers is hence to be evaluated under industrial conditions. The consortium partners are developing methods to ensure consistently high graphene and hBN quality as a basis for the suitability for production in deposition and integration processes.

Aixtron is now starting the production of GR/hBN layers for consortium partners and the optimization of the layers and processes. Participants in the project are the research center IHP – Leibniz Institute for Innovative Microelectronics, the firms Infineon, Protemics and LayTec, and RWTH Aachen University. Aixtron is the project coordinator.

Supporting the industrial application of graphene/hBN

“After installation and test of the new CVD system we have taken a decisive step forward... because we now have the specific system and thus the instrument with which we can start our work on developing of processes for the production of layers with the necessary wafer size and quality,” says Dr Michael Heuken, Aixtron’s vice president corporate R&D and professor at RWTH Aachen University. “This is extremely important for applications in the fast growing markets of microelectronics and sensor technology,” he adds. “Now we are ready for the next, exciting steps towards new devices and new applications as well as production in this important research project.”

Graphene and hBN could be decisive drivers in the development of innovative products and in achieving the required energy efficiency in view of the climate crisis, reckons Aixtron. A wide range of applications such as transistors, sensors and photonic devices are possible. Due to its extremely high charge carrier mobility, graphene opens up the possibility of manufacturing radio-frequency transistors with cut-off frequencies in the terahertz (THz) range. Numerous applications in energy-efficient high-frequency electronics are conceivable for them. “Graphene and CVD-grown hBN could thus make a

significant contribution to one of the major challenges, namely the need for significantly higher energy efficiency,” says Heuken.

Potential for improving energy efficiency

Graphene can not only be used for sensors for vehicle safety in the automotive sector. Mobile applications (e.g. smartphones, watches) are also playing an increasingly important role. Graphene is an important building block for achieving competitive advantages with products such as magnetic sensors, microphone pressure sensors or optical sensors, in which graphene can be used as a functional and market-differentiating component, says Aixtron.

Last but not least, new combinations of wafer-level-based graphene and silicon photonic devices are possible. These would allow the creation of graphene-based modulators with high thermal stability and significantly reduced device footprint and also photodetectors that offer superior performance to currently available photonic integrated components (silicon and III/V semiconductors).

The GIMMIK project is funded by Germany’s Federal Ministry of Education and Research (BMBF) (funding number: 03XP0210A).
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EVG Academy established for customer training

Training space and technical trainers doubled

EV Group of St Florian, Austria — a supplier of wafer bonding and lithography equipment for semiconductor, micro-electro-mechanical systems (MEMS) and nanotechnology applications — has established the EVG Academy, a training facility for customers that provides technical training on all classes of EVG equipment as well as on the firm's CIM Framework software platform in an optimized environment.

Established at the firm's headquarters, the EVG Academy comprises a new 800m² facility created in tandem with the Cleanroom V expansion project (completed in July 2020). By attending in-depth, tiered training classes at the EVG Academy, customers can be qualified to perform basic repairs as well as preventative maintenance on equipment without the need to contact customer support, providing greater flexibility for tool maintenance. The new training facility also serves as the education and training hub for EVG's global organization.



"The EVG Academy was purpose-built with the goal to enable in-depth customer training on all EVG platforms utilizing the latest equipment and technologies, including our most advanced fully automated high-volume manufacturing (HVM) tools," says Helmut Pfeifer, VP of customer support. "EVG has made significant investments in updating our training infrastructure, and we are extremely proud of this world-class facility, which sets new standards for knowledge transfer in our industry," he claims. "The new EVG Academy will greatly enhance the learning experience for both our customers and our international

customer support teams."

The EVG Academy builds on the firm's existing training facilities at its headquarters, doubling the amount of training space and technical trainers. It includes eight individual training areas — one for each major class of EVG equipment

— as well as four classrooms and a dedicated workshop area for electrical and mechanical training. Due to the additional floorspace, the EVG Academy has also expanded the number and type of tools available for training, including the firm's fully automated HVM platforms, such as the GEMINI FB automated production wafer bonding system with SmartView NT3 bond aligner and the BONDSCALE automated production fusion bonding system.

The EVG Academy is now open for training. Interested customers can contact academy@evgroup.com.

www.evgroup.com/products/process-services

k-Space offers new accessory for in-situ metrology tools

Wafers and platen viewable in real-time from within k-Space software

k-Space Associates Inc of Dexter, MI, USA — which makes in-situ, ex-situ and in-line thin-film metrology instrumentation for both research and manufacturing of microelectronic, optoelectronic and photovoltaic devices — has added a new accessory, kSA Insight, for its metrology tools.

The tool allows researchers and operators to view their wafers and platen in real-time from within the k-Space software. The imaging system uses a high-resolution color camera and is plug-and-play compatible with all k-Space thin-film metrology software.

"Several customers have requested the ability to see their wafers and platen from their computer screen during deposition, so we designed



Left: The kSA Insight without the protective cover, revealing the camera and optics in the system.

Right: Protective cover in place as the system would be used in a research or production environment.

kSA MOS or kSA ICE, you can seamlessly view your platen and wafers with this plug in."

Customers can adapt the accessory to viewports of various sizes, and the included zoom lens allows for focus over a large range of working distances. The live video can be zoomed in or out, and full-resolution

this tool to seamlessly integrate with their existing k-Space software," says CEO Darryl Barlett. "So, whether you are running kSA 400, kSA BandiT,

color images can be snapped and stored at any time from within the k-Space software.

www.k-space.com

MRSI and Palomar settle litigation

IP dispute ended with respect to all existing product lines

MRSI Systems LLC of North Billerica, MA, USA (which makes fully automated, high-precision high-speed die bonding and epoxy dispensing systems) and photonics and microelectronic device assembly & packaging equipment maker Palomar Technologies Inc of Carlsbad, CA, USA have reached a confidential agreement that settles all litigation pending between them.

Filed by MRSI in the United States District Court for the Southern District of California in December 2019, the patent infringement lawsuit alleged that Palomar's die, wire and wedge bonder products infringed MRSI's US Patent Nos.:

- 7,324,710 'Method and Device for Determining Nominal Data for Electronic Circuits by Capturing a

Digital Image and Compare with Stored Nominal Data';

- 9,032,611 'Apparatus for Generating Patterns on Workpieces';
- 9,648,795 'Pick-and-Place Tool';

and

- 7,109,510 'Method and Apparatus for Aligning a Substrate on a Stage'.

These patents cover core functionalities used in Palomar's main product lines.

MRSI also continued to challenge a patent lawsuit filed by Palomar in 2015 in Southern California that MRSI successfully transferred to its home district court in Boston, Massachusetts in 2018 (Palomar Technologies Inc vs MRSI Systems LLC, Case No. 1:18-cv-10236-FDS (D. Mass.)). MRSI maintained that

Palomar's US Patent No. 6,776,327 asserted in that lawsuit was invalid on numerous grounds, including because the patent claims were directed to ineligible subject matter, and were invalid in light of prior art as well as MRSI's marketing and sales of the relevant technology in its own products many years before Palomar filed for its invalid patent. MRSI previously invalidated one of Palomar's three independent claims through the Inter Partes Review process before the US Patent & Trademark Office.

The settlement ends the intellectual property disputes between the companies with respect to all existing product lines.

www.mrsisystems.com

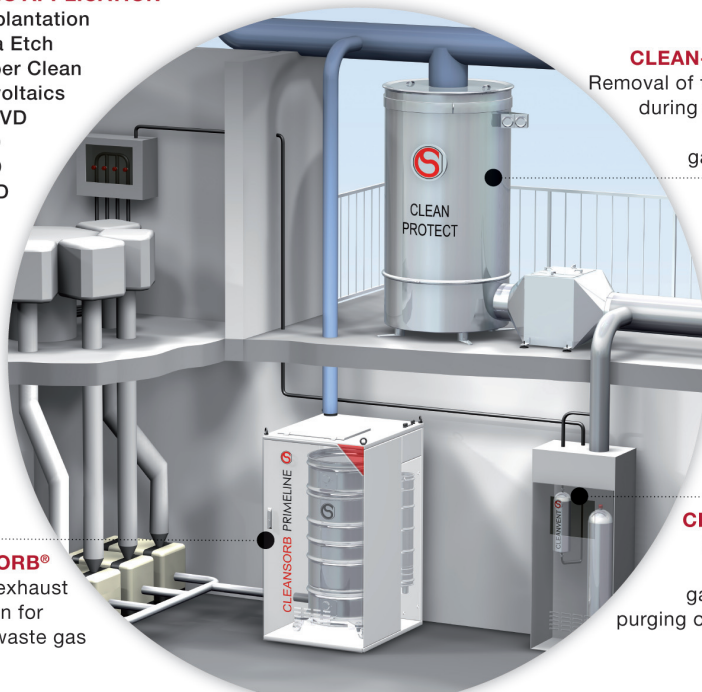
www.palomartechologies.com



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www.csclean.com

NS Nanotech showcases portable far-UVC ShortWaveLight Purifier at Consumer Electronics Show

Emitters of 200–230nm germicidal light target coronavirus on surfaces and in air

In its virtual booth at the All-Digital Consumer Electronics Show (CES 2021) on 11–14 January, NS Nanotech of Ann Arbor, MI, USA highlighted its ShortWaveLight Purifier, along with products and services being developed by early-adopter customers.

Drawing on a decade of work on nitride semiconductors by researchers at McGill University and the University of Michigan, NS Nanotech's patented technologies are said to dramatically improve the fabrication process and resulting efficiency of nano-scale light-emitting materials.

To be available in 2021, the portable ShortWaveLight Purifier is claimed to be the first personal, portable product to inactivate coronavirus and other pathogens on surfaces and in the air by using far-UVC germicidal light.

It is powered by NS Nanotech's solid-state ShortWaveLight Emitters, which are claimed to be the first solid-state products to emit short-wavelength ultraviolet light in the far-UV range of 200–230nm. Unlike standard UV bulbs, which operate at high temperatures and require the use of caustic gases, they run cool, are small enough to integrate into portable tabletop devices, and do not use dangerous gases, notes the firm.

ShortWaveLight to power Kryptolights

Initial customer Kryptolights is utilizing ShortWaveLight Emitters in a new suite of commercial and residential products for cleansing pathogens from the environment. "This essential technology is vital to curbing the current pandemic and in preventing one in the future," believes Kryptolights' co-founder Shey Godoy. "Many industries could utilize our products to regain people's trust by offering customers a

clean environment to conduct business. This spectrum of light offers normalcy, as it can seamlessly integrate into people's businesses and lives."

UV Ray Lights to rent ShortWaveLight emitters to event planners

Another new customer, UV Ray Lights (which utilizes years of experience in specialized lighting to bring a safer UV germicidal light to events), is to rent out tabletop UltraClean UV sterilizers equipped with ShortWaveLight Emitters to meeting and event organizers. Through collaboration with NS Nanotech and Kryptolights, UltraClean UV can be deployed at events ranging from conferences to conventions. Each device assigned to an attendee will sterilize surfaces and air in front of it, reducing the viral load in the room, says co-founder Ray Stewart.

"Now we are ready to deploy a real tool to help curb the rising infection rates not only of the current pandemic, but from other viruses and germs people share when they gather for conferences or conventions. Scientific studies are coming out consistently now showing that the real potential of this technology is just emerging," he adds.

"We are excited to be on the forefront of bringing it to the marketplace through our unique rental service. It will now be possible for businesses and industry to gather together for networking, education and other important in-person events."

Many industries could utilize our products to regain people's trust by offering customers a clean environment to conduct business

Far-UVC disinfection

The market for disinfection solutions using UV light is 100 years old, but the COVID-19 pandemic set suppliers in the UV market on a search to address the unprecedented disruption to the global economy and daily life for communities worldwide, says NS Nanotech. The far-UVC range of light can inactivate pathogens (including coronaviruses) by attacking their RNA and making it impossible for them to reproduce. Also, recent scientific studies have found that, due to its short wavelength of 230nm or less, far-UVC light does not penetrate living cells on the surfaces of skin and eyes.

"Revolutionary solid-state nanotechnologies from NS Nanotech are making it practical to deploy short-wave far-UVC light in many settings," says Godoy. "Unlike standard UV bulbs, which operate at high temperatures and require the use of caustic gases, the solid-state ShortWaveLight Emitters run cool, are smaller, and do not use dangerous materials. Whereas previous UV emitters were difficult to operate, now we can bring Kryptolights UltraClean solutions to the market and make a difference in everyone's lives," he adds.

"We are delighted to announce our partnerships with both UV Ray Lights and Kryptolights on the eve of CES," says CEO & co-founder Seth Coe-Sullivan. "We designed our new solid-state far-UVC ShortWaveLight Emitters to be useful for thousands of applications that will protect consumers and businesses from coronavirus and future pathogens," he adds. "Kryptolights and UV Ray Lights are early adopters developing innovative far-UVC disinfection solutions that we expect will have a big impact in the near future and in coming years."

www.nsnanotech.com

SETI and Seoul Viosys' Violeds technology kills 99% of coronavirus within a second

KR Biotech verifies sterilization results for UV LED technology

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 UV LED product maker Seoul Viosys Co Ltd (SVC) — both subsidiaries of South Korean LED maker Seoul Semiconductor — say that their Violeds technology has been shown to quickly and effectively kill 99.437% of SARS-CoV-2 coronavirus in less than 1 second. Testing was conducted in December through KR Biotech, a South Korea-based research institute specializing in sterilization testing of the new coronavirus.

The test results demonstrate that Violeds UV LED technology could be an effective method to disinfect

airborne viruses, water systems and areas where COVID-19 patients are housed, including hospital rooms, say the firms.

After exposing SARS-CoV-2 to the Violeds UV LED module for 1, 3 and 5s respectively, the research team observed an inactivation rate of virus particles of 99.437% within 1 second.

Test results demonstrate that Violeds UV LED technology could be an effective method to disinfect airborne viruses, water systems and areas where COVID-19 patients are housed

"The COVID-19 pandemic and the accompanying risk of virus variants continue," comments

Seoul Viosys. "Despite vaccination with influenza vaccines, flu deaths in the US average more than 10,000 per year. As hundreds of millions of people around the world are exposed to various infectious diseases, prevention through disinfection is now an essential method for reducing infections," it adds. "Due to the hazards of chemical disinfection methods, professionally designed UV LED disinfection systems represent a safer solution and may be the world standard in the future."

SETI currently has two sample disinfection products demonstrating UV-C LED technology available for purchase at <https://violedsstore.com>.

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

AquiSense's PearlAqua Micro water disinfection range approved by NSF to new Standard 55

UV-C LED product range first fully certified to NSF/ANSI 55-2019

Nikkiso Group company AquiSense Technologies LLC of Erlanger, KY, USA (which designs and manufactures water, air and surface disinfection systems based on UV-C LEDs) claims Class B component certification for its PearlAqua Micro range.

Multiple models were tested and certified by NSF International (which develops public health standards and certification programs that help to protect food, water, consumer products and environment) in compliance with the new NSF/ANSI 55-2019 standard for disinfection performance, materials compliance, and structural integrity. Standard 55, Class B, certifies ultraviolet water systems for supplemental bactericidal treatment of disinfected public drinking water and is commonly specified for drinking water products.

As the first range of products using mercury-free, instant-on, UV-C LED technology, this opens considerable opportunities for use in residential and commercial point-of-use water dispensers, reckons AquiSense.

The PearlAqua Micro is claimed to be the smallest UV-C LED water treatment system, and production has already exceeded 10,000 units per month. The platform includes five discrete model sizes and a range of custom variants offering flow rates of up to 8 liters per minute (LPM). Supplemental third-party disinfection validation in accordance with US EPA UV Disinfection Guidance Manual protocols show up-to 6-log (99.9999%) bacterial reduction, with additional certifications and compliance including: Watermark – AZ/NZS 3497:1998; EMC – EN 55022; CB

scheme – IEC 60335 & IEC 62471; CE; RoHS; REACH; Japan Food Sanitation and Water Works Law (pending); and WRAS – BS 6920 (pending).

This wide range of certifications make the PearlAqua Micro platform the most extensively tested UV-C LED water treatment product on the market, it is claimed. It is manufactured in the AquiSense Kentucky, USA facility to ISO-9001:2015 quality standards.

"Our team has worked for years supporting NSF International to ensure the new 55 Standard is robust and future-proof," says chief technology officer Jennifer Pagan PhD. "Our OEM partners will now benefit from the added claim of integrating an NSF-certified component."

www.aquisense.com

Epistar and Lextar form JV Ennostar, targeting mini/micro-LEDs

Integrated compound semiconductor group to span epitaxy, chips, packaging, modules, and foundry

Ennostar Inc has been formally established as a joint venture between Epistar Corp and Lextar Electronics (via a share swap) and listed on the Taiwan Stock Exchange (with the stock code 3714).

Epistar and Lextar will still operate independently under Ennostar, which comprises three business areas: Epistar will focus on upstream LED epitaxy and chips, Lextar will focus on downstream packaging and modules, and Unikorn Semiconductor Corp (under Epistar) will develop compound semiconductor foundry.

Collectively, Ennostar aims to be an integrated compound semiconductor group, providing a one-stop service.

Focusing on the rapid development of mini/micro-LED displays as well as the next-generation compound semiconductor market, the establishment of Ennostar targets industrial collaboration and resource integration in Taiwan. In addition to investing in mini/micro-

LEDs, Ennostar aims to speed the development of advanced technology in automotive, sensing, power device, 5G communication and wafer manufacturing.

Specifically, in response to the fast development and strong market demand for compound semiconductors, Ennostar will participate in the power electronics and wireless communication sectors, providing technologies and services for fast charging, electric vehicle (EV) and 5G communication applications.

At the meeting of Ennostar's board of directors, Epistar's chairman Dr Biing-Jye Lee was appointed chairman & CEO of Ennostar, Lextar's chief financial officer Bo-yi (B.Y.)

Ennostar aims to speed the development of advanced technology in automotive, sensing, power device, 5G communication and wafer manufacturing.

Chang was appointed CFO & spokesman, and Epistar vice president Rider Chang was appointed officer of corporate governance.

"Ennostar is the only investment platform in the compound semiconductor industry that incorporates both LED and advanced compound semiconductor technologies," claims Biing-Jye Lee. "In the future, it will contribute to the advancement of mini/micro-LED display, sensing, automotive, power and 5G communication applications," he adds. "Epistar and Lextar are actively accelerating the integration of the two companies, which will give full play to the synergy of industrial resource in a short period of time," he adds. "We are cautiously optimistic about 2021 and be ready to embrace market recovery in the coming years."

www.epistar.com.tw
www.ennostar.com
www.lextar.com

Rohinni doubles mini-LED placement speed with 100Hz placement technology

High-volume mini-LED manufacturing given boost

Rohinni LLC of Coeur d'Alene, ID, USA (which has developed a proprietary method for transferring mini- and micro-LEDs to substrates) has achieved what it claims is the fastest proven mini-LED placement speed of 100Hz with its new bondhead. The new technology effectively doubles placement speed and halves the cost of placing mini-LEDs compared with the firm's first generation of placement technology.

"In 2021, we will start to see mainstream adoption of premium products using mini-LEDs in TV,

video wall and consumer electronics applications like tablets and notebooks," says CEO Matt Gerber.

"Our new bondhead technology is driving this market by enabling true high-volume manufacturing at a lower cost," he adds. "This translates into less expensive devices for consumers, which will drive adoption and spur manufacturers to start implementing new designs for the coming wave of mini-LED-based products," Gerber says.

Rohinni says that its placement technology enables its joint ventures

in design and manufacturing of mini-LED-based logos and keyboard backlighting (Luumii), displays (BOE Pixey) and mobility (Magna Rohinni Automotive) to provide faster speeds, resulting in lower manufacturing costs.

Rohinni says that OEMs in markets ranging from consumer to automotive to outdoor signage can incorporate its technology, yielding products that are brighter, thinner, lighter, lower power and more dynamic than those currently on the market.

www.rohinni.com

Asahi Kasei & Crystal IS launch second round of UV Accelerator funding initiative

Ideas sought on returning people to offices or commercial buildings safely post-COVID

Crystal IS Inc of Green Island, NY, USA, which makes proprietary ultraviolet light-emitting diodes (UVC LEDs), and its parent firm Asahi Kasei have announced the second round of their UV Accelerator funding initiative for supporting the development of new disinfection products that use ultraviolet-C (UVC) LEDs. Following the funding of two companies in the first round (launched in June 2020), the endeavor again aims to team up with innovative companies that have ideas for new applications of UVC LEDs in a post-COVID world by providing investments of up to \$250,000 per company.

Led by Dr Steven Berger, managing director of Asahi Kasei America

and former CEO of Crystal IS, the UV Accelerator has been established as a proactive measure for developing solutions that can be used to stop the spread of deadly viruses and bacteria and help to provide information to further contribute to the ongoing fight against COVID.

At its sole discretion, Asahi Kasei will fund successful applicants up to \$250,000 per company to support and accelerate product development. Crystal IS will provide engineering expertise for the design and control of the UVC LED light source, as necessary. Applications are currently being accepted and screened for organizations with ideas for UVC LED-based disinfection

products, and discussions are expected to begin this March.

In the first round of the AK UV Accelerator, many creative ideas for UVC-based products were received and, as a result, two investment awards were made. In this second round the Accelerator is again looking for creative product ideas but particularly encourages ideas on how UVC-based hardware and software can be safely used to help people (employees or customers) to become comfortable with returning to offices or commercial buildings.

Second-round applications for funding to www.uvaccelerator.com will be accepted until 31 March.

www.uvaccelerator.com

www.cisuv.com/products/klaran

Lumileds prevails at ITC over LSG's LED chip patents

Lighting Science Group's patent ruled invalid; investigation terminated

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

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

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

"We are pleased with the ITC's thoughtful analysis of the issues and findings of no violation," comments Lumileds' chief legal officer & senior VP Cheree McAlpine.

"We will continue to defend and protect our valuable intellectual property rights while respecting those of others."

www.lumileds.com

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Osram's launches Osconiq C 2424 high-power LED for outdoor lighting

First CSP LED with integrated ESD enables dense clustering

Osram Opto Semiconductors GmbH of Regensburg, Germany says that its new compact high-power LED Osconiq C 2424 offers a broad color temperature range from cool to warm white and various color rendering indices (CRIs), enabling a large variety of different lighting designs. The firm also says that it is the only chip-scale package (CSP) LED with an integrated electrostatic discharge device (ESD) available on the market, protecting the LED from any electrostatic damage.

The Osconiq C 2424 is suitable for high-power applications and is available in three CRIs: 70, 80 and 90. It spans the 2200-6500K color temperature range. In particular, the CRI 70 version achieves luminous flux of 328 lumens at a drive

current of 700mA and a luminous efficacy of 167 lumen per watt.

"The quality of our LEDs is as important to our customers as our ability to create lighting solutions that reduce their overall system costs," says Mike Martens, senior product manager at Osram Opto Semiconductors in North America.

"Within its compact design, the Osconiq C 2424 does both, all the while providing long-lasting performance with a high level of brightness and efficiency."

Lighting manufacturers can also benefit from the LED's robust epoxy package, which provides increased stability and protects the component from corrosion and external shocks. Other advantages include what is claimed to be the lowest

thermal resistance (R_{th}) and best color-over-angle performance for a CSP product on the market. In addition, the Osconiq C 2424 features Osram's proven UX:3 chip technology and an integrated ESD, which protects against damage caused by electrostatic voltages up to 8kV.

The Osconiq C 2424 package measures 2.4mm x 2.4mm x 0.6mm. The chip or the light-emitting surface (LES) of the LED is 2.1mm x 2.1mm. Because the package and chip have approximately the same dimensions, it is considered to be a CSP. This allows the individual LEDs in the luminaire to be placed close together, ensuring homogeneous illumination, says the firm.

www.osram.com

Nichia unveils dual-function LED for general lighting and bacteria disinfection

Visible 380–420nm light inactivates *Pseudomonas aeruginosa* by 98.9% after 5 hours

Nichia Corp of Anan City, Tokushima, Japan has announced a new dual-function LED that provides both white light and high doses of energy geared for the inactivation of various prevalent bacteria.

UV-C and UV-B wavelengths (ranging from ~200–380nm) have long been used for disinfection. However, it has recently been proven that visible light, ranging from ~380–420nm, also has a bacteria disinfection effect.

With the continued surge of the COVID-19 pandemic and the global impact, there is a heightened awareness of cleanliness in all aspects of life, says Nichia. While this certainly applies to viruses, it also applies to various types of bacteria present in daily

living environments.

Typical examples of bacteria that cause infections are *Pseudomonas aeruginosa* and *Staphylococcus aureus*. Additionally, *Escherichia coli* (e-coli, O157), which causes food poisoning, continues to plague various parts of the world and remains problematic.

Nichia says that, to assist with the global efforts in reducing these harmful bacteria, it has developed an innovative white LED that is also capable of inactivating bacteria. The new 4.0mm x 3.6mm NF2W585AR-P8 LED has a peak pump emission wavelength of ~405nm, and is a staple of Nichia's General Lighting portfolio. Nichia says that, through its phosphor and die technology (which has been refined over decades of innovation),

it is able to achieve a balance between general white lighting and disinfection bacteria, all out of a single LED.

In tests at the Tokushima Prefectural Industrial Technology Center using a lightbar fixture comprising nine NF2W585AR-P8 LEDs, results indicate an inactivation rate for *Pseudomonas aeruginosa* bacteria (at a temperature of 25°C) of 98.9% after 5 hours of irradiation with 380–420nm light from a distance of 40cm (a luminous flux per unit area of 1000lx, or 0.127mW/cm²).

Nichia envisions that this LED will be widely used for environmental hygiene maintenance in food factories, kitchens, hospitals, public facilities and similar applications.

www.nichia.co.jp

Ushio Deutschland and BLV merge to form Ushio Germany

Ushio Deutschland GmbH of Steinhöring, Germany, which was founded in 1992 as a European production and distribution base of Japanese laser & LED lighting manufacturing parent company Ushio Inc, is to merge on 1 February with its Steinhöring-based sister firm BLV Licht- und Vakuumtechnik GmbH to form the new company Ushio Germany GmbH. The merger aims to ensure consistency by unifying Ushio's European entities

under a common English language naming convention.

BLV, a well-known brand of lighting manufacturer in the horticulture industry, will continue to operate independently within the new company.

From 1 February, the five core companies of the Netherlands-based Ushio Europe group will be legally registered as: Ushio Europe B.V., Ushio France S.A.R.L., Ushio Poland Sp. z o.o., Ushio U.K Ltd,

and Ushio Germany GmbH.

Ushio Europe group reiterates to its customers and partners that, regardless of region, the name change will not affect any existing or future orders, contracts or framework contracts etc. As part of the rebranding process, all invoicing, packaging and related documentation will switch to the new Ushio Germany GmbH name and related data from 1 February.

www.ushio.de

Ushio achieves record 19W output for single-chip 850nm IR LED

In February, Ushio is releasing the SMBB850DS-1200 series of 850nm infrared LED packages. Intended for imaging and analysis under infrared (IR) illumination using surveillance cameras, automatic number-plate recognition (ANPR) and similar devices, the new product has achieved both narrow-angle irradiation (down to $\pm 19^\circ$) and record power output for a 850nm infrared LEDs, of 4W per package in CW operation (three times that of conventional LEDs) and 19W per package in pulsed mode (five times conventional LEDs).

Compared with the existing SMBB850DS-1100 LED for use with surveillance cameras, the SMBB850DS-1200 has achieved five times higher output per package, an irradiated area about four times wider, and about two times higher central illuminance, when used for long-distance irradiation.

This is the latest model in the SMBB family of high-power LED packages, which were developed by Ushio in 2013 and have been used for diverse applications including the quality inspection (sorting) of food and other products, medical devices, and defect inspection. At 850nm wavelength, the SMBB850DS-1200 realises narrow-angle irradiation and record power output, which is effective for long-distance irradiation, so it permits long-distance imaging

using a surveillance camera, ANPR, or similar device. Further, the high output power permits a reduction in the number of LED packages per system, enabling infrared irradiation equipment to achieve smaller dimensions and lower costs. The new product hence contributes to increased adoption of surveillance systems, and eventually to building a social environment with increased security and peace of mind, Ushio reckons.

Development background

Reflecting the growing awareness of safety and security among people in recent years, surveillance cameras have begun to be used not only in buildings but also outdoors, such as in areas around buildings, parking areas, and city streets. The application of ANPR has also been expanded to expressways and public highways. Amid this trend, the distances that infrared illumination for outdoor surveillance cameras are required to irradiate have increased (to distances ranging between one hundred and several hundred metres), demanding higher power.

In addition, while LED packages with lenses are used for the narrow-angle irradiation (which is necessary for long-distance irradiation using infrared rays), multiple packages need to be aligned in these units to provide a sufficient amount of light. This results in

larger size, larger area required for installation, and higher cost of the irradiation equipment. Further, while there is technology for mounting multiple chips in a package to provide sufficient light, a large-sized outer lens must also be mounted on these packages to enable narrow-angle irradiation. This technical challenge had to be overcome to achieve further downsizing.

Increasing LED chip area and adapting package with a lens

In response, Ushio has developed the SMBB850DS-1200 series package with a lens, which is capable of emitting a narrow-angle beam (with a selection of lenses available with light distribution angles ranging from $\pm 61^\circ$ down to $\pm 19^\circ$, according to the installation environment) using only one chip while significantly increasing the output power per package with a larger LED chip area. This enables a reduction in the number of packages mounted on the irradiation equipment for surveillance cameras or ANPR and removes the need for an outer lens, allowing systems to be miniaturized and their cost reduced.

The product can also realize an irradiation area four times wider and two times brighter in central illuminance than conventional products when used for long-distance irradiation (100m or longer).

ams introduces first AEC-Q102- and ISO 26262-compliant VCSEL flood illuminator

Multiple-wavelength and field-of-illumination options allow optimization for in-cabin sensing applications such as driver monitoring, interior monitoring and gesture sensing

High-performance sensor designer and manufacturer ams AG of Premstaetten, Austria has announced the pre-release of the TARA2000-AUT family of vertical-cavity surface-emitting laser (VCSEL) flood illuminators for automotive applications — claimed to be first to be qualified to the AEC-Q102 automotive quality standard and the ISO 26262 functional safety standard.

TARA2000-AUT products are suitable for new optical in-cabin sensing (ICS) systems based on two-dimensional near-infrared (2D NIR) imaging or three-dimensional (3D) time-of-flight (ToF) sensing, which support the next generation of assisted and autonomous driving technologies in vehicles.

In driver monitoring systems (DMS) — which track whether the driver is alert and attentive while driving — high optical power distributed over the whole field of illumination (FOI) means that a single TARA2000-AUT illuminator can replace multiple lower-power emitters. This offers automotive OEMs savings in space, component count, and cost, says ams. With peak optical output centered at 940nm and a very narrow spectrum, the TARA2000-AUT also makes it easy for automotive OEMs to achieve high immunity to interference by sunlight, improving the monitoring system's performance and reliability, says ams.

The TARA2000-AUT is also available with an ultra-wide FOI to give what is described as excellent responsiveness in gesture-sensing applications for use by both the driver and passengers. The wide-FOI version is also suitable for interior monitoring systems, for example for the detection of passengers who should be wearing a seat belt, or for the detection of



baby seats and child passengers for automatic airbag adjustment. These systems also help to detect children, pets or objects left behind inside parked cars (which is a potential cause of serious harm that can be prevented by the implementation of optical interior monitoring).

The availability of ams' high-performance, AEC-Q102-qualified product has finally given automotive OEMs the confidence to switch to VCSEL technology for in-cabin sensing applications, says Firat Sarialtun, In-Cabin Sensing segment manager at ams. "Technical evaluation of the optical characteristics of the TARA2000-AUT shows that its high optical power uniformly distributed over the whole FOI gives a high signal-to-noise ratio and provides high image quality, so minimizing the number of illuminators needed for the scene. Our solution's excellent thermal behavior also ensures stable operation at all temperatures without sacrificing optical power, and eliminating the need for additional cooling measures," he adds. "By using the TARA2000-AUT, automotive manufacturers can develop in-cabin sensors which perform better at a lower system cost."

Integrated supply chain

ams says that automotive manufacturers can take assurance from its vertically integrated manufacturing model for VCSEL illuminators, which enables it to make high-volume production commitments without depending

on third parties for key elements of the product. The TARA2000-AUT is a combination of a VCSEL emitter designed and manufactured in-house by ams and an optical diffusor made with proprietary ams micro-lens array technology, all integrated into a single module.

Matching the micro-optics to suit the characteristics of the VCSEL emitter, the illuminator produces a uniform beam with edge-to-edge high-power illumination over a rectangular field. This tightly controlled illumination profile and FOI match the field of view of the IR image sensors used in 2D and 3D systems, increasing the strength and integrity of the reflected optical signal.

Range of product options

The TARA2000-AUT family of illuminators offers two wavelength options:

- 850nm for systems requiring maximum sensitivity at the CMOS image sensors; and
- 940nm to avoid visible red glow and interference from sunlight.

Depending on the wavelength of choice, the TARA2000-AUT is available with an ultra-narrow, narrow or ultra-wide FOI. TARA2000-AUT flood illuminators are available for sampling now.

<https://ams.com/TARA2000-AUT>

ams introduces VCSEL IR emitters for industrial mass-market 2D/3D sensing

Wavelength and field-of-illumination options suit ranging, object detection and face recognition applications

High-performance sensor designer and manufacturer ams AG of Premstaetten, Austria has introduced the EGA2000 family of infrared vertical-cavity surface-emitting laser (VCSEL) flood illuminators, which can help industrial manufacturers to develop new applications for robots, cobots (collaborative robots), autonomous guided vehicles (AGV) and smart devices that perform 2D and 3D optical sensing.

With everything including VCSEL and diffuser managed in-house by ams for tight quality control and supply-chain management on key components, the new flood illuminators provide uniform, tightly controlled and high-output power illumination, says ams. This is essential for evolving applications using ranging, object detection and face recognition, which use 2D and even the more sophisticated 3D sensing techniques based on time-of-flight (ToF) or stereo vision (SV).

The implementation of 3D sensing was pioneered in mobile phones, where it is used for secure face recognition. It is now emerging in the industrial mass market as a technique for applications such as:

- object dimension detection in robotics;
- 3D mapping of the environment supporting the operation of AGVs (including automatic vacuum cleaners and lawnmowers);
- face recognition in industrial systems such as e-payment kiosks and smart locks; and
- night-vision cameras.

"The rate of innovation in markets such as logistics and warehousing, home and building automation, and Industry 4.0 is remarkable," says Markus Luidolt, senior marketing director for 3D Sensing Modules and Solutions at ams. "A mass market is emerging for new



IR emitter architecture. Matching the micro-optics to suit the characteristics of the VCSEL emitter, the EGA2000 illuminators produce a uniform beam, which has a homogeneous rectangular profile. This tightly controlled illumination profile and field of illumination (FoI)

product categories such as home cleaning robots, cobots to assist human factory operators, and AGVs to replace conventional fork-lift trucks in warehouses," he adds. "The superior optical performance of the EGA2000 family and the range of options which it provides will help industrial companies to achieve more reliable ranging and depth mapping, speeding the go-to-market with fewer design iterations and less system debugging. Furthermore, to support customers' R&D investments in industrial products serving a wide range of challenging applications, the EGA product family is designed for long-term availability."

Uniform, precisely shaped beam

The optical performance of the EGA2000 flood illuminators is a feature of the integrated ams



ams' new EGA2000 VCSEL

match the field of view of the IR image sensors used in 2D and 3D ranging and detection systems, increasing the strength and integrity of the reflected optical signal, says ams.

Range of product options

The EGA2000 family of illuminators offers two wavelength options:

- 850nm for systems requiring maximum sensitivity; and
- 940nm for easier compliance with eye-safety regulations (superior rejection of sunlight interference also makes the 940nm illuminators suitable for use outdoors).

Each wavelength option is also available in one of three beam configurations:

- ultra-wide FoI — suitable for obstacle avoidance in robotics, and people-counting applications;
- wide FoI — used in machine-vision systems such as volume measurement in logistics systems; and
- narrow FoI — for use cases such as contour measurements and allowing long-range measurement.

The EGA2000 flood illuminators are available now for sampling, targeting mass production by second-quarter 2021. An evaluation kit will be available in the coming weeks.

www.ams.com/EGA2000

NUBURU strengthens IP portfolio with patents spanning 3D printing and material processing

NUBURU Inc of Centennial, CO, USA, which specializes in high-power industrial blue lasers, has been awarded seven new patents, adding to its intellectual property portfolio in visible laser technology for applications across 3D printing and material processing.

Specifically, NUBURU was awarded US patent nos. 10,562,132, 10,656,328, 10,634,842 and 10,804,680. It was also awarded Russian patent no. 2710819, Japanese patent no. 6648170 and Korean patent no 10-2143220.

The new patents join the firm's foundational patent '3D printing Devices and Methods' (PCT/US14/35928), which was awarded in 16 countries, with several other applications and continuations pending around the world, including with the US patent office (2016/0067780).

The latest patents range from 'Material Processing with Visible

Raman Laser' to the technology required to build the unique single-mode visible lasers. NUBURU has also received several notices of allowances inclusive of the technology and the application of blue lasers to material processing and 3D printing.

"NUBURU's IP portfolio is broad and deep," says CEO Dr Guy Gilliland. "Industry analysts and organizations have recognized the strength of our technology and its IP portfolio, including StartUp Insight, who identified NUBURU as one of the 'Top 5 Additive Manufacturing Start Ups Impacting the Automotive Industry,'" he adds. NUBURU was founded in 2015.

NUBURU says that its blue lasers provide speed and quality control for metal processing operations, such as welding and additive manufacturing in a variety of growing industries such as e-mobility and automotive, where materials such as

copper, stainless steel and aluminum are increasingly critical. Previous technologies are inflexible, slow and produce poor-quality metal joints, says the firm, which adds that its industrial blue lasers leverage a fundamental physical advantage to produce defect-free welds up to four times faster than the traditional approaches — all with the flexibility inherent to laser processing.

"These patents firmly establish that NUBURU invented the blue laser technology for 3D printing and material processing," claims founder & chairman Dr Mark Zediker. "The company portfolio widely covers blue laser technology, multi-mode and single-mode as well as broad applications within 3D printing and material processing... 22 patents have been awarded to date, with 90 applications currently in process for a number of claims in excess of 4000."

www.nuburu.net

Seoul Viosys begins production of 25G VCSELs for 5G Production for sensor applications to start in Q1/2021

Seoul Viosys Co Ltd (a subsidiary of LED maker Seoul Semiconductor) says that, for the first time in Korea, it has succeeded in developing vertical-cavity surface-emitting laser (VCSEL) technology, a near-field-only 25Gbps laser diode compatible with 5G wired networks for transmitting and receiving. The firm has started mass production to supply these products to three initial customers.

As a light-based communication technology, VCSELs can achieve ultra-high-speed data communication in 5G environments. They are also necessary for augmented reality (AR)/virtual reality (VR), 3D sensing and the camera-applied ToF (time of flight) for smartphones, as well as automotive light detection & ranging (LiDAR). Seoul Viosys' VCSELs for sensor applications have already received customers'

approval and will be mass-produced in first-quarter 2021, and the LiDAR technology is also undergoing the approval process to be supplied to an automotive system provider. According to the market research firm Yole Développement, the VCSEL market is expected to grow 18.4% annually from \$1.1bn in 2020 to \$2.7bn in 2025.

The 25Gbps VCSEL market has seen three large US-based companies — II-VI, Lumentum and Broadcom — involved in a power struggle for these high-value-added products (which have a selling price more than 10 times larger than that of an LED). Seoul Viosys' VCSEL can be implemented in single-channel or four-channel configurations, depending on the intended use, with the four-channel implementation providing 100Gbps (4x)

data reception and transmission. Although VCSEL technology involves a high degree of difficulty in implementation, it is expected to span a wide range of applications in the future, as it is price competitive compared with horizontal-type laser diodes that emit light from the sides.

"As the paradigm shift has progressed in the recent non-contact era, interest in VCSEL technology is growing, since it is a critical technology for implementing the Internet of Things (IoT) environment," says Seoul Viosys. "Seoul Viosys will continue to research and develop the VCSEL technology to expand and apply our differentiated VCSELs to 5G communication-based smart cities, autonomous driving applications, AR/VR, and industrial IoT markets."

www.seoulviosys.com

Vector leading £1.5m BLOODLINE project to develop chips for 3D metal laser printers PCSELS to replace CO₂ lasers and fiber lasers in selective laser melting of metal powders

Semiconductor laser start-up Vector Photonics Ltd (which was spun off from Scotland's University of Glasgow in March) is leading the £1.5m project BLOODLINE (Bright Laser diodes for aDvance metal addItive maNufacturing systEms), an international consortium — funded by UK Government agency Innovate UK (which provides funding and support for business innovation as part of UK Research and Innovation) — that is developing chips based on its photonic-crystal surface-emitting laser (PCSEL) technology, targeting 3D metal laser printing applications. This market is forecasted to quadruple to \$10bn by 2025 (according to the report 'Additive Manufacturing with Metal Powders, 2019' from SmarTech Analysis).

Vector Photonics is joined in the project consortium by a Japanese epitaxy manufacturer and the UK's not-for-profit Compound Semiconductor Applications (CSA) Catapult (established by Innovate UK and based in South Wales), which will undertake chip reliability testing. A "leading industrial equipment manufacturer" in Japan will provide product assessment and, ultimately, a route to market, although the chips produced will be suitable for any printer manufacturer.

"3D metal laser printers hold metal powder in a 'powder bed' at just below melting point," says Vector's chief technology officer Dr Richard Taylor. Currently, CO₂ or fiber lasers, directed by mirrors, scan over the surface of the powder, melting the metal powder to the

layer below (selective laser melting, SLM).

"Vector Photonics' PCSEL technology will revolutionize the SLM process," reckons Taylor. "PCSELS offer a unique combination of increased laser power (by scaling up the PCSEL arrays), improved reliability (by removing the mirrors and offering an entirely solid-state solution), and greater manufacturing efficiency (the result of higher-resolution printing with less finishing overheads and faster printing speeds)," he adds.

"We believe that PCSELS will enable an entirely new class of next-generation metal printers and contribute to even greater market growth," Taylor concludes.

www.vectorphotonics.co.uk

Vector joins European Photonics Industry Consortium PCSEL-based Glasgow spin-off joins 644 other companies

Semiconductor laser start-up Vector Photonics Ltd (which was spun off from Scotland's University of Glasgow in March) has joined the European Photonics Industry Consortium (EPIC), the largest active network of photonics-related companies in Europe.

EPIC's membership of 644 companies spans industry sectors including photonics integrated circuits; optical components; lasers and sensor production; optical fiber communications; and further industries enabled by photonics-related technologies. "It has worldwide recognition and influence, providing a strong, network environment for photonics-enabled companies," comments Vector Photonics' CEO Neil Martin. "EPIC seeks to facilitate technological and commercial growth for members and to identify new



and emerging photonics markets for research and development. EPIC is a critical part of the European photonics industry," he adds.

"Vector Photonics brings an exceptional contribution to the consortium through its revolutionary new PCSEL-based compound semiconductor laser technology," com-

ments Dr Jose Pozo, director of technology & innovation at EPIC. "Neil Martin was a keynote speaker at our AGM in Glasgow last year. It's great to have his new company amongst our membership and to retain his photonics expertise within our organization."

www.epic-assoc.com

www.vectorphotonics.co.uk

BluGlass completes optical coating manufacturing step for 405nm lasers

Initial tests of unpackaged, coated devices demo target performance

In an update on its laser diode business, BluGlass Ltd of Silverwater, Australia has reported the recent demonstration of strong output power from its standard 405nm laser design.

Laser diode product progress — 405nm coated, unpackaged lasers performing within target specs

BluGlass has advanced the development of its first standard laser diode product with completion of the optical coating step of the manufacturing process of several 405nm laser devices. The firm says that its 405nm laser design has demonstrated strong initial performance results in line with its target specifications.

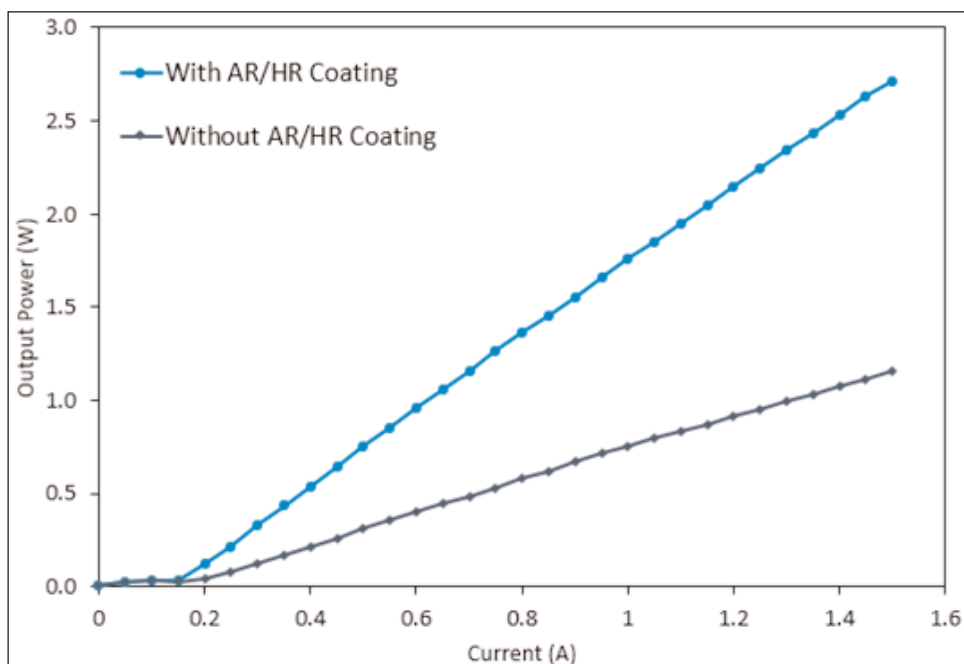
405nm light output with/without AR-HR coating

For lasers to achieve optimal performance, the two edge surfaces of the device are coated with specialty optical materials. One is a highly reflective (HR) coating to achieve maximum light reflection — effectively a mirror surface that allows the light to reflect brightly back and forth. The other is an anti-reflective (AR) coating, designed to let the light pass through while ensuring that very little light is lost and that all light emission occurs from one end.

These specialist AR and HR coatings result in a significant improvement in the light output measured from the device. With the addition of these specialist coatings, BluGlass' 405nm laser output power has more than doubled, and they demonstrate strong initial performance specifications in-line with expectations for an unpackaged device.

BluGlass laser diode manufacturing steps

These devices are now in the process of being packaged at BluGlass' facility in the USA, before further burn-in testing and performance measurements can be



Unpackaged device
10µm x 1200 µm ridge
Pulsed Measurement using 5% Duty cycle and 500ns pulse width

LIV Data at 0.5 A operating current

Parameter	Uncoated	AR/HR Coated
Light Output Power (W)	0.31	0.75
Voltage (V)	4.4	4.5
Conversion Efficiency (%)	14.1	33.6

LIV Data at 1.0 A operating current

Parameter	Uncoated	AR/HR Coated
Light Output Power (W)	0.76	1.76
Voltage (V)	5.9	6.0
Conversion Efficiency (%)	12.9	29.3

completed. At this point, the devices can be tested according to industry standards and generate the final commercial specification of the BluGlass 405nm product design. Additional laser diode designs of other wavelengths and product specifications are also progressing through the firm's

development pipeline and various manufacturing steps.

BluGlass says that it remains on track to provide sample products to customers in early 2021 to meet its technology, manufacturing and commercial milestones, in line with its published roadmap.

www.bluglass.com.au

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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

Kyocera completes acquisition of SLD Laser

Kyocera's fine ceramics to create synergies with SLD's expertise in GaN

Kyocera Corp of Kyoto, Japan (which manufactures fine ceramic components) has completed its acquisition of SLD Laser of Goleta, near Santa Barbara, CA, USA (formerly Soraa Laser Diode Inc).

Soraa Laser was spun off in 2013 from Soraa Inc of Fremont, CA, USA — a developer of solid-state lighting technology built on 'GaN on GaN' (gallium nitride on gallium nitride) substrates — and was co-founded by Dr Shuji Nakamura (the 2014 Nobel Laureate in Physics), Dr Steve Denbaars, Dr James Raring and Dr Paul Rudy.

With 169 staff (as of 31 August) and facilities in both Santa Barbara and Fremont, CA, SLD Laser develops, manufactures and markets high-efficiency, high-luminance GaN laser-based products for automotive & mobility, specialty

lighting, consumer, and industrial applications. The firm's LaserLight sources have safety certifications from both ANSI/UL (American National Standards Institute/Underwriters Laboratories Inc) and IEC (the International Electrotechnical Commission). SLD Laser is also ISO 9001 certified and automotive compliant to IATF 16949.

SLD Laser has now commenced operations as a subsidiary and group company of Kyocera Corp, under the name Kyocera SLD Laser Inc (KSLD).

"Leveraging our spirit of innovation and strength as a Kyocera group company, we are dedicated to the safe and successful application of laser-based innovations for high-brightness illumination and displays," says KSLD's president & CEO Dr James Raring. "Together

with Kyocera, we will continue the pursuit of our 'Beyond Lighting' vision to pioneer LaserLight products in applications such as precision sensing, high-speed LiFi communication, industrial processing, and biomedicine."

Kyocera Corp says that, together, they aim to attain synergies by integrating KSLD's GaN expertise with Kyocera's production technologies and R&D capabilities in fine ceramic-related businesses.

For the All-Digital Consumer Electronics Show (CES 2021), KSLD is hosting live virtual meetings (featuring its 2021 Prism Award nominated LaserLight products) by appointment from its Silicon Valley light tunnel and showroom (12–15 January).

<https://digital.ces.tech>
www.SLDLaser.com

PIRT announces Phase II Award from MDA to develop ToF camera for 3D imaging

InGaAsP APD plus ROIC to form 128x128 50µm-pixel-pitch LADAR

Princeton Infrared Technologies Inc (PIRT) of Monmouth Junction, NJ, USA — which specializes in short-wave-infrared (SWIR) linescan cameras, visible-SWIR science cameras, and 1D & 2D imaging arrays based on indium gallium arsenide (InGaAs) — has announced a Phase II Small Business Innovation Research (SBIR) award from the US Missile Defense Agency (MDA) to fund the development of a 128x128 50µm-

pixel-pitch radiation-hardened laser detection & ranging (LADAR) system.

Princeton Infrared Technologies says that it will focus on developing a flash LADAR module featuring indium gallium arsenide phosphide (InGaAsP) linear-mode avalanche photodiodes (APDs) optimized for detection of 1.06µm light hybridized to a custom readout integrated circuit (ROIC) and operated with time-of-flight (ToF)

camera electronics.

In Phase I, PIRT developed the InGaAsP APD material structure and a unique ROIC circuit optimized for the application.

"The new APD detector structure, combined with this unique ROIC design, will enable an exciting space-based 3D LADAR system," says PIRT's president Martin H. Ettenberg Ph.D.

www.princetonirtech.com

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SLD launches first dual-emission white/IR LaserLight source for automotive and consumer applications

Firm to demo new lighting for illumination, sensing and LiFi at CES

SLD Laser of Goleta, near Santa Barbara, CA, USA has announced the production launch of what it says is the first dual-emission white light and infrared (IR) LaserLight source for automotive and consumer lighting, night-vision illumination, precision long-range sensing beyond 250m, and high-speed LiFi communications faster than 20Gb/s. The firm demonstrated the innovation and its expanded LaserLight product line during its virtual All Digital Consumer Electronics Show (CES 2021) event exhibition and application showcase (12–15 January).

The firm says that white/IR dual emission sources are critical for automotive lighting, advanced driver assistance systems (ADAS) and autonomous vehicle (AV) light detection & ranging (LiDAR) 3D sensing, as well as mobility applications including avionics, drones, railway and marine. Also, dual-emission sources are required for consumer and professional product portable lighting products, night-vision illuminators, and rangefinders for recreation and outdoor, search & rescue and security applications. SLD says that its new source delivers high-brightness white light with a beam distance of 1km, while independently producing IR illumination from the same emission spot to achieve ranging to more than 250m with 1% accuracy. Moreover, these sources generate LiDAR video imagery and data when integrated with sensor chips, to enable next-generation 3D imaging headlights.

The new LaserLight Dual White/IR sources deliver high-brightness, safe incoherent white light of 500 lumens with near-infrared emission up to 1W average power and 100W peak power that can emit either together simultaneously or independently, depending on the application's needs. The White/IR

LaserLight source technology is available in several high-volume product configurations including SLD's MicroSpot module, FiberLight module, and SMD (surface-mount device) component. Until now, high-speed dual-emission white/IR sources have not been possible because LEDs and legacy lamp-based light sources are unable to deliver high-brightness dual-wavelength emission from the same point source, and they are incapable of being modulated at the high speeds required for accurate sensing and fast data rates, says SLD.

Utilizing the white/IR dual-emission LaserLight sources, SLD is now offering a commercial LiFi development kit with 1Gb/s data rate for customers to design LiFi into emerging optical communication applications for a myriad of mobility use cases, as well as future smart cities such as intelligent streetlights, and smart buildings such as healthcare facilities and factories. By delivering both white and IR from the same source and fusing together lighting, sensing and communication functionalities, SLD's LaserLight LiFi kit enables users to commercialize potent intelligent illumination systems, the firm says. These systems will provide a unique combination of precision white lighting, accurate sensing and ultra-high-speed communication with unconstrained optical bandwidth, as well as secure and efficient data transmission without RF interference of the incumbent WiFi technology.

White/infrared dual emission sources are critical for automotive lighting, ADAS and AV LiDAR 3D sensing, as well as mobility applications

SLD's high-brightness white light LaserLight products are also being showcased at its virtual CES event. Its automotive-certified LaserLight Fiber sources are now deployed into multiple vehicle platform headlights and are on the road globally. SLD says that it has been named a Grade A supplier for excellent quality by a leading global tier-1 supplier and was recently ranked seventh in Fortune magazine's '2020 Best Workplaces in Manufacturing & Production' companies. Its white light sources were once again used by the winning drivers at the BFGoodrich SCORE Baja 1000 off-road race.

SLD has expanded its white LaserLight sources with the introduction of the 1000 lumen SMD and MicroSpot, enabling low-beam and high-beam full-field illumination, as well as off-road boost and ultra-wide-angle panoramic illumination. These sources are more than 10 times brighter than LEDs, enabling safe stopping distance with precise illumination patterns and minimum glare, while meeting stringent safety regulations of UL and IEC.

These LaserLight modules are $\frac{1}{3}$ the size of LED sources, saving critical space in the car, and providing what is claimed to be unmatched design freedom for ultra-thin styling possibilities.

Utilizing the 1000 lumen source, SLD has extended its FiberLight source with transport and emissive fiber illumination up to 10,000cd/m² for ultra-bright lighting for vehicle exterior grills, logos and interiors. With 10 times the brightness of LED solutions, these sources produce brilliant and efficient illumination from thin, low-cost plug-and-play fiber optics and a modular light source, says the firm.

<https://digital.ces.tech>
www.SLDLaser.com

POET enters into development and supply agreements with photonic neural network systems firm

Integrating photonics targeted at accelerating AI computation

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 entered into development and supply agreements with a “technology leader in photonic neural network systems for artificial intelligence (AI) applications”.

Artificial intelligence is driving unprecedented demand for computation at the same time that the physics of digital semiconductors, driven by Moore’s law, is reaching its end, says POET. Transistor scaling is approaching its limits and AI accelerator companies are struggling to keep pace with demands, particularly in ‘edge’ applications that require greater power and cost efficiency, it adds. Domain-specific architectures targeted at AI workloads can make up for some of the

slowdown in transistor advances, but that approach also has its limits.

The chipset market for AI applications is projected to grow from about \$18bn in 2020 to over \$65bn by 2025. POET says that its new development and supply agreement for photonic AI computing represents an entry point into this new, large and extremely high-growth market. The firm says that its customer for these applications is breaking the digital semiconductor mold by integrating photonics into accelerators for AI workloads, enabling step-change advancements in AI computation. Harnessing light to perform data-parallel calculations is many orders of magnitude faster, more power efficient and lower cost than in traditional semiconductors, so photonic computing changes the game in the field of artificial intelligence, POET reckons.

“Photonics has been readied for optical computing as a result of over a decade of advancements in photonics design and fabrication driven by telecommunications and data communication and promises to be the technology to usher in the next era of rapid growth for AI computing,” says chairman & CEO Suresh Venkatesan. “POET is now well positioned to participate meaningfully for a new class of high-volume, high-growth applications, expanding the addressable markets for our Optical Engines and Optical Interposer platform products,” he believes. “In addition to highlighting the tremendous adaptability of the POET Optical Interposer platform, this project is anticipated to result in revenue for POET this year in the form of NRE [non-recurring engineering] and potentially initial product sales.”

www.poet-technologies.com

POET announces special meeting of shareholders

Board seeks authorization to consolidate shares prior to listing

POET is holding a special meeting of shareholders on 19 February in order to seek their authorization to enable the board of directors (within its sole discretion) to consolidate the firm’s issued and outstanding common shares, on the basis of a ratio to be determined from within a range of ratios to be proposed at the Special Meeting.

The decision to pursue a share consolidation was taken after considering factors including access to US institutional investors, prospective broadening of US-based investor interest in the firm and, if required, the structuring of potential future financings. Also, the board believes that the reduced number of common shares may better position the firm for a future listing on a senior stock exchange.

The ratio determined for any consolidation (if implemented) will be applied to all shareholdings equally. Securities convertible or exercisable for common shares that are outstanding on the effective date of the consolidation will be adjusted to give effect to the consolidation (as applicable) in accordance with their terms. No fractional common shares would be issued as a result of the consolidation. All fractions of post-consolidation common shares would be rounded down to the nearest whole number. The exact number of common shares outstanding after the consolidation will vary based on the elimination of fractional shares.

The authority of the board to consolidate the shares in its sole

discretion is conditional on the prior approval of the shareholders and the TSX Venture Exchange (TSXV). If approved, the consolidation would take place upon a decision by the board within the proposed range agreed to by the shareholders following approval. Specific details will be provided by the firm at a later date. A Management Information Circular for the upcoming special meeting is being mailed to shareholders and filed by the firm on SEDAR.

The firm also reported that its total shares outstanding increased in recent weeks to 303,875,813 as a result of convertible debenture conversions, warrant and stock option exercises that added about C\$3,680,000 (US\$2,875,000) to its cash balance.

POET opens product design and development center in Shenzhen

Dr Jinyu Mo appointed as senior vice president, Asia

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 opened a product design and development center in Shenzhen, China, which will be focused on the optical engine, reference designs for customer applications, and new product activities.

POET has also appointed Dr Jinyu Mo as its senior VP of Asia, responsible for managing activities in China and Singapore. As a highly experienced technical and business veteran of the photonics and optoelectronics industries, Mo has over 22 years of experience spanning several companies, including MACOM Technology Solutions, Bookham/Oclaro, Huawei, I2R in Singapore, and Nexvave Photonics Technology Co, which she founded and served as chief technology officer. She was most recently with MACOM as senior director and chief scientist of the Lightwave business unit in Asia and site leader in Shen-

zhen. Mo received her PhD degree in Optical Communications from Nanyang Technological University (NTU) Singapore. She is a senior member of IEEE and has been a member of IEEE's Technical Committees for several international conferences.

POET Optoelectronics Shenzhen Co Ltd., a wholly foreign-owned enterprise (WFOE) and wholly owned subsidiary of POET, will augment the firm's existing design, development and engineering operations in Allentown, Pennsylvania, USA and Singapore. The Shenzhen operation will also support the activities of Super Photonics Xiamen Co Ltd, the firm's joint venture with China's Sanan IC (a subsidiary of Sanan Optoelectronics Co Ltd).

Additional engineering staff have been hired at POET's Shenzhen operation as it builds a critical team of experienced senior engineers and managers that are being recruited from a large pool of optical and photonics engineering talent currently working in the Shenzhen area.

"Shenzhen is home to many global players in the photonics industry and is one of the leading locations to find talented engineers in our industry," comments POET's president & general manager Vivek Rajgarhia. "Being in close proximity to potential customers enables us to respond quickly to their needs in real-time and in the same language and cultural environment, which is an absolute requirement for technology-based companies like POET," he adds. "We anticipated the need for such an operation even before we considered the joint venture with Sanan IC, however having an operation in-country to support the joint venture at its inception is an added advantage for our future success."

In addition to his role as president & general manager of POET, Rajgarhia is the legal representative of POET in China for POET Optoelectronics Shenzhen Co Ltd. and is scheduled to be appointed to the board of directors of Super Photonics Xiamen Co Ltd.

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Lumentum to acquire Coherent for \$5.7bn

Over \$150m of annual run-rate synergies expected in first 24 months

Lumentum Holdings Inc of San Jose, CA, USA (which designs and makes photonic products for optical networks and lasers in industrial and consumer markets) has entered into a definitive agreement to acquire Coherent Inc of Santa Clara, CA (which provides lasers and laser-based technology for scientific, commercial and industrial applications) for \$5.7bn (\$100 per share in cash and 1.1851 shares of Lumentum common stock for each Coherent share, as unanimously approved by the boards of directors of both companies). The transaction value represents a premium of 49% to Coherent's closing price on 15 January. At closing, Coherent's stockholders are expected to own about 27% of the combined firm.

Lumentum intends to finance the cash consideration of the transaction through a combination of cash on hand from the combined company's balance sheet and \$2.1bn in new debt financing from a fully committed Term Loan B.

Two members of Coherent's board will be appointed to Lumentum's board, which will be expanded to nine directors, at the closing of the transaction (which is expected in second-half 2021, subject to approval by Lumentum's and Coherent's stockholders, receipt of regulatory approvals and other customary closing conditions).

The combination unites Coherent's photonics and lasers businesses, including in the microelectronics, precision manufacturing, instrumentation and aerospace & defense markets, with Lumentum's telecom, datacom and 3D sensing photonics businesses, creating a diversified photonics technology company with significantly increased scale and market reach. It should accelerate Lumentum's penetration of the more than \$10bn market for lasers and photonics outside of the communications and 3D sensing applications, it is reckoned. The R&D engine of the combined firm is expected to accelerate innovation in existing and future markets that need the unique capabilities of photonics. The combined company should be better positioned to serve the needs of a global customer base increasingly dependent on photonics to enable key end-market transitions including the shift to digital and virtual approaches to work and life, the transition to 5G in wireless networking, advanced bioinstrumentation, advanced microelectronics, and new materials for next-generation consumer electronic devices, flat-panel and organic light-emitting diode (OLED) displays, communications equipment, electric vehicles (EVs) and autonomous vehicles (AVs), and energy storage.

"Today's announcement is an important advancement of Lumentum's strategy," says the firm's president & CEO Alan Lowe. "In our five years as a standalone public company, we have focused on developing the most innovative products and technology in our industry and partnering with market-leading customers to help them compete and win in their markets. As we look ahead, we are thrilled to join forces with Coherent to create one of the world's largest and most diverse photonics technology companies with leading positions in the growing market for photonics. Coherent brings one of the most recognizable and respected brands in the photonics industry and a very talented and innovative team. By increasing our scale, expanding our portfolio, and bolstering our R&D capabilities at a time when global markets are increasingly relying on photonics products and technologies, we are confident in our combined ability to pursue exciting new growth opportunities," he adds.

"Together, we expect to increase the pace of innovation, and to be at the forefront of the long-term market trends that are dependent on the capabilities of photonics," continues Lowe. "The combined company will also have a strong financial profile with a diversified

Lumentum's quarterly revenue up 4.6% year-on-year

Profits surpass last quarter's records

In preliminary results for its fiscal second-quarter 2021 (ended 26 December 2020), Lumentum Holdings Inc of San Jose, CA, USA (which designs and makes photonic products for optical networks and lasers in industrial and consumer markets) is reporting net revenue of about \$478.8m, up on \$452.4m last quarter and \$457.8m a year ago (a 4.6% rise year-on-year).

On a non-GAAP basis, operating income is \$163-169.9m (operating margin of 34-35.5% of revenue), up further from the record \$152.5m (33.7% margin) last quarter and \$132m (28.8% margin) a year ago.

Net income is \$149.4-155.7m (\$1.91-1.99 per diluted share), likewise up further from the record \$139.2m (\$1.78 per diluted share) last quarter and \$119.4m (\$1.53

per diluted share) a year ago.

Lumentum plans to release its full fiscal Q2/2021 results on 2 February.

Separately, Lumentum announced that it had entered into a transaction to acquire Coherent Inc of Santa Clara, CA (which provides lasers and laser-based technology for scientific, commercial and industrial applications).

www.lumentum.com

► revenue mix and significant synergy opportunities that will deliver enhanced value to our stockholders," he believes. "We look forward to welcoming Coherent's talented employees to the team and are confident in our ability to execute a smooth integration focused on supporting both companies' employees and customers," concludes Lowe.

"We anticipate the combined complementary product portfolio, breadth of customer application knowledge, and R&D capabilities, all based on photonics, will accelerate innovation and adoption of photonics across the many markets that we serve," says Coherent's president & CEO Andy Mattes.

"We are excited to bring Coherent's strength in OLED display manufacturing, semiconductor wafer inspection and life science instrumentation to Lumentum's portfolio, to name but a few of the key applications we serve, and believe Lumentum's expertise and scale in world-class photonics components

and systems will accelerate Coherent's vertical integration and addressable market expansion in several high-growth areas, such as directed energy in defense and precision battery welding in automotive. We look

forward to contributing to a customer-centric, innovative culture with a track record of operational excellence," he adds. "We are also pleased to deliver immediate and substantial value to our stockholders, as well as

The combination unites Coherent's photonics and lasers businesses, including in the microelectronics, precision manufacturing, instrumentation and aerospace & defense markets, with Lumentum's telecom, datacom and 3D sensing photonics businesses

meaningful participation in the long-term growth opportunities created by the combined company... I look forward to working closely with Alan and the Lumentum team on a smooth transition."

Substantial run-rate synergies and solid accretion to earnings

Lumentum reckons that there are significant efficiency gains in combining derived by the increased scale, reducing redundancies, and leveraging the best capabilities in the combination. The combined firm is expected to generate more than \$150m in annual run-rate synergies within 24 months of the closing of the transaction. The transaction is expected to be accretive to the combined firm's non-GAAP earnings per share during the first full year. Upon closing, there is expected to be a solid balance sheet and strong operating cash flow, creating substantial financial flexibility to pursue continued growth initiatives.

www.Coherent.com

Emcore shipping Optiva next-gen L-band fiber-optic links Extended bandwidth for native S- and C-band from 50MHz to 6GHz

Emcore Corp of Alhambra, CA, USA — which provides mixed-signal products for the aerospace & defense and broadband communications markets — is now shipping its Optiva OTS-1LNG Next-Gen L-band fiber-optic links featuring extended bandwidth for native S- and C-band. The new transmitter and receiver modules for the Optiva Platform are suitable for satellite antenna signal transport and interfacility link applications.

Optiva Next-Gen L-band fiber-optic transmitter (Tx) and receiver (Rx) pairs are said to be a cost-efficient design using Emcore's latest high-speed uncooled distributed feedback (DFB) laser technology. With capability up to 6GHz covering S- and C-band, they enable users to future-proof their systems with better performance at a lower cost than competing alternatives, claims the firm. The native C-band coverage

also provides an optimal solution for 5G C-band interference, it adds.

The Optiva platform enables long-distance fiber-optic links over 100km with 1/10th the size and weight of coaxial cable. Fiber is much less expensive than coaxial cable over any reasonable distance, and the ability to keep the signal in the native satellite frequency reduces signal errors caused by up- and down-conversion. Fiber also provides greater immunity from electromagnetic interference (EMI), hum and distortion of the signal.

"Our Optiva Next-Gen L-band fiber-optic links present a very high-value proposition to our customers, with the extended bandwidth capability to native S- and C-band providing a major improvement in performance at a lower cost than our previous generation," says David Wojciechowski, vice president & general manager

of Defense Optoelectronics.

"Our latest Optiva products have a simplified communications architecture, resulting in reduced network complexity with lower maintenance cost and increased overall up-time compared to currently available solutions."

Optiva OTS-1LNG modules feature a robust API (application-programmable interface) design, 30dB Tx & Rx adjustable gain range, SmartGain for enhanced AGC (automatic gain control) performance, peak optimizer for quick and easy setup, and RF power monitoring via the front panel and SNMP. They feature DWDM operation that increases transport capacity without increasing fiber count and, when housed in the same Optiva chassis with other Optiva cards, enable a full-redundancy system in a single chassis.

www.emcore.com/satcom

Tower to develop integrated-laser-on-silicon photonics foundry process

Partial funding comes from DARPA's LUMOS program addressing high-speed communications

Specialty foundry Tower Semiconductor Ltd (which has fabrication plants in Migdal Haemek, Israel, and at its US subsidiaries in Newport Beach, CA and San Antonio, TX, and at TowerJazz Japan Ltd) is participating in the program 'Lasers for Universal Microscale Optical Systems' (LUMOS), with partial support from the US Defense Advanced Research Projects Agency (DARPA), to create an integrated-laser-on-silicon photonics foundry process, combining III-V laser diodes with its PH18 production silicon photonics platform.

Multi-project wafer (MPW) runs will be coordinated with the new process, when ready. The initial versions of the process development kit (PDK) are expected in 2021 and

will include laser and amplifier blocks.

The benefits of laser integration on silicon include an increase in the density of lasers, a reduction in coupling losses between the laser and the photonics, a reduction in components required,

The benefits of laser integration on silicon include an increase in the density of lasers, a reduction in coupling losses between the laser and the photonics, a reduction in components required, and a much-simplified packaging scheme

and a much-simplified packaging scheme, says Tower. When combined with the firm's suite of passive and active silicon photonics elements — such as silicon and silicon nitride waveguides, Mach-Zehnder modulators (MZM), and germanium (Ge) photodiodes — the co-integration will enable new products unavailable currently from a volume semiconductor or photonics foundry, it is reckoned.

The integrated-laser-on-silicon photonics foundry process will be part of DARPA's LUMOS program, which aims to bring high-performance lasers to advanced photonics platforms, addressing commercial and defense applications.

www.towersemi.com/manufacturing/aerospace-defense

Alpine produces 400G PAM4 optical engine using Tower's PH18 silicon photonics process

Designed for use in 400Gbps DR4 transceivers supporting high-speed connectivity in data centers

Alpine Optoelectronics Inc of Fremont, CA, USA (which was founded in 2017 and supplies high-data-rate silicon photonics optical engine chips) has begun production of its 400G PAM4 nCP4 optical engine on the PH18 silicon photonics technology platform of specialty foundry Tower Semiconductor Ltd (which has fabrication plants in Migdal Haemek, Israel, and at its US subsidiaries in Newport Beach, CA, USA and San Antonio, TX, USA and at TowerJazz Japan Ltd). Alpine's nCP4 chip converts four lanes of 56Gbaud electrical input into four lanes of optical output for use in 400Gbps DR4 transceivers to support high-speed connectivity in data-center applications.

"Alpine selected Tower Semiconductor as a foundry partner two years ago because we believe in Tower's capabilities of technology development and to seamlessly ramp production," says Alpine's CEO Dr Tongqing Wang. "We were able to develop a proprietary design to enable wafer-level testing and a flexible yet efficient edge coupler that works with both lens coupling and fiber-array attachment," he adds. "We are also pleased with the high OE bandwidth of our modulators, thanks in part to Tower's selection of PN junction doping."

Tower's PH18 silicon photonics open-foundry process offers a set of optical components including ultra-high-bandwidth modulators, photodetectors and low-loss

waveguides that combine to enable highly integrated photonic products.

"Our unique foundry process provides customers like Alpine not only a sustainable level of maturity but also the flexibility to innovate in a market that is still young and expected to grow strongly in the coming years as 400Gb and 800Gb platforms are deployed," says Dr Marco Racanelli, senior VP & general manager of Tower's Analog IC business unit.

According to LightCounting's recent Integrated Optical Devices Report, the market for silicon photonics-based optical transceivers is growing by 45% annually from 2019 to \$3.9bn in 2025.

www.alpineoptoelectronics.com
www.towersemi.com/technology/

Inphi samples next-gen 400G DR4 silicon photonics platform for hyperscale data-center networks

High-volume silicon wafer-scale manufacturing enables faster time to ramp and lower cost per bit

Inphi Corp of San Jose, CA, USA (a provider of high-speed mixed-signal ICs for communications, computing and data-center markets) is sampling its next-generation 400G DR4 silicon photonics platform, which includes a silicon photonics integrated circuit (PIC), a flip-chip transimpedance amplifier (TIA), and an analog controller; all designed to work seamlessly with Inphi's Porrima PAM4 (4-level pulse amplitude modulation) digital signal processor (DSP) to enable faster time to ramp and lower cost per bit.

Inphi says that it brings high-volume silicon wafer-scale manufacturing to the optics industry by offering the option to purchase Inphi-designed high-performance 400G DR4 PICs in full 200mm wafer form. Customers receive silicon PIC wafers direct from an Inphi fab partner and will be able to continue with high-volume wafer-scale manufacturing and 3D heterogeneous integration in

their own factories. This business model brings silicon wafer-scale manufacturing to the optics industry to enable faster ramp and lower cost per bit, the firm says.

"Inphi has been the leading force to define and create a PAM4 ecosystem of optical modules for cloud and data-center networks," claims Dr Loi Nguyen, founder & senior VP, Optical Interconnect at Inphi. The announcement will mark "the beginning of a new era of the 'fab-less optics' industry," he believes. "Optical transceiver manufacturers can leverage silicon high-volume wafer scale in the manufacturing of transceivers without owning a fab."

Key features of 400G DR silicon photonics platform solution include:

- Inphi's complete silicon photonics transceiver with four low-loss, transmit Mach-Zehnder modulators and four high-responsivity, receive photodiodes;
- low-power, flip-chip TIA with excellent sensitivity, overload and error floor;

- analog controller IC, which replaces multiple discrete components for laser bias, configuration and monitoring of silicon photonics, and TIA control;

- Inphi's Porrima Gen3 low-power PAM4 DSP with integrated 56Gbaud laser driver.

"Cloud Light is a premier supplier of advanced optical modules for data-center interconnect and has a strong heritage of design and manufacturing with silicon photonic devices," says Matt Davis, VP of sales & marketing for Cloud Light Technology Ltd. "We are excited about Inphi's silicon photonics solution and look forward to working with them to offer a compelling cost-per-bit solution for the industry."

Inphi participated in the virtual exhibition of ECOC 2020 (7-9 December) and showcased a demonstration of its new silicon photonics platform with Cloud Light's optical module.

www.ecoco2020.org

www.inphi.com

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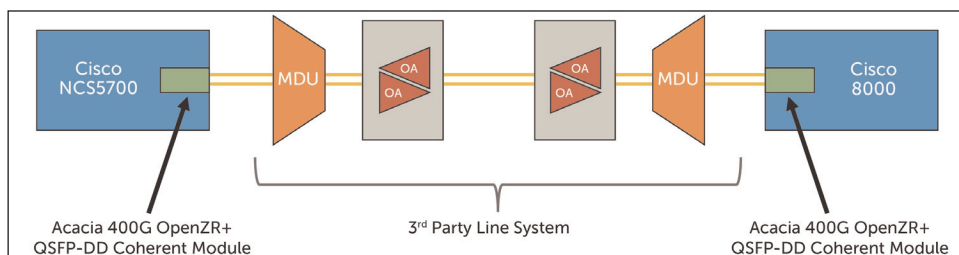
Telia Carrier using Acacia's OpenZR+ coherent modules plugged directly into Cisco routers

First network operator to demo 400G coherent connections between Cisco's NCS 5700 & 8000 platforms over third-party open line system

Telia Carrier of Stockholm, Sweden (said to be the world's number-one Internet backbone) says that, to simplify its networks, it is preparing to converge its IP and optical networking layers. Using 400G coherent modules from Acacia Communications Inc of Maynard, MA, USA plugged directly into Cisco routers, this architecture will enable Telia Carrier to address increasing bandwidth demand while significantly reducing both capital and operational expenditures.

Historically, scaling and operating a multi-layer architecture has always been a challenge. Due to innovations spanning silicon, optics and routing systems, complex layers can finally converge into a simpler and more scalable architecture (routed optical networking).

In preparation for this new solution, Telia Carrier has already deployed open line systems and terminal equipment that can support new 400G pluggable technology. As an early adopter of this architecture, it is one of the first network operators to perform full end-to-end validation of the solution. Leveraging Acacia's 400G QSFP-DD coherent modules with OIF 400ZR and OpenZR+ operating modes, the solution can support data rates of 100G to 400G, depending on the desired reach.



The modules also support client $n \times 100\text{GbE}$ multiplexing functionality as well as 400GE transport.

"Conventional architectures and technologies built on decades of accumulated complexity and yesterday's truths fall short in helping us keep up with customer demands for more consistent bandwidth and a high-quality experience," says Telia Carrier's CEO Staffan Göjeryd. "Starting in the metro, standardized coherent pluggable modules are the next natural step in evolving cost structures, efficiency and scaling capabilities. This follows our global deployments of open optical line-systems and bandwidth-optimized switch-router silicon already powering thousands of 400GE-capable ports in the network," he adds.

"Pluggable 400G coherent optical transceiver modules are important to enable service providers such as Telia Carrier to migrate to a more converged network architecture capable of enabling OpEx and CapEx savings, as well as a pay-as-you-grow business model," says

Fenghai Liu, Acacia's VP of product line management. "Coherent pluggables, like Acacia's 400G coherent module, have been designed to provide a scalable and cost-effective way to meet increasing bandwidth demands," he adds.

"Adding support for pluggable 400G optics directly into mass-scale routing platforms allows operators to converge historically complex infrastructure into a simple, single-layered architecture," comments says Kevin Wollenweber, VP/general manager Mass-scale Infrastructure Routing & Automation at Cisco. "The benefits — easier to maintain, faster to adapt, and cheaper to operate — are so compelling that we expect communication service providers to aggressively transition existing metro and long-haul networks to a Routed Optical Networking solution. This architecture can cost-effectively handle the projected traffic growth for the coming years while preparing to support the next transition to 800G or beyond."

www.acacia-inc.com

II-VI Inc ranked in industry awards at ODC 2020

II-VI Inc of Saxonburg, PA, USA, which supplies optoelectronic devices and micro-optics, says that it was twice recognized at a recent industry awards ceremony in China.

The firm was ranked third in the category 'Top 10 competitiveness enterprises in the optical components and auxiliary equipment field

of global market in 2020' and ranked eighth in the category 'Top 10 brand competitiveness enterprises in the optical communications field of China market in 2020' at the awards ceremony held during the 14th Global & China Optical Communications Development and Competitiveness Forum (ODC 2020) in Beijing, China.

The II-VI Asia Regional Headquarters is located in Fuzhou, China. The company says that it maintains a large manufacturing operations and product development presence in China in the cities of Fuzhou, Guangzhou, Shanghai, Shenzhen, Suzhou and Wuxi.

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III–V photovoltaics for dust-sized IoT devices

Higher power density than all prior micro-PVs on silicon and silicon-on-insulator.

IBM T J Watson Research Center in the USA has developed a wafer-level package process to integrate III–V photovoltaic (PV) devices with electronic components with a view to Internet of Things (IoT) applications [Ning Li et al, *Adv. Mater.*, vol32, issue 49, p2070369]. The dust-sized devices “achieve higher power density than all prior micro-PVs on silicon (Si) and silicon-on-insulator (SOI) substrates”, it is claimed.

The team sees their work as contributing to realizing distributed ‘edge’ computing where the processing and storage of data is performed close to where it is used, reducing response times and increasing bandwidth. Power for such systems needs to be autonomous.

IoT dust systems could see deployment in authentication, industrial monitoring, block chain payment/transaction encryption, healthcare, sensing and tracking, and defense. Presently, such devices need power supplies of more than 100µW, up to ~100mWs for high-data-rate artificial intelligence (AI) and neuromorphic computing.

The researchers report: “We show that our monolithically integrated micro-PV is the first demonstration of

high-throughput and low-cost manufacturing of small edge computers.” III–V semiconductor heterostructures were used to achieve high power density. The high-throughput and low cost is key to deployment — previous wirebond and chip-stacking attempts have suffered throughput and cost limitations.

The PV components were fabricated on SOI substrates (Figure 1). The interconnection to the processor and memory components was through electroplated copper with copper pillars attached on solder bumps. Separately fabricated processor and memory ‘chipelets’ were attached in a wafer-level process. Singulation used deep reactive-ion etch to give low kerf loss.

The researchers envisage the devices being run using energy transfer via laser or high-power LED illumination. The energy could then be stored in on-chip batteries or used directly. Two types of PV cell were fabricated: large ones designed to deliver a photocurrent at around a 1V level, while the smaller ones increased the voltage for particular needs. The PV cell sizes ranged from 45µm×45µm to 400µm×200µm.

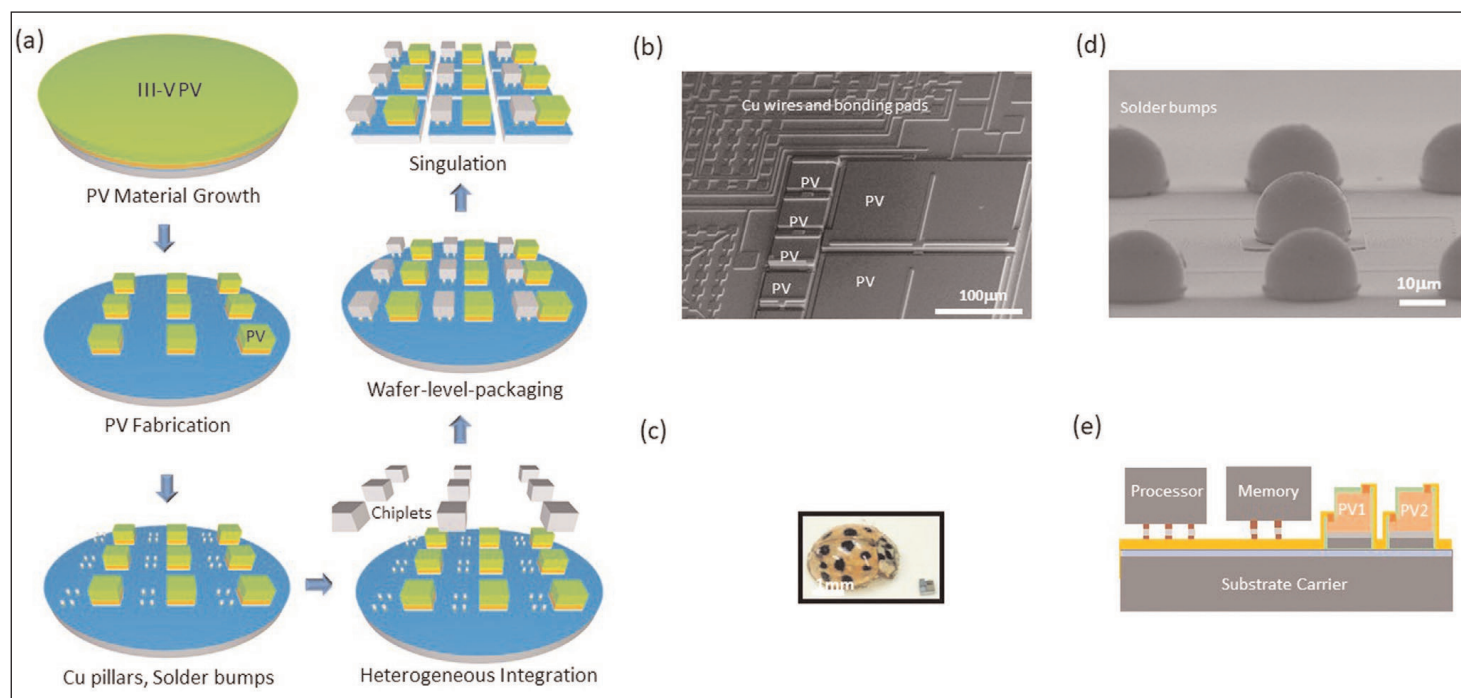


Figure 1. (a) Schematic package flow: III–V PV growth on SOI substrate, PV mesa etched down to buried oxide (BOX), PV cell fabrication and copper (Cu) interconnect, Cu pillar and solder bump formation for chip packaging, wafer-level selective bonding of fabricated chips, and chip singulation using deep Si reactive ion etching (RIE). (b) Scanning electron microscopy image of wiring and pads for pillar and solder bumps. (c) Picture of dust device with ladybug to illustrate relative size. (d) Scanning electron microscopy image of solder bumps. (e) Cross-section schematic of small computer system.

The researchers see some advantages arising from the use of LEDs rather than laser diode sources: the larger spot size gives higher tolerance to misalignment, and LEDs are less likely to damage eyesight. IBM used a two-lens collimation and focusing setup to illuminate the PV devices with high-power LEDs. The team comments: "For the case of a production line or shipping center, where automated alignment tools may be available, the alignment of the PVs and LEDs is much easier. The high-power LEDs and lens are not part of the small computer. They are part of a device to power and interrogate the small computer."

The PV structures also enabled communication at rates up to 1Mbit/second with simultaneous data and power transmission from LED sources. The resistance-capacitance (RC)-limited 3dB frequency bandwidth (f_{3dB}) for $20\mu\text{m} \times 20\mu\text{m}$ devices was calculated at 7.5GHz. The researchers report: "The RC-limited f_{3dB} is much higher than the previously reported PV as data receiver due to small size and thus small capacitance." A thicker absorber layer of $\sim 2.3\mu\text{m}$ reduces the bandwidth to 1.5GHz due to the longer diffusion time through the base/absorber region. Silicon PV cells have much lower bandwidths ($\sim 100\times$).

Illumination from laser diodes and LEDs is generally narrower in wavelength spread than that emanating from the sun. This enables the use of tuned PV devices with higher power-conversion efficiencies for near-band-edge illumination.

The researchers used a $1.5\mu\text{m}$ gallium arsenide (GaAs) absorber structure (Figure 2), which can achieve power-conversion efficiencies of $\sim 60\%$ with 800nm $10\text{W}/\text{cm}^2$ light input, compared with just 25% for $1.5\mu\text{m}$ Si-based devices with 450nm illumination. Increasing silicon thicknesses to $9\mu\text{m}$ enables a higher efficiency of 35% with 650nm light.

A $100\mu\text{m} \times 100\mu\text{m}$ GaAs-based PV device with anti-reflective coating achieved 40% power conversion under 830nm 1mW illumination. This is close to what can be achieved with structures grown on GaAs substrates (45%, approaching the theoretical limits).

The III-V-materials were grown in a two-step process with cyclic annealing to reduce heteroepitaxial defect densities. While the $1.5\mu\text{m}$ absorber was relatively thin, the overlying window layers were thicker than usual in solar PVs to reduce sheet resistance. The researchers report they have also produced PV structures on silicon with wider-bandgap absorber materials like aluminium gallium arsenide (AlGaAs) and indium gallium phosphide (InGaP) with a view to higher output voltage needs.

The penalty in open-circuit voltage for the $100\mu\text{m} \times 100\mu\text{m}$ GaAs PV on Si, compared with on GaAs, was around 19% at low illumination, but this reduced to around 13% at high powers of $10\text{W}/\text{cm}^2$. ■

<https://doi.org/10.1002/adma.202004573>

Author: Mike Cooke

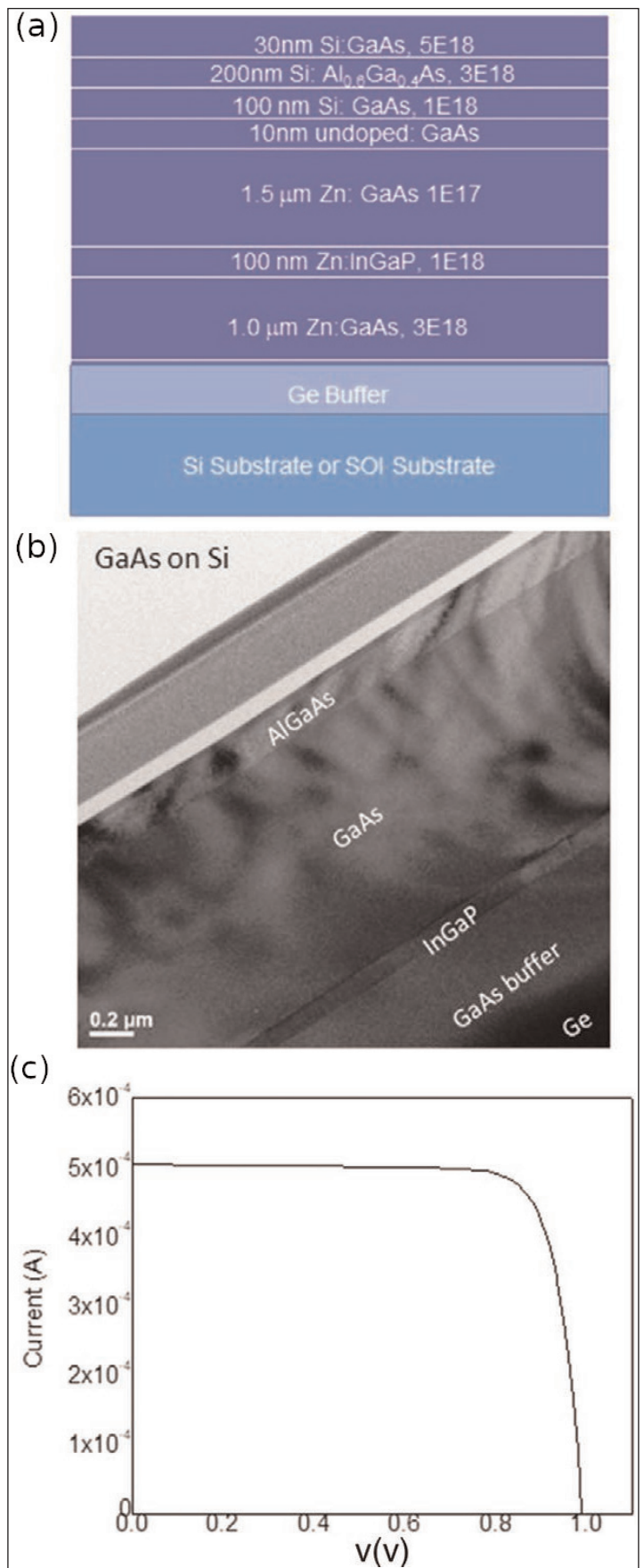


Figure 2. (a) Schematic layer stack of GaAs PV device on 6°-offcut Si substrate. (b) Cross-sectional transmission electron microscope image of GaAs photovoltaic device. (c) Current-voltage characteristics of GaAs-on-Si PV with 1mW 830nm light input.

Displaced misfits boost QD laser on silicon

Researchers see performance improvements comparable to order-of-magnitude reductions in threading dislocations.

Researchers, mainly with University of California Santa Barbara (UCSB) in the USA, have improved indium arsenide quantum dot laser

diode (InAs QD LD) performance on silicon (Si) by introducing layers designed to shift misfit dislocations (MDs) away from the dot-in-well (DWELL) active light-generating region [Jennifer Selvidge et al, Appl. Phys. Lett., vol117, p122101, 2020].

The team, which included researchers from Korea Institute of Science and Technology (KIST) and Intel Corp in the USA, comments: "Our results suggest that devices employing both traditional threading dislocation reduction techniques and optimized misfit dislocation trapping layers may finally lead to fully integrated, commercially viable silicon-based photonic integrated circuits."

Such technologies are hoped to increase data network bandwidth and energy efficiency, along with other applications in chip-scale sensing, detection, and ranging. Direct growth of III-V optoelectronic semiconductors on silicon should reduce production

costs through economies of scale.

Up to now, devices have suffered from performance challenges that have often been blamed on high

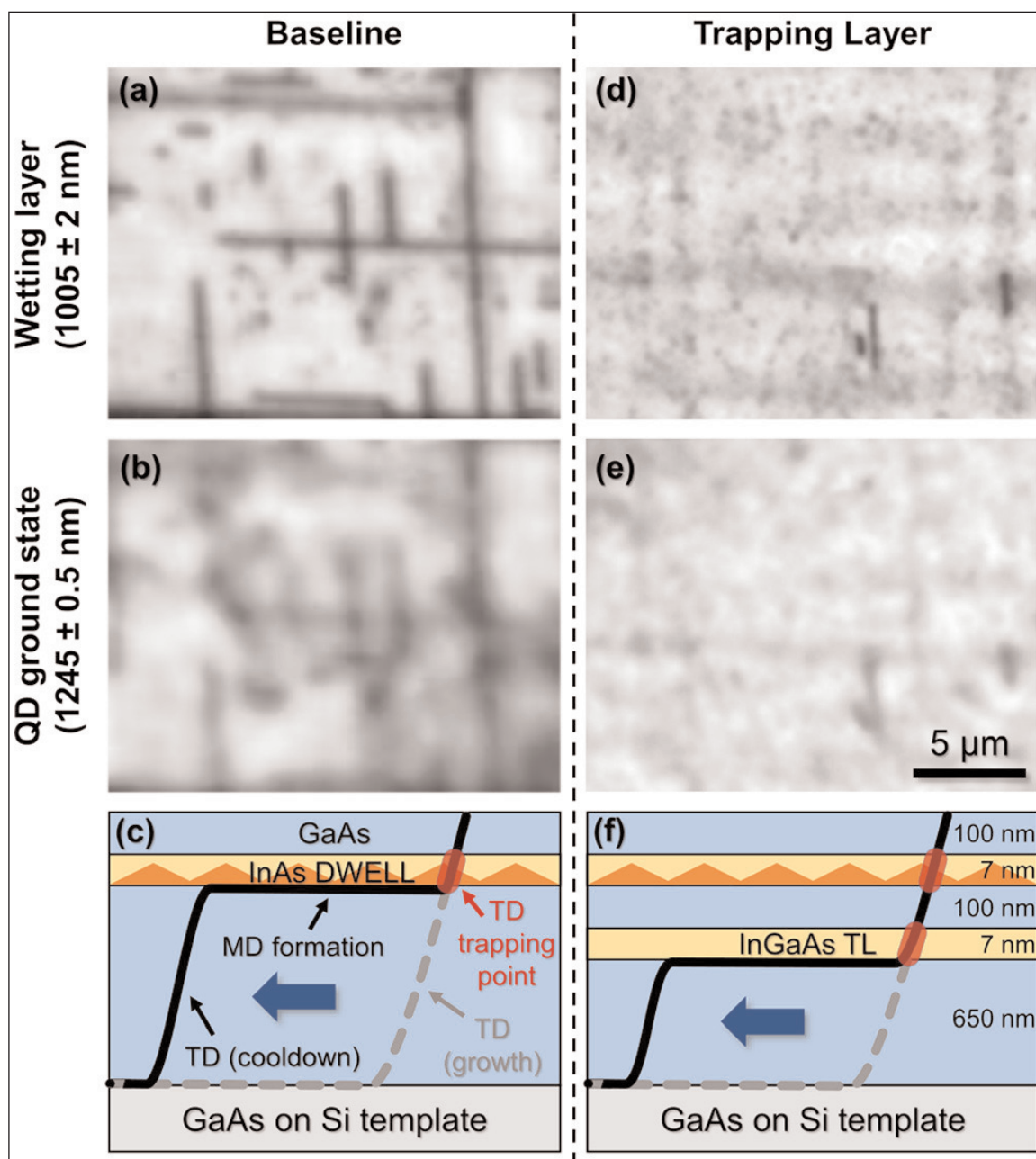


Figure 1. (a) and (b) Monochromatic cathodoluminescence (CL) images of baseline structure at (a) QD wetting-layer emission wavelength (1005nm) and (b) QD ground-state emission wavelength (1245nm). (c) Schematic of proposed dislocation evolution in baseline structure. (d) and (e) Comparable wetting/QD layer CL images for trapping layer structure (f).

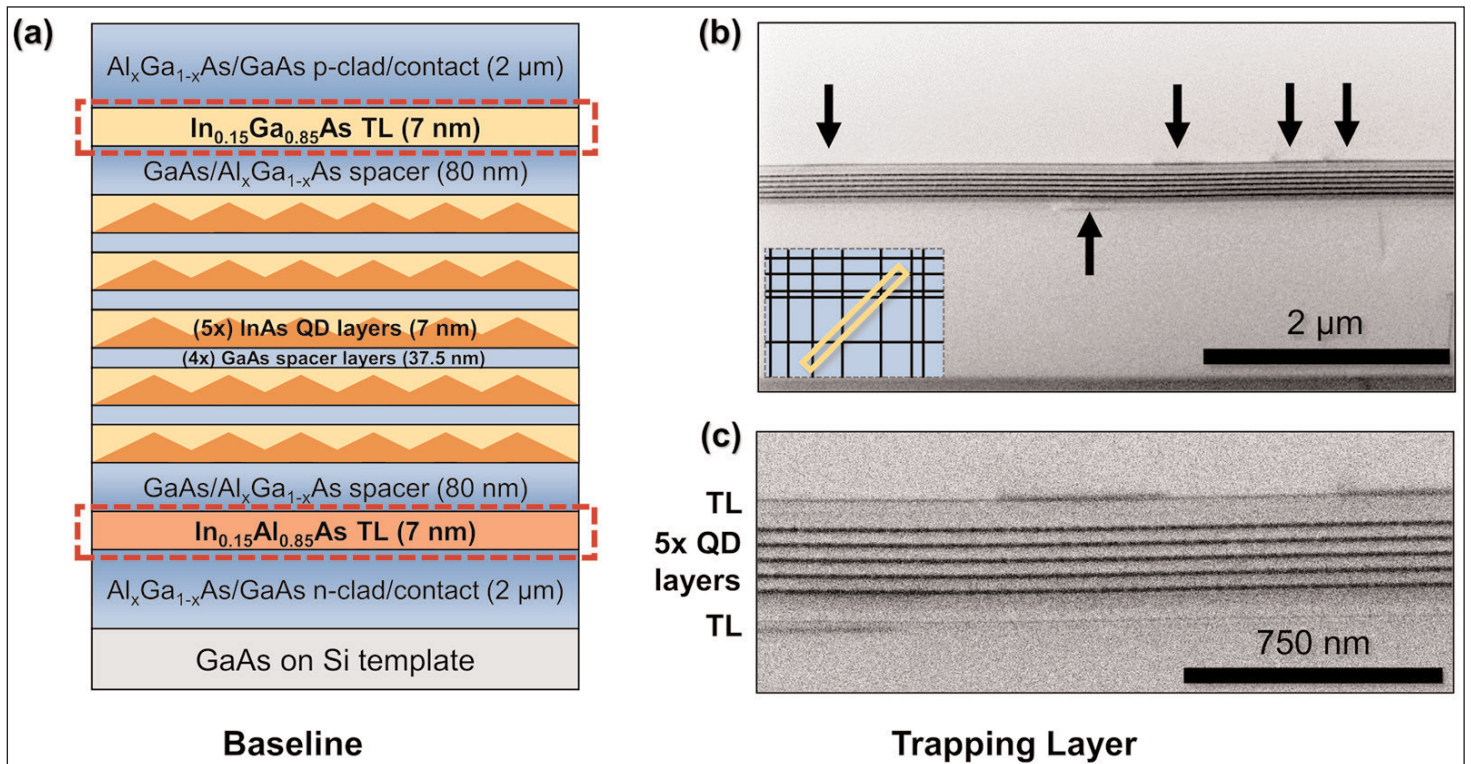


Figure 2. a) Schematic of laser with trapping layers (TLs) (red boxes) above and below QD layers. (b) Cross-sectional bright-field STEM ([100] zone) of TL laser. Inset foil orientation relative to misfit dislocations. Arrows mark misfit dislocation segments at trapping layers. (c) High-magnification image of (b).

threading dislocation densities (TDDs), which create non-radiative recombination centers. However, the UCSB/KIST/Intel team has recently found that misfit dislocations can also sap quantum DWELL efficiency.

The team explains: "These <110>-oriented misfit dislocations, like threading dislocations, limit performance and reliability because they, too, are potent non-radiative recombination centers. Worse still, they may be far more damaging as they have a much larger interaction area with the active region."

The researchers suggest that the low number of reports of misfit dislocations in III-V heterostructures is due to the difficulty in seeing them in cross-sectional transmission electron microscopy (TEM) with QD strain contrast masking that from misfit dislocations.

The researchers believe that the misfit dislocations form during cool-down from the 540°C growth temperature, not during growth, since the DWELL layer is below the critical thickness for misfit dislocation formation. The difference between the thermal expansion of gallium arsenide (GaAs) and silicon is around $3 \times 10^{-6}/\text{K}$.

At around 300°C during the cooling process, the biaxial tensile strain is about 0.1%, inducing mobile threading dislocation segments to glide in GaAs layers thicker than a few hundred nanometers, it is believed. This is not a problem in itself, but the threading dislocations passing through the DWELL layer are not so compliant, resulting in misfit dislocations close to the DWELL, creating non-radiative recombination potential (Figure 1).

The researchers comment: "We hypothesize that this mechanical hardening arises from uneven stress fields generated by the strained QDs and alloy fluctuations in the $\text{In}_{0.15}\text{Ga}_{0.85}\text{As}$ QW. The latter effect, similar to alloy hardening phenomena reported previously in bulk semiconductors, occurs because the difference in covalent radii of indium (142pm) and gallium (124pm) generates in-layer stress fluctuations."

No misfit dislocation structures were seen above the DWELL since the GaAs cap layer was too thin for threading dislocation gliding. In fact, the team saw placing a thin glide-free layer between the misfit dislocation and the DWELL as a means to improve performance. This was achieved by inserting a 7nm $\text{In}_{0.15}\text{Ga}_{0.85}\text{As}$ trapping layer (TL) about 100nm below the DWELL.

The researchers then produced laser structures, fabricated into $3\mu\text{m} \times 1.5\text{mm}$ ridge-waveguide laser diodes (Figure 2). The substrate was a GaAs/Si template with $7 \times 10^7/\text{cm}^2$ threading dislocation density buffer. Since the top p-GaAs contact layer was thick enough for threading dislocation gliding to occur, the researchers inserted trapping layers 80nm above and below the five layers of DWELLS used as active layer.

The indium contents of the two trapping layers were the same, but gallium was replaced with aluminium (Al) in the bottom trapping layer. The covalent single-bond radius for Al is 126pm, compared with 124pm for Ga. A 'baseline' device was also produced without trapping layers.

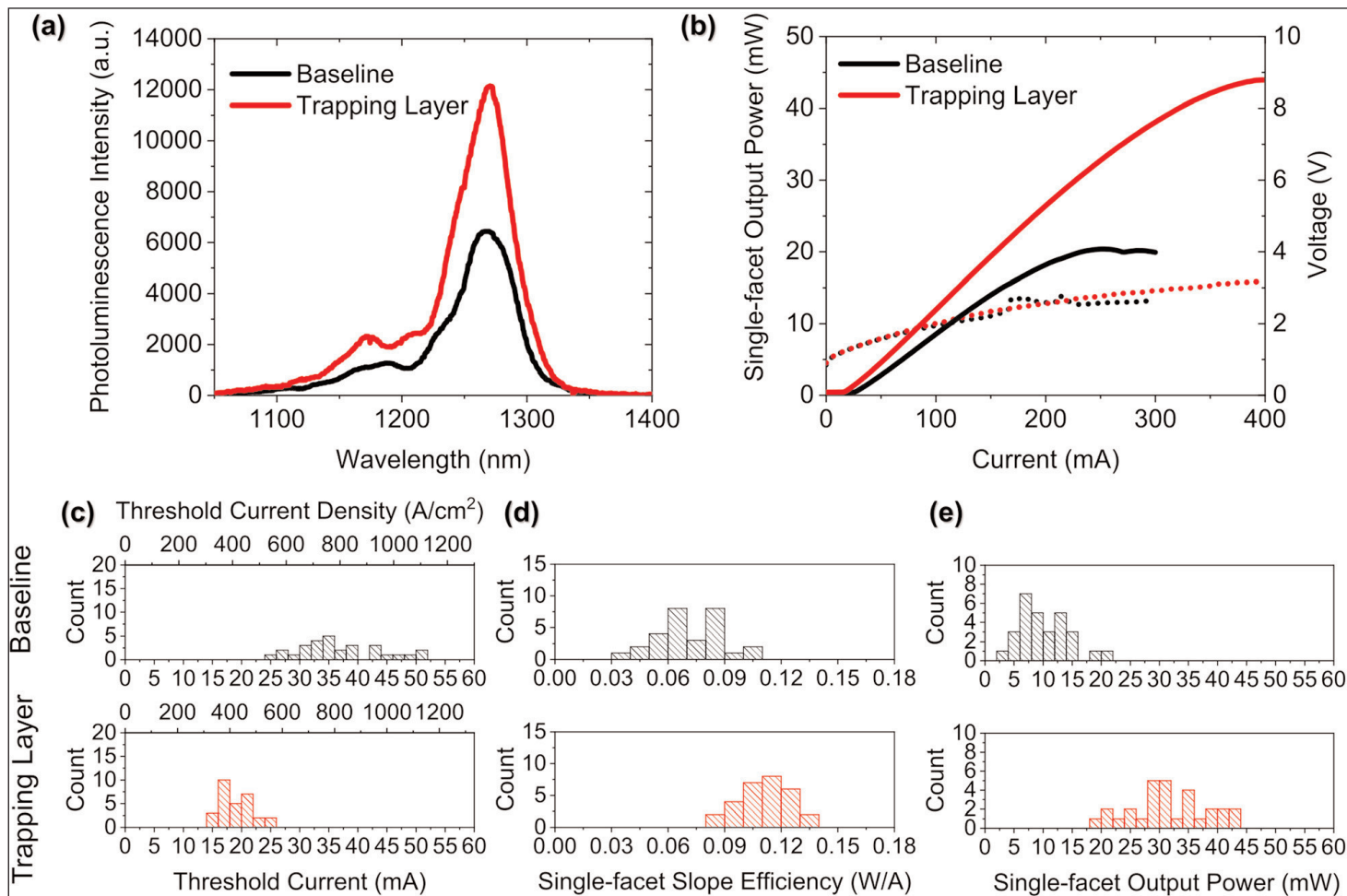


Figure 3. (a)–(e) Comparisons of baseline (black) and trapping layer (red) lasers. (a) Photoluminescence intensity. (b) Single-facet output power (solid) and voltage (dashed) as function of current. (c)–(e) Histograms showing performance improvements of trapping layer devices: (c) threshold current, (d) slope efficiency, and (e) output power.

► Deeper inspection using tomography techniques suggest that, even with the trapping layers, there was some threading dislocation glide, but not as extensive as without the layers. The team reports that trapping layers displace most of the misfit dislocation length from the QDs, on the basis of plan-view scanning transmission electron microscopy (STEM).

The presence of trapping layers increased photoluminescence by almost a factor of two (Figure 3). Under electrical bias, the threshold current with trapping layers was also reduced by a factor of about two. The lowest thresholds achieved with trapping layers was 16mA, a 40% decrease on the lowest baseline value. Despite having 4x the threading dislocation density of 'state-of-the-art' devices on silicon reported in 2019, the threshold current with trapping layers was 20% lower in this case too.

Other improvements were shown in median slope efficiency (+60%) and median peak single-facet output power (3.4x) over the baseline laser diodes. The median input power was 0.85W before thermal roll-over with trapping layers, compared with 0.46W for the baseline. The researchers comment:

"This indicates — assuming comparable thermal impedances — that the inclusion of trapping layers increases the lasers' optical amplification (gain)."

The team sees the performance gains from trapping layers as comparable to those achieved by reducing threading dislocation density from $7 \times 10^7/\text{cm}^2$ to $7 \times 10^6/\text{cm}^2$.

The researchers write: "As device thicknesses are critical for many applications, it is highly advantageous that these performance gains made using thin misfit trapping layers compare favorably to those achieved using hundreds of nanometers of traditional threading dislocation filters."

The team also suspects that reported lifetime improvements with reduced threading dislocation density could be likely explained by an "unseen reduction in the total misfit dislocation line length", adding: "All dislocation line length, whether misfit dislocation or threading dislocation, within the active region degrades laser performance and lifetime; the inclusion and optimization of trapping layers thus complement important, ongoing threading dislocation density reduction efforts." ■

<https://doi.org/10.1063/5.0023378>

Author: Mike Cooke



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Indium gallium nitride laser with n-type ridge on silicon

An inverted diode structure has been shown to slash Joule heating and boost thermal management.

China's Suzhou Institute of Nano-Tech and Nano-Bionics (SINANO) has fabricated indium gallium nitride (InGaN) violet-emitting laser diodes (LDs) on silicon with n-type ridge waveguides (nRWs), which demonstrated lower electrical resistance and improved thermal performance over pRW-LDs [Rui Zhou et al, ACS Photonics vol7 (2020), issue 10, p2636 (23 September 2020)]. Normally, process limitations dictate that the RW in InGaN-based laser diodes are on the p-side of the device. The thermal and electrical problems arise because p-GaN is much more resistive than n-GaN.

The team, which also included a researcher from Tsinghua University in China, believes that nRW-LD devices could be fully compatible with large-scale silicon-

based complementary metal-oxide-semiconductor (CMOS) mainstream electronics and could be used in monolithically integrated silicon photonics as an efficient on-chip light source for high-speed data communication and computation.

Magnesium (Mg) is the usual p-type dopant in III-nitride structures. This imposes a number of restrictions in the growth and activation annealing required to create p-type conductivity. First, Mg tends to hang around in reaction chambers. This 'memory effect' means that subsequent layers will have some level of Mg incorporation, whether desired or not. The memory effect therefore tends to result in growth processes being designed with p-type layers being grown last.

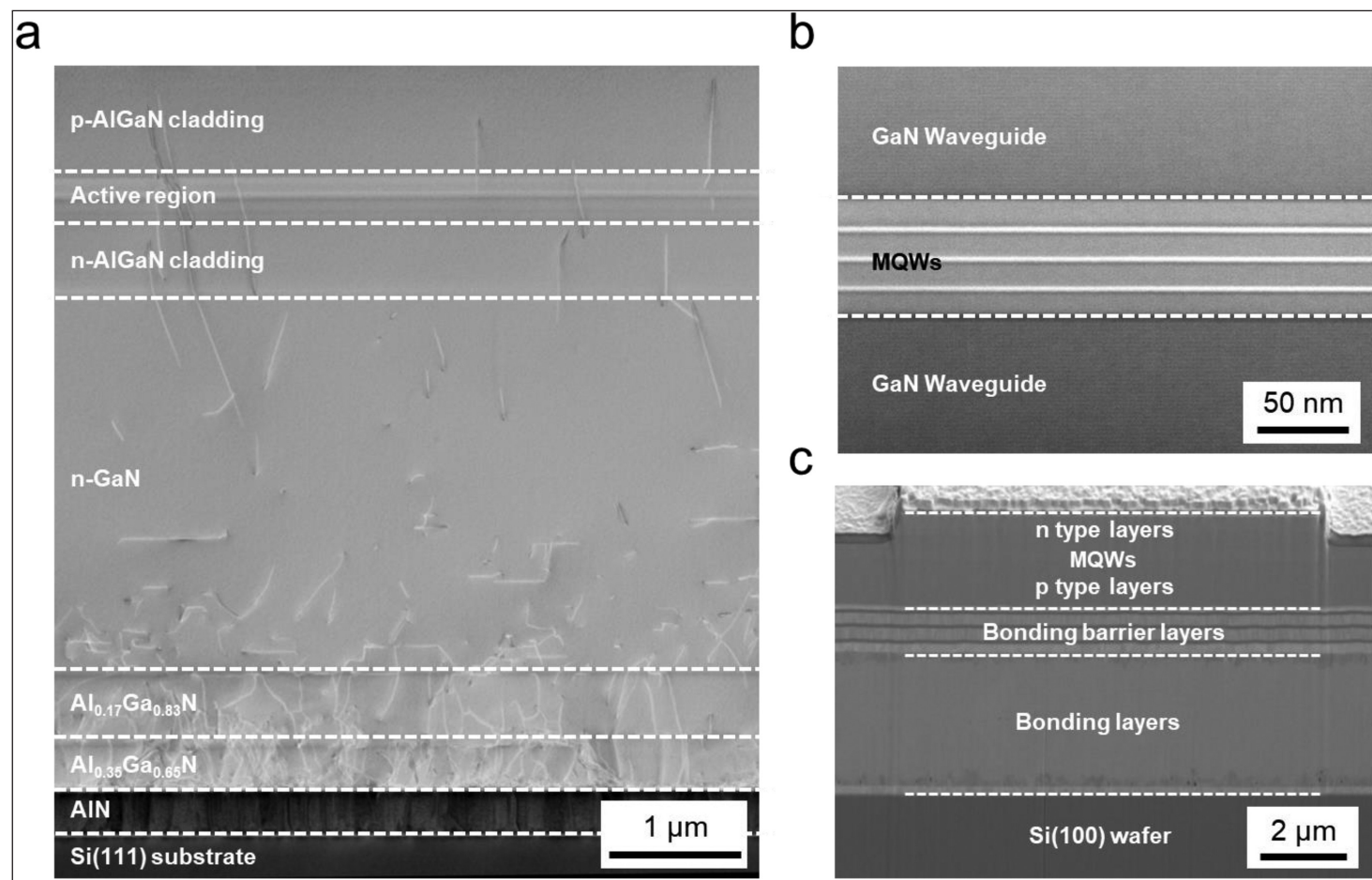


Figure 1. Cross-sectional images of nRW-LD structures. (a) Scanning transmission electron micrograph of nRW-LD epitaxial structure on Si(111) substrate. (b) Enlarged image of InGaN/GaN quantum wells. (c) Cross-sectional scanning electron micrograph of device bonded to Si(100) wafer.

Also, Mg-doped GaN/InGaN is passivated (i.e. rendered ineffective) with hydrogen incorporation. A key part of activation of the p-type layers consists in driving out this hydrogen, usually by raising the temperature in an annealing process, encouraging diffusion of these atoms out of the structure. This requires the hydrogen to travel as small a distance as possible before exiting the material.

The III-nitride heterostructure for the RW-LDs was grown on silicon with (111) crystal orientation. Measures were taken to control threading dislocation density. The laser diode structure consisted of five InGaN quantum wells sandwiched between waveguide layers (Figure 1). The n-side waveguide and the nearest 50nm of the cladding were undoped, avoiding current spreading in the ridge-waveguide structure.

The laser diode structure was bonded p-side down to an exact Si(100) wafer with a p-type ohmic contact electrode surface. The Si(111) growth substrate was removed with wet etching. Further dry plasma etch removed the AlN/AlGaIn growth buffer structures. The inverted RW-LD structure allows the n-type side of the cladding to be much thinner than usual, $\sim 0.5\mu\text{m}$. In non-inverted structures the n-cladding lies on top on a thick GaN template, which has an 'anti-guiding' effect. The p-side of the inverted RW-LD cladding was thicker, at $1.2\mu\text{m}$.

The researchers comment: "The thickness reduction of the n-type AlGaIn cladding layer with a low thermal conductivity can largely decrease both the thermal resistance and the tensile stress resulting from the lattice mismatch between AlGaIn and GaN template, which boost the device performance and fabrication yield."

The bonded material was finally fabricated into $10\mu\text{m}\times 800\mu\text{m}$ RW-LD devices (Figure 2). The effective

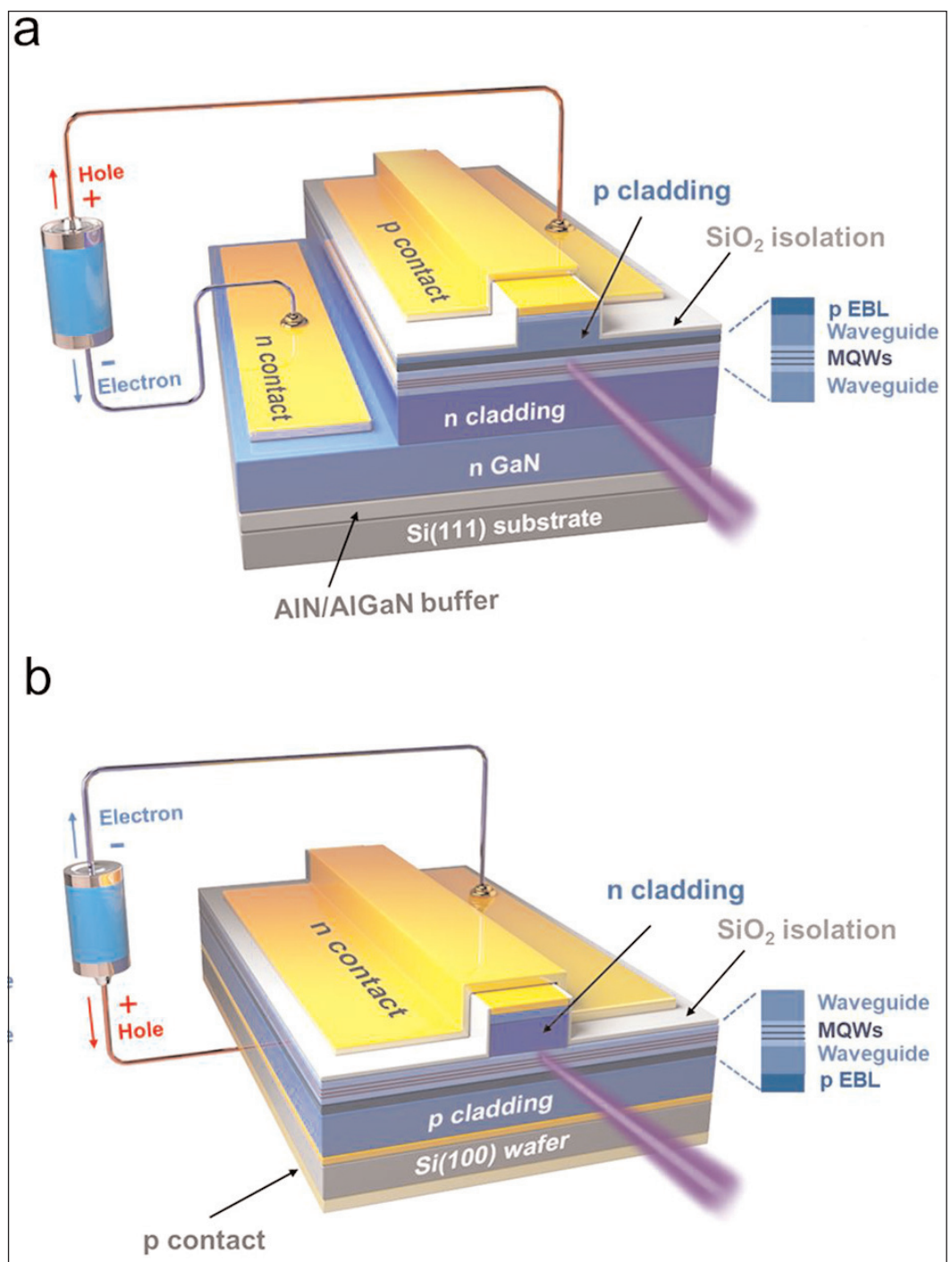


Figure 2. Schematic architecture of InGaN-based (a) pRW-LD on Si(111) and (b) nRW-LD on Si(100).

area of the p-electrode was estimated to be $300\mu\text{m}\times 800\mu\text{m}$.

The reverse leakage current was $\sim 10^{-7}\text{A}$ at -5V reverse bias. The turn-on voltage was around 3.0V . Increase in bias beyond this gave much higher current injection in the inverted RW-LD, compared with a normal pRW-LD on Si(111). This reflected the lower series resistance on the wider p-type region.

The differential resistance at 350mA injection into the inverted nRW-LD was 1.2Ω , compared with 2.3Ω for the normal pRW device. This reduced the operation voltage 1.41V to 4.15V . The lower voltage meant

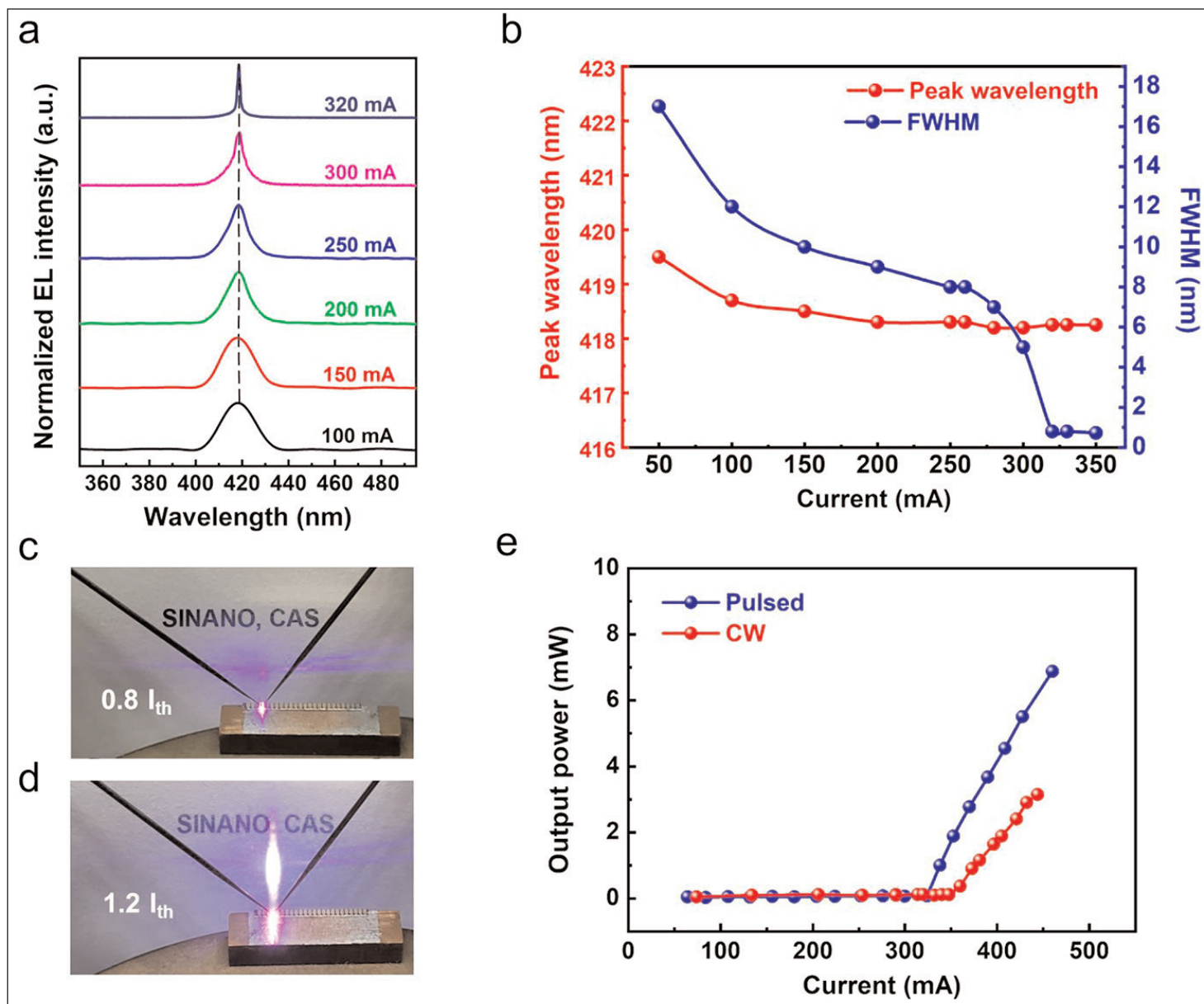


Figure 3. Electroluminescence of nRW-LD under electrical injection. (a) Spectra under pulsed currents (0.4% duty cycle, 10kHz repetition rate) at room temperature (RT). (b) Peak wavelength and FWHM of spectra versus pulsed injection current at RT. (c, d) Far-field patterns observed 0.8x and 1.2x threshold current. (e) Light output power versus pulsed and CW injection current at RT.

reduced Joule heating, delaying thermal degradation of laser performance. The inverted device thermal resistance was estimated to be 18.2K/W, compared with 26.5K/W for the normal p-ridge laser diode. The junction temperatures under continuous wave (CW) operation at 350mA were 48.5°C and 73.5°C, respectively. The 25°C lower junction temperature was attributed to the lower Joule heating and to the shorter heat dissipation path length.

There is also scope for improvement, since the researchers used nickel-tin solder in the wafer bonding process, which has a relatively low thermal conductivity. A copper-based alternative could be a way forward to an even better thermal performance.

The nRW-LD structure had a 12nm full-width at half maximum (FWHM) spectral line at 100mA injection

(Figure 3). The linewidth narrowed to 0.8nm at 320mA, giving a laser mode wavelength of 418.3nm at threshold.

The threshold current density of 4.37kA/cm² is seen as high relative to state-of-the-art InGaN laser diodes under CW operation. The lifetime was also only 5 minutes before “a drastic degradation of output power” was observed. The researchers blame a high 6x10⁸/cm² threading dislocation density and an unoptimized active region. Threading dislocations provide non-radiative recombination centers and leakage current paths that sap efficiency and reliability. Some studies suggest lifetimes of laser diodes can be increased to 10,000 hours by reducing threading dislocations to 10⁶/cm². ■

<https://dx.doi.org/10.1021/acsp Photonics.0c01061>

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AIPN vapor phase epitaxy on gallium nitride

Potential for high-electron-mobility transistors and distributed Bragg reflectors.

Nagoya University and National Institute for Materials Science (NIMS) in Japan report on aluminium phosphide nitride (AIPN) vapor phase epitaxy (VPE) on gallium nitride (GaN) that results in low 150Ω/square sheet resistance material [Markus Pristovsek et al, Appl. Phys. Express, vol13, p111001, 2020].

The low resistance promises power electronics applications such as high-electron mobility transistors (HEMTs). Another potential arises from an increased refractive index contrast relative to III-nitride alternatives for distributed Bragg reflectors (DBRs) in short-wavelength vertical-cavity surface-emitting lasers (VCSELs).

The alloying of P and N to give AlGaPN semiconductor material has previously been proposed in patent form (now expired). The Nagoya/NIMS researchers express scepticism as to whether the process described in the patent was ever realized, since there was no subsequent supporting publication.

GaN alloys have been studied to an extent, but suffer from problems such as P substitution on the Ga-site, rather than the desired N-site, even forming P_3N_3 domains. This relates to the covalent radius of P (107pm) being closer to that of Al (121pm) and Ga (122pm), relative to N (71pm). However, the tensile strain of AlN on GaN should favor P incorporation on the group-V N-site, avoiding this problem.

The source of the phosphorus component of the AIPN was tertiary-butylphosphine (tBP). This organic compound was chosen over the simpler carbon-free ammonia-analog phosphine/phosphane (PH_3), due to its lower toxicity, high vapor pressure, and low decomposition temperature. In fact, the lab where the material was grown is not permitted to handle PH_3 due to safety considerations.

The lead author, Markus Pristovsek, comments that he began his scientific career around the year 2000 at Germany's Technical University Berlin (TUB), looking for alternative precursors of arsenic and phosphorus for VPE, finding tBP and tBAs to give the best performance.

The AIPN was grown on c-plane (0001) GaN/sapphire templates through metal-organic VPE. The other precursors were trimethyl aluminum (TMAI) and ammonia (NH_3). Hydrogen gas (H_2) was used to carry the precursors to the deposition reactor chamber.

Initially the researchers switched on the tBP and TMAI together, but later found that starting with a few seconds

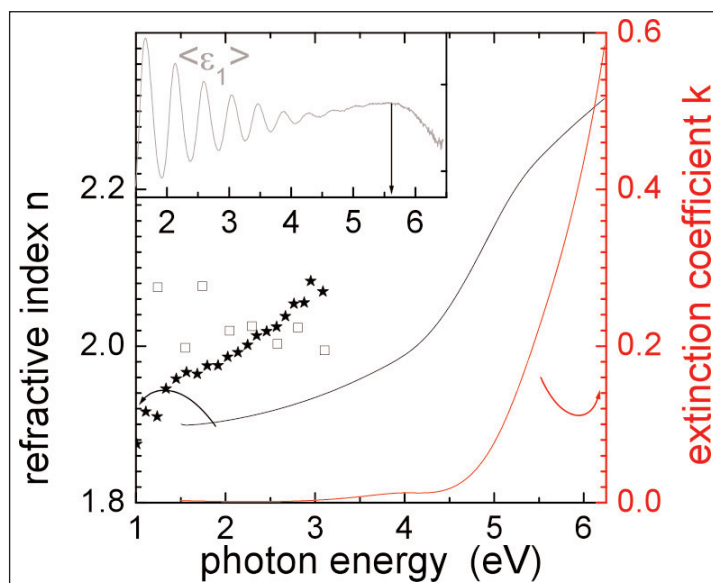


Figure 1. Refractive index and extinction coefficient averaged from three AIP_{0.13}N_{0.87} layers of 180nm, 315nm and 655nm on GaN-sapphire. Points from vertical incidence reflection measurements of 315nm (open box) and 655nm (star) AIPN. Inset: effective $\langle \epsilon_1 \rangle$ dielectric constant of 655nm AIPN on 22μm carbon-doped GaN on sapphire, to suppress GaN Fabry-Perot oscillations.

of tBP flow improved the AIPN quality. The tBP and NH_3 flow was also maintained during the initial cooling after growth at 1050–1250°C, down to 950°C.

The team used an empty metal-organic line for the tBP, but this is known to cause gas-phase reactions in AlGaP growth with TMAI/tBP pre-reactions occurring in the lines and showerhead. In future work, the researchers plan to use a group-V inlet to try to avoid these problems. One result of these drawbacks was a gradient in the P-content of grown material, leading to cracking.

The initial experiments explored the effect of tBP partial pressure on the grown material. The researchers found that an increased tBP partial pressure reduced cracking of the material.

X-ray diffraction on 7nm/14nm AIPN/GaN superlattices found an incorporation limit of 18–20%, based on the disappearance of satellite peaks. The researchers attributed the limit to compressive strain arising in the superlattice. Compressive strain has a similar effect on GaPN growth. At the pure AlN extreme, the strain in the superlattice is tensile.

Thicker lattice-matched AIPN layers were found to be dark, unlike AlN, which is transparent to visible light. The team suggests that carbon (C) from the tBP precursor is to blame. The high temperatures result in the presence of high numbers of single CH_x radicals.

The researchers explain: "The tBP partial pressure is about 50x higher than the TMAI partial pressure, and tBP contains four carbon atoms instead of three for TMAI. Hence, during AIPN growth about 70x more CH_x radicals are present than for AlN growth."

Increasing the ammonia partial pressure was found to enable almost transparent 100nm layers of AIPN to be grown with little impact on P incorporation. The ammonia increased the supply of active hydrogen atoms, reducing the radical concentration.

The researchers aimed to grow a lattice-matched AIPN layer with 10.6% P, but x-ray diffraction revealed the P content to be fractionally lower at 10.3%, giving a slight tensile strain.

Ellipsometry measurements gave refractive indices in the range 1.95–2.05, close to the values found for pure AlN. These values give a difference relative to GaN about 2x that of Al_{0.83}In_{0.17}N, which could be useful for the construction of DBR in VCSELs. The team reports: "A Bragg mirror from AIP_{0.11}N_{0.89} could reach 99% reflectivity with only 14 pairs for wavelengths between 300 and 550nm."

The growth rate was relatively high at 700nm/hour. Considering that the process did not need temperature ramping or gas exchanges, the researchers suggest that a Bragg mirror could be produced in less than 3 hours, in contrast to the 12 hours for AlInN mirrors, once problems like material cracking during growth are sorted.

Experiments on a 655nm layer of AIP_{0.13}N_{0.87} showed Fabry–Perot oscillations up to around 5.5eV, suggesting this as being the region of the optical bandgap. Such a value would suggest a smaller bandgap bowing parameter for the AlN–AIP alloy system of 3eV, compared with 9eV for GaN–GaP. A more precise bandgap assessment using cathodoluminescence was "inconclusive".

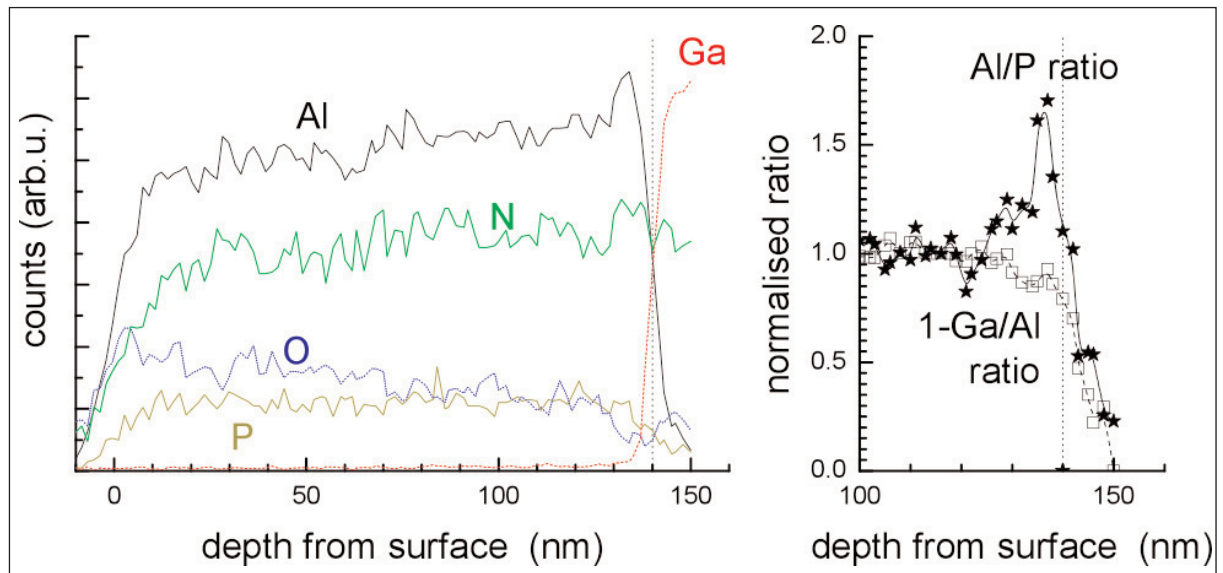


Figure 2. TEM–EDS trace from 140nm AIPN layer after storage in air for about 2 months (left). Ga signal reduced by 3x while N, P and O increased 2.5x. Vertical line marks GaN interface. Wedge shape of TEM slice gives EDS gradient towards surface. Right: normalized (1–Ga)/Al ratio (open box) and Al/P ratio (star).

Resistance mapping of an unoptimized sample gave a sheet value of $(150 \pm 50) \Omega/\text{square}$ for the two-dimensional electron gas arising from the high charge polarization contrast of the AIPN and GaN material. The researchers comment: "A mean value of $150 \Omega/\text{square}$ would be an excellent value for an AlInN/AlN/GaN heterostructure, and at least on the same order as the Al_{1-x}Sc_xN system, which is expected to have a high polarization too."

One possible problem with AIPN is oxidation in air. Cubic AIP is known to oxidize in seconds to Al₂O₃, releasing PH₃. Indeed, this is one technique for creating Al₂O₃ surface passivation. Although the researchers found their AIP_{0.13}N_{0.87} to be less susceptible to oxidation, it did dissolve within a minute in an alkaline developer. "On the positive side, this makes AIPN an easily removable, lattice-matched sacrificial layer," the team writes.

An AIP_{0.13}N_{0.87} sample from the initial growth experiments without tBP pre-flow was found to contain 10–20% oxygen after storage in air for two months, according to an energy-dispersive x-ray spectroscopy (EDS) and transmission electron microscope (TEM) study (Figure 2). At the same time, an abrupt ~5nm interface between the AIPN and GaN template was observed in the same material. With other materials, such as aluminium indium nitride (AlInN), there is often a problem with Ga incorporation.

However, within 30nm of the GaN the P content was lower than desired. The researchers comment: "This P-deficient layer is probably the reason why we had observed sometimes cracking even for lattice-matched layers before we introduced the tBP-preflow." ■

<https://doi.org/10.35848/1882-0786/abbbca>

Author: Mike Cooke

GaN for fast chargers joining SiC in power electronics market, as 5G infrastructure drives GaN RF

5G handsets and Wi-Fi 6 are powering growth in the GaAs power amplifier market for RF front-end modules, says **Yole Développement**.

Market research and strategy consulting company Yole Développement says that its 'Compound Semiconductor Quarterly Market Monitor' on silicon carbide (SiC) and gallium nitride (GaN) applications evolved in fourth-quarter 2020 to incorporate two new modules:

- Module I: GaN and SiC for power electronics applications;
- Module II: GaAs and GaN for RF electronics applications.

The firm lists the market dynamics for the sectors as follows.

Power electronics:

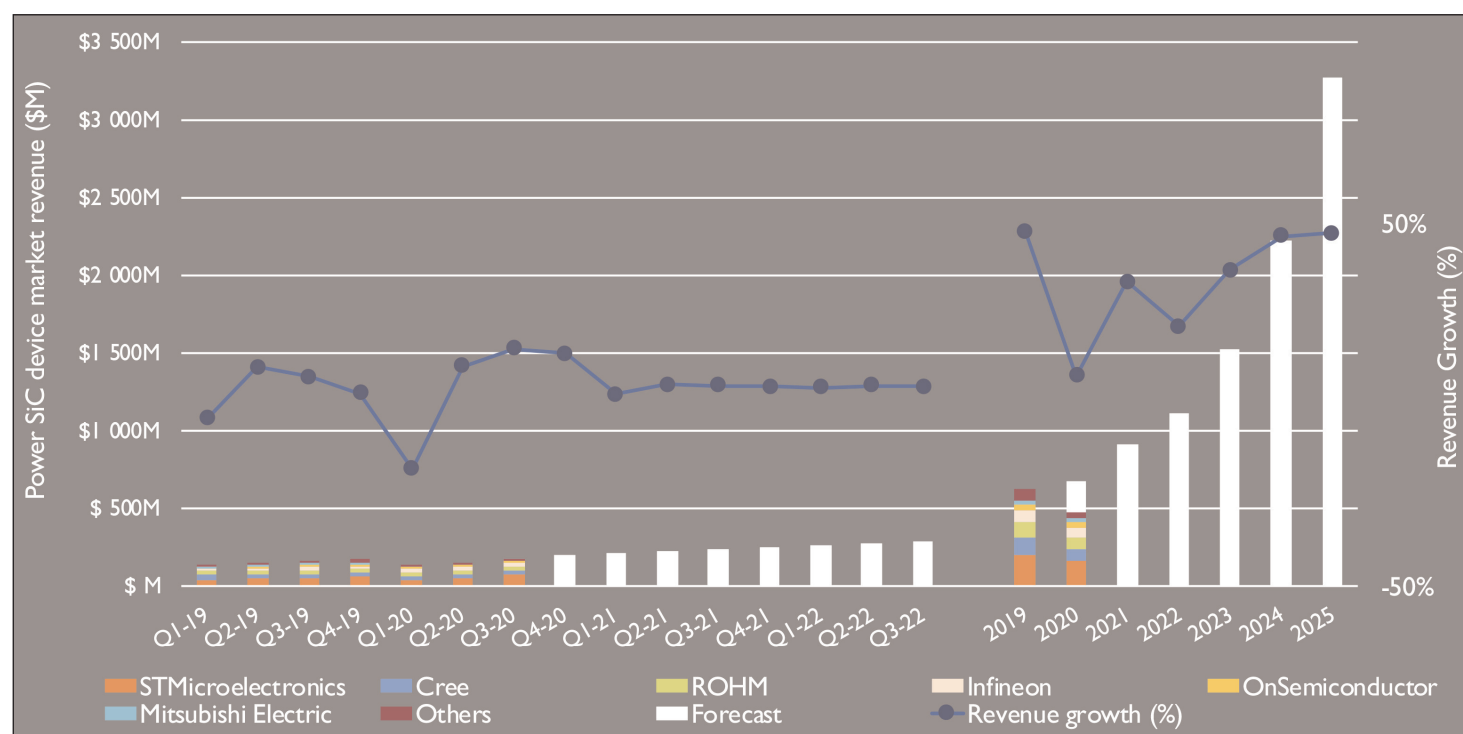
• Power SiC — Despite the short-term impact as a result of the COVID-19 pandemic, SiC device market revenue continues to grow and is expected to exceed \$3bn by 2025. Electric vehicles and hybrid electric vehicles (EVs/HEVs) still represent the killer application for SiC devices. Despite the global slowdown in first-half 2020 due to the COVID-19 outbreak, design wins for SiC solutions have recently multiplied, with a bright market outlook for 2019–2020 period, reckons Yole.

• Power GaN — Yole projects that GaN business will exceed \$680m in 2025. The adoption of GaN high-electron-mobility transistors (HEMTs) for Oppo's in-box fast charger at the end of 2019 boosted the penetration of this wide-bandgap material. Yet GaN has just begun its inroads into the end-consumer mass market, where it will reach volume production, says Yole.

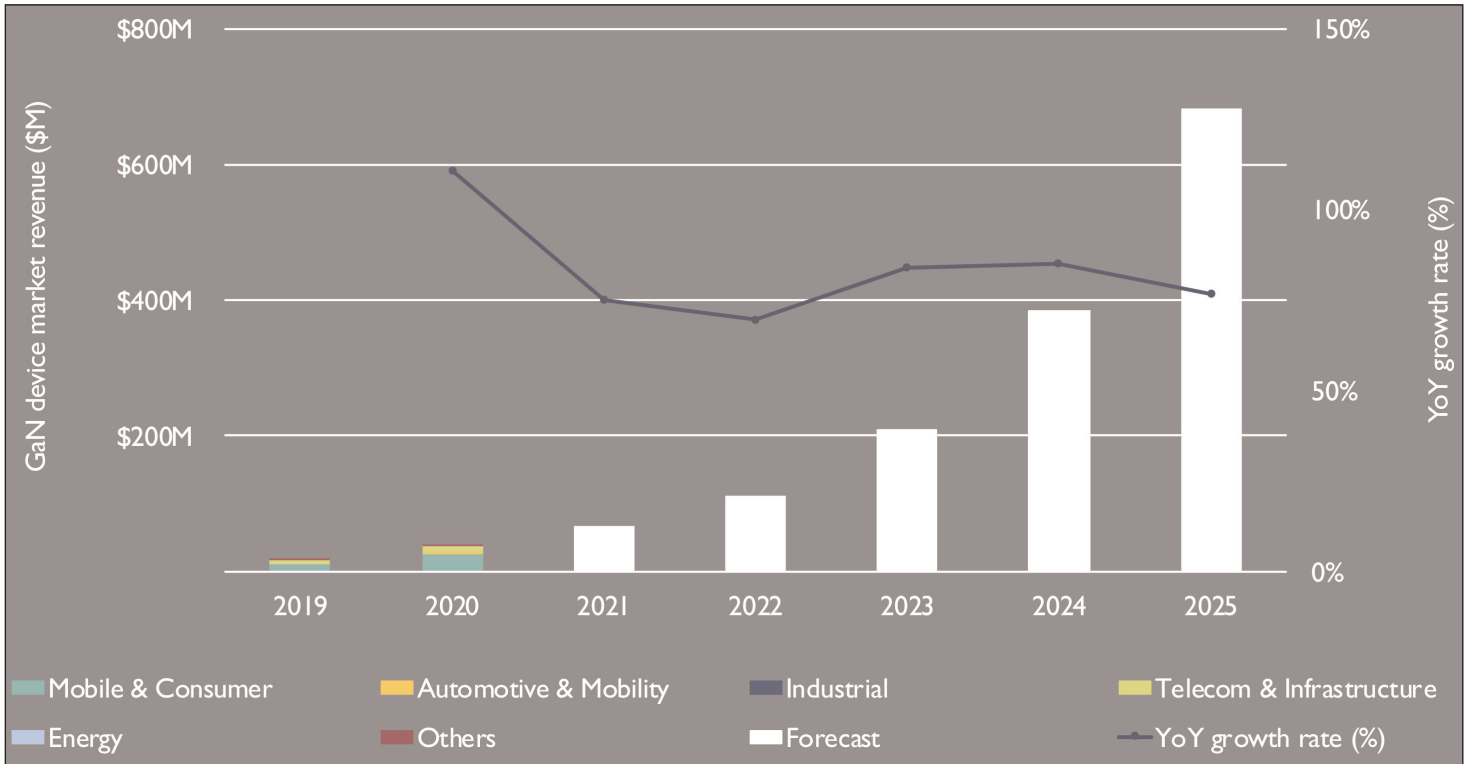
RF:

• GaN RF — Yole estimates that the GaN RF device market is rising at a compound annual growth rate (CAGR) of 12% from 2019 to beyond \$2bn in 2025. This will be driven by telecom and defense applications, but GaN RF devices for military use are expected to grow rapidly, to more than \$1bn by 2025. However, GaN RF business is dependent not only on OEM technology choices but also on the geopolitical context.

• GaAs RF — The market for RF GaAs die is rise from about \$2.8bn in 2019 to over \$3.6bn in 2025, driven by the rise of 5G and Wi-Fi 6 demand for handset applications, reckons Yole.



Power SiC device market revenues.

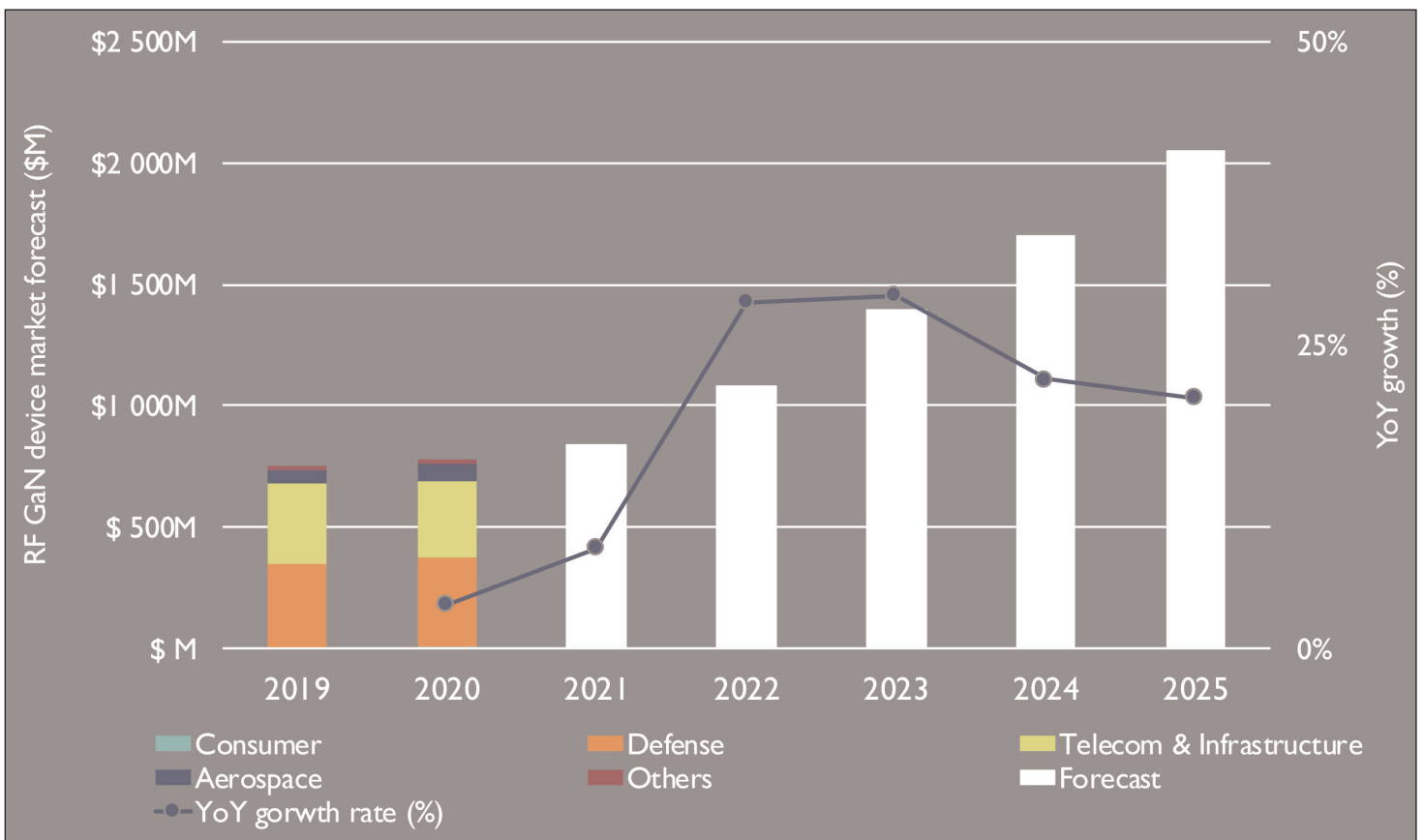


Power GaN device market forecast between 2019 and 2025.

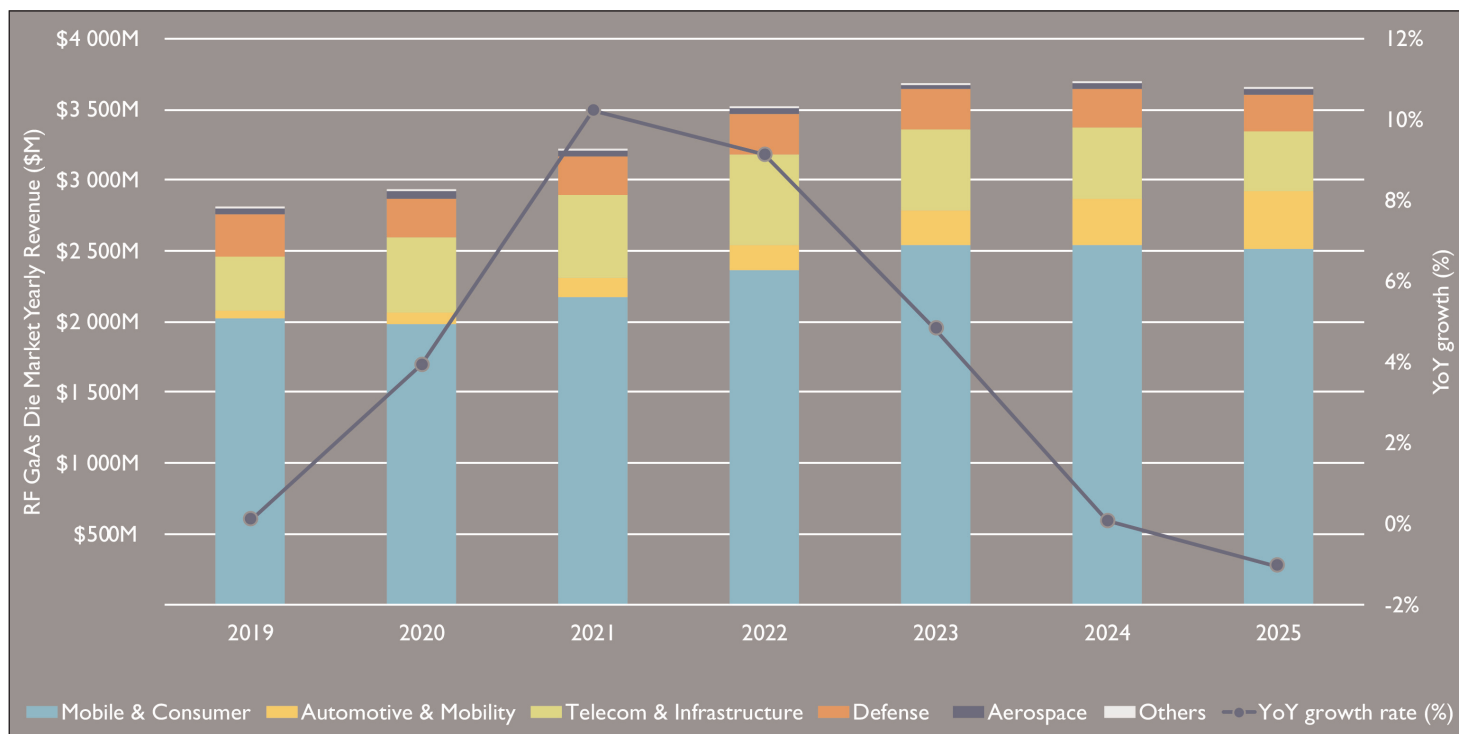
5G telecom infrastructure: gallium nitride's ascendency

"In the dynamic 5G infrastructure market, there is a continuous race for more efficient antenna types," notes Ahmed Ben Slimane PhD, technology & market

analyst Compound Semiconductor Monitors, at Yole. "Switching technology from RRH [remote radio head] to AAS [active antenna system] will transform the RF front ends from a low number of high-power RF lines to a large number of low-power RF lines." ▶



RF GaN device market forecast by application between 2019 and 2025.



RF GaAs die market forecast by application between 2019 and 2025.

Meanwhile, deployment of higher frequencies in the sub-6GHz and millimeter(mm)-wave regimes is pushing OEMs to look for new antenna technology platforms with larger bandwidth, higher efficiency and better thermal management. In this context, GaN technology has become a serious competitor to silicon-based LDMOS and GaAs in RF power applications, showing continuous performance and reliability improvement, potentially leading to lower cost at the system level. Following its penetration into the 4G LTE telecom infrastructure market, GaN-on-SiC is expected to maintain its strong position in 5G sub-6GHz RRRH implementations. However, in the emerging segment of 5G sub-6GHz AAS - massive MIMO deployments — the rivalry between GaN and LDMOS continues. While cost-efficient LDMOS technology carries on with noteworthy progress in high-frequency performance for sub-6GHz, GaN-on-SiC offers remarkable bandwidth, power-added efficiency (PAE) and power output.

GaAs, a key part of the power semi industry

The handset market is the big driver for GaAs devices, with power amplifier (PA) content increasing per phone. In general, 4G LTE cellular phones need to span multiple frequency bands, with an increasing number of PAs per phone. The 5G demand for PAs is at least a factor of two more than for 4G. Adding to that, the stringent requirements for linearity and power make GaAs the material of choice for PAs in the RF front-end module (FEM). Even though CMOS has lower cost per chip, it will not necessarily have the advantage over GaAs when it comes to modules and performance.

“For mobile connectivity, Wi-Fi 6 began to enter the

market in 2019,” says Poshun Chiu, technology & market analyst, Compound Semiconductors & Emerging Materials. “Some OEMs launched new phones with Wi-Fi 6: Samsung’s Galaxy S10 in Q1/2019, Apple’s iPhone 11 in Q3/2019, and in Q1/2020 Xiaomi was the first Chinese handset company to have Wi-Fi 6,” he adds. “GaAs solutions are becoming of great interest owing to their linearity and high power output, compared to traditional solutions,” he adds.

Power SiC device boom due to automotive

Since the first commercialization of SiC diodes, the power SiC device market has been driven by power supply applications. Nevertheless, the automotive segment is becoming the killer application, following SiC’s notable adoption for Tesla’s main inverters in 2018. Since then, announcements of SiC solution design wins from different car-makers have multiplied. In 2020, BYD also adopted an SiC-based main inverter solution for its premium models. Other carmakers, such as Audi, Volkswagen, and Hyundai are expected to adopt SiC in their next generation models. In the prospering SiC power market, the automotive segment is undoubtedly the foremost driver, and will hence hold more than 60% of total device market share in 2025.

“However, following the global COVID-19 outbreak, almost all automotive OEMs had to shut down and the supply chain faced significant disruption,” says Ezgi Dogmus PhD, team lead analyst, Compound Semiconductors, at Yole. “In this context, we expect the power SiC market’s year-on-year (Y-o-Y) growth to slow down to 7% in 2020, with a significant impact in Q1/2020 and Q2/2020.” ■

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Silicon carbide device market growing at 30% CAGR to over \$2.5bn in 2025

The automotive sector is growing at 38% to exceed \$1.5bn, says Yole.

The silicon carbide (SiC) device market is estimated to be rising at a compound annual growth rate (CAGR) of 30%, from \$225m in 2019 to more than \$2.5bn in 2025, according to the report 'Power SiC: Materials, Devices and Applications — 2020 edition' by Yole Développement.

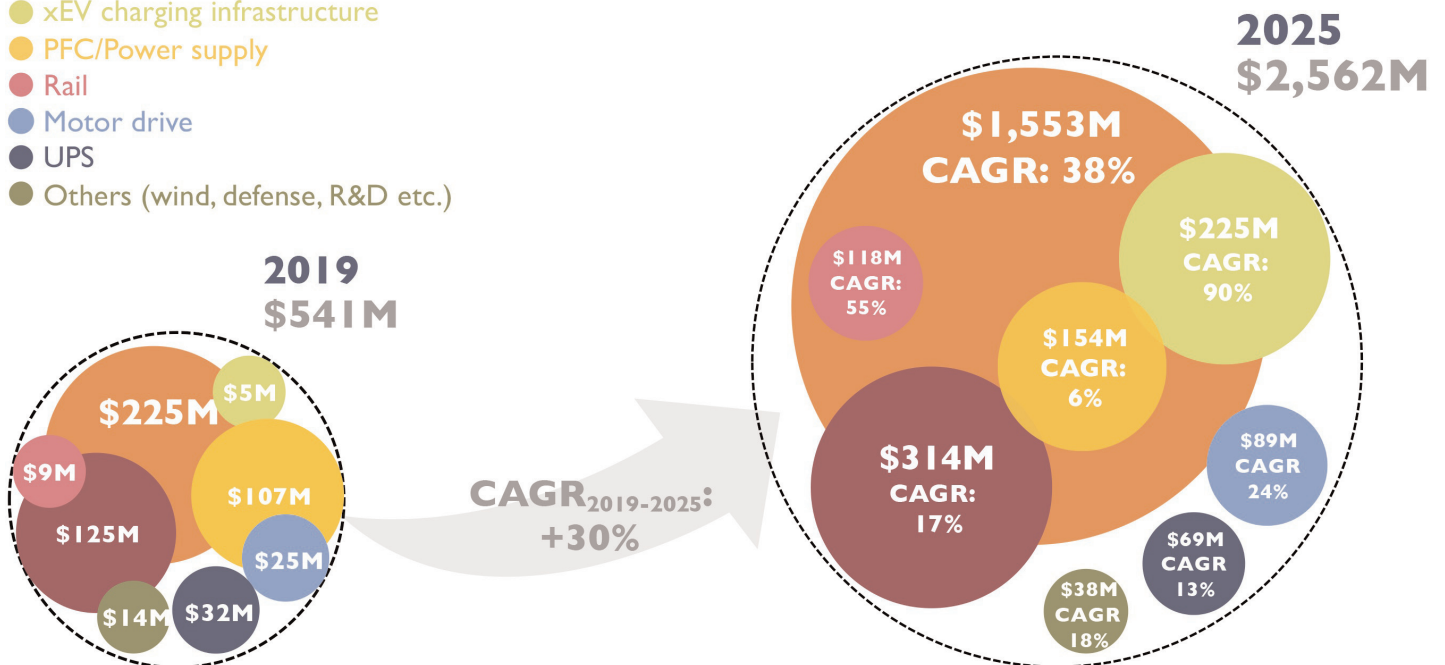
"SiC technologies are gaining the confidence of many customers and are penetrating various applications," says Ezgi Dogmus PhD, team lead analyst Compound Semiconductor & Emerging Substrates at Yole. "Indeed, driven by EV-related applications, SiC for power electronics applications will for sure grow strongly in the next five years," she adds.

Due to the COVID-19 pandemic, SiC device and materials market growth in the electric vehicle/hybrid electric vehicle (EV/HEV) sector slowed in first-half 2020 due to lockdown measures and lower production rates at the facilities of both original equipment manufacturers (OEMs) and SiC players. Nevertheless, the market outlook for SiC is positive. Numerous car makers continue qualifying SiC discrete devices or modules in the inverter, on-board chargers (OBCs) and DC/DC converters for their next-generation models. As one of the main drivers of the overall power electronics market, automotive applications are hence expected to remain one of the major markets in the SiC power sector.

2019-2025 power SiC market forecast split by application

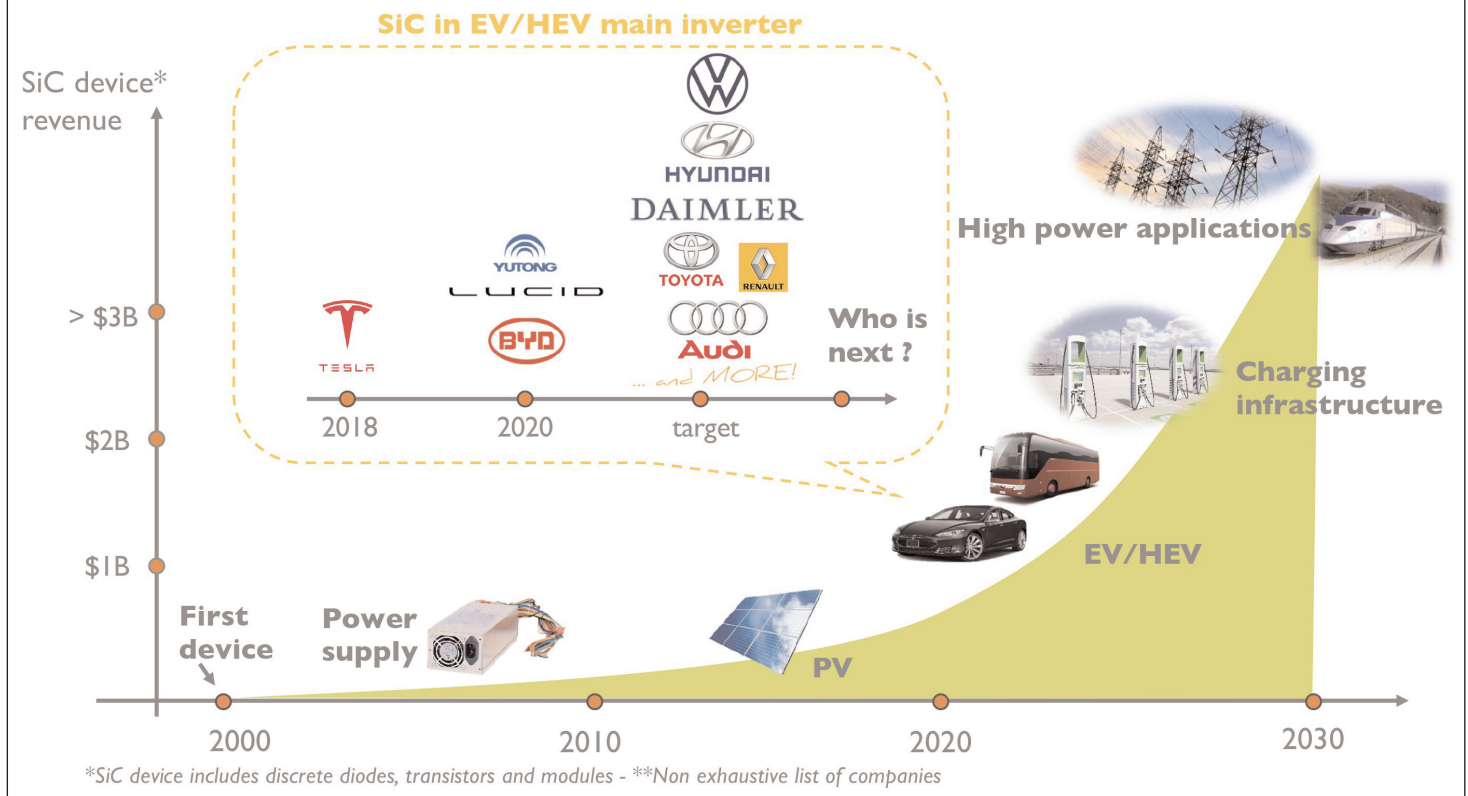
(Source: Power SiC: Materials, Devices and Applications 2020 report, Yole Développement, 2020)

- xEV (main inverter+OBC+DC/DC converter)
- Photovoltaics + energy storage systems
- xEV charging infrastructure
- PFC/Power supply
- Rail
- Motor drive
- UPS
- Others (wind, defense, R&D etc.)



Roadmap for power SiC devices**

(Source: Power SiC: Materials, Devices and Applications 2020 report, Yole Développement, 2020)



In this context, the silicon carbide automotive market is expected to grow at a 38% CAGR to exceed \$1.5bn in 2025.

Along with EV applications, SiC is of great interest to the charging infrastructure market, which is growing significantly. Indeed, high-power chargers can benefit from SiC's higher efficiency and higher frequency by offering more compact solutions than silicon-based insulated-gate bipolar transistors (IGBTs). This market is growing at a 90% CAGR from just \$5m in 2019 to \$225m in 2025, reckons Yole.

Besides the automotive sector, applications such as photovoltaics (PVs), rail and motor drives will also show double-digit CAGRs in the 2019–2025 period.

Technical and commercial development

Since the commercialization of the first SiC devices in 2001, their performances and value have gradually been proven. Their price has also become increasingly attractive to end users.

"SiC transistors still have some technical and commercial challenges to face, despite the value they add," comments Amine Allouche, technology & cost analyst at System Plus Consulting. "These include the wafer price and the complexity of some process steps, specifically SiC etching and high-temperature implantation. These challenges still hinder SiC adoption on a large commercial scale."

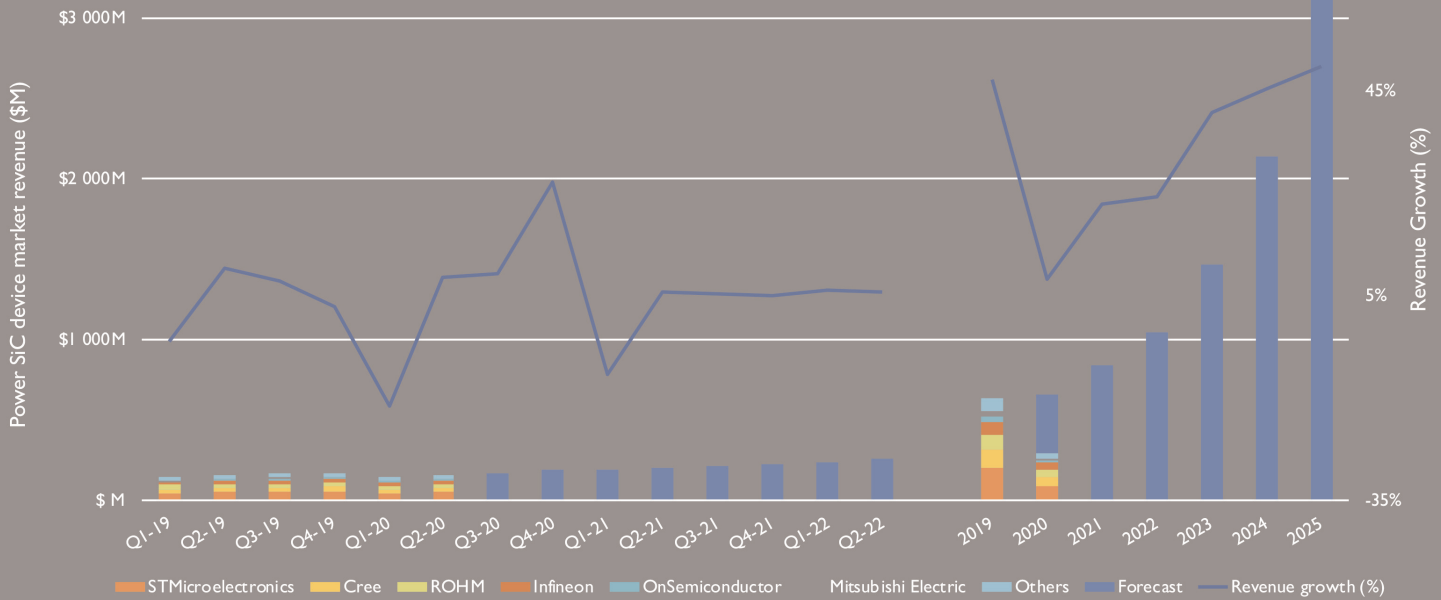
SiC is of great interest to the charging infrastructure market, which is growing significantly. Indeed, high-power chargers can benefit from SiC's higher efficiency and higher frequency

In parallel, the performance and added value of SiC diodes have also been demonstrated. Now, their price has also become increasingly acceptable to end users. The report 'SiC Diodes Comparison 2020' from System Plus Consulting gives a benchmark overview of the various SiC diodes available on the market and analyzes 11 of them from seven of the main SiC diode suppliers. "The 11 SiC diodes are spread across three voltage classes: 650V, 1200V, and 1700V," explains Allouche. "Devices from Infineon Technologies, Wolfspeed, Rohm, STMicroelectronics, ON Semiconductor, Microsemi and UnitedSiC have been analyzed. They target different power applications, including two AEC-Q101-qualified SiC diodes."

The report 'SiC Transistors Comparison 2020' from System Plus Consulting includes 29 SiC transistors: 25 SiC MOSFETs and four SiC JFETs, in five voltage classes. Developed by Rohm, STMicroelectronics, Wolfspeed, Infineon Technologies, Littelfuse, ON Semiconductor, Microsemi and UnitedSiC, they target various power applications, including two automotive-qualified devices.

Power SiC device revenues – Market dynamics, quarter by quarter

(Source: Compound Semiconductor Quarterly Market Monitor, Q3 2020, Yole Développement)



Different strategies to grab the EV/HEV SiC module business*

(Source: Power SiC: Materials, Devices and Applications 2020 report, Yole Développement, 2020)

Vertically integrated device manufacturers with Tier 1s



Substrate suppliers expanding to vertical integration



Established discrete and power module manufacturers



EV/HEV SiC module business

EV/HEV OEMs and Tier 1s



*Non exhaustive list of companies

Substrate supply

In 2018, the increase in SiC wafer demand as well as the transition from 4" to 6" diameters resulted in wafer shortages. Consequently, securing wafer supply has become the priority for device makers.

"Facing growing demand, wafer suppliers such as Cree, II-VI, SiCrystal (a ROHM company), Tankeblue, SiCC and many others have invested heavily to expand their capacity," notes Poshun Chiu, technology & market analyst Compound Semiconductors & Emerging Substrates at Yole. "Numerous device manufacturers such as STMicroelectronics, Infineon Technologies and ON Semiconductor have signed several long-term wafer supply agreements with Cree, SiCrystal and GTAT. The value of long-term agreements in 2019–2020 amounted to more than \$900m, notes Yole. In parallel, Korea's SKSiltron acquired Dupont's SiC wafer business and STMicroelectronics completed the acquisition of Norstel," he adds.

Following US-China trade tensions, Chinese players have accelerated their plan to create a domestic SiC supply chain. More than \$2bn has been invested by Sanan, Tankeblue, SiCC and other Chinese suppliers spanning wafer and epiwafer fabs and packaging.

Silicon carbide module market

In 2020, substrate supplier II-VI made an important step toward vertical integration in the SiC module business. By acquiring Ascatron and Innovion and licensing GE's SiC module technology, the firm has internalized the epi and device manufacturing steps. II-VI's strategy was clearly to secure new business in the growing module market.

"The SiC market is very dynamic, with lots of investments as well as partnerships to accelerate the time to market," concludes Ahmed Ben Slimane, technology & market analyst, Compound Semiconductors & Emerging Substrates at Yole.

Regarding the module business, during 2019–2020 Cree partnered with StarPower, ABB, ZF and Delphi on SiC-based powertrain systems for electric cars and e-buses, while ROHM teamed up with Vitesco and Leadrive Technologies to work on SiC powertrain solutions. Automotive tier-1 player Bosch is also internally developing SiC modules, Yole notes. ■

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Optimizing silicon carbide MOSFET performance

Researchers claim a record-breaking combination of on-resistance and breakdown for power applications.

Two researchers at the State University of New York Polytechnic Institute (SUNY Poly) in the USA claim record-breaking performance for 4H-

polytype silicon carbide (SiC) lateral metal-oxide-semiconductor field-effect transistors (MOSFETs) [Nick Yun and Woongje Sung, IEEE Transactions On Electron Devices, published online 14 October 2020]. In particular, a 0.3 μm -channel device with 2.5 μm gate-drain spacing achieved 7.7m $\Omega\text{-cm}^2$ specific on-resistance and 450V breakdown.

SiC-based devices are looking to supplant the more mature silicon technology for power integrated circuit applications, based on a larger 3MV/cm critical electric field for breakdown, an order of magnitude larger than for silicon. A challenge for SiC-based devices has been to achieve low on-resistances combined with high breakdown voltages.

Yun and Sung's work was partially supported by the US Office of Energy Efficiency and Renewable Energy (EERE), Department of Energy, with North Carolina State University's Power America Institute.

Yun and Sung designed a wide range of MOSFETs (Figure 1), using varied dimensions. The devices were fabricated under a range of process conditions at the

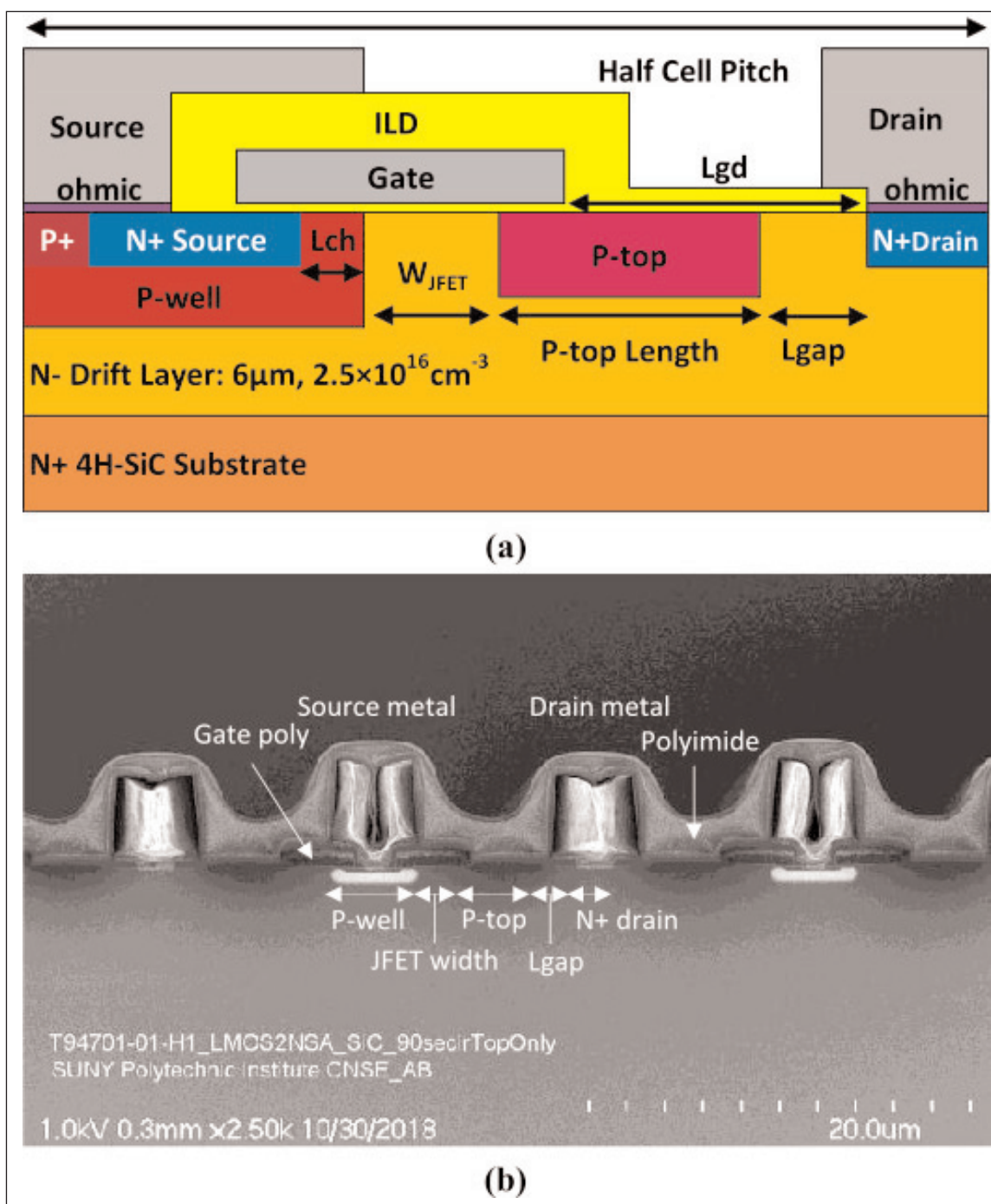


Figure 1. (a) Schematic and (b) scanning electron microscope cross-sectional view of fabricated 600V 4H-SiC lateral MOSFET.

X-FAB 6-inch wafer foundry in the USA. The substrate featured a $6\mu\text{m}$ heavily-doped n^+ drift layer.

Aluminium ion implantation was used for the various p-type regions. The p-top region formed a single reduced surface field (RESURF) structure. Combined with the p^+ body region, the p-top region made up concentric floating field ring and junction-termination-extension (JTE) structures for hybrid-JTE edge termination. The p-well enabled accumulation- and inversion-mode channels to be realized. The accumulation mode generally resulted in lower specific on-resistance ($R_{\text{ON,sp}}$).

High-temperature nitrogen ion implants created the n^+ source and channel-stop regions. The doping was activated with a 10-minute anneal at 1650°C , under a carbon cap.

The gate insulation was achieved using 1175°C dry oxidation and annealing in nitric oxide (NO). After the gate oxide was patterned, the interlayer dielectric (ILD) was applied. Nickel was then used to give a self-aligned silicide transistor formation process. This was followed by rapid thermal annealing (RTA) at 900°C or 1000°C . The higher temperature resulted in lower contact resistance.

The device fabrication was completed by $4\mu\text{m}$ aluminium deposition for the source contact and gate pad, and nitride/polyimide front-side passivation.

The lateral layout of the device consisted of multiple interdigitated fingers in source- or drain-centered formats (Figure 2). The source-centered layout did not require edge-termination, while the drain-centered transistors needed such structures to "alleviate crowding of electric fields at P^+ regions in the periphery and extend the horizontal depletion layer to achieve the specified breakdown voltage of the device".

The source-centered approach achieved a $100\mu\text{A}$ blocking voltage of 600V without edge-termination. By contrast, such blocking was limited to 280V in drain-centered devices. Even worse 180V blocking behavior was seen in devices without p-top RESURF structures, regardless of layout. Edge-termination in the drain-centered MOSFETs enabled comparable 600V blocking to the source-centered device.

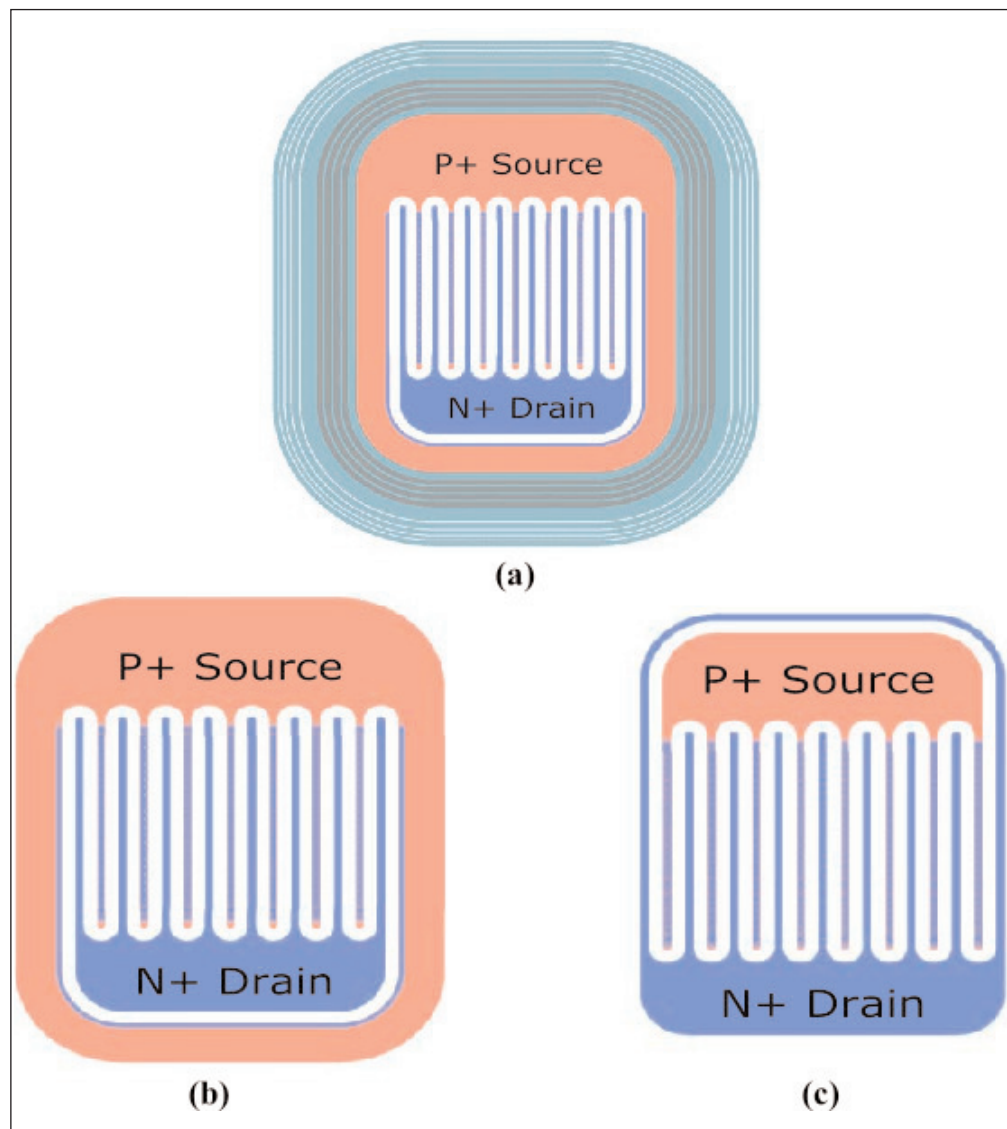


Figure 2. Simplified topological view of drain-centered layout methodology with (a) and without (b) edge termination, and (c) source-centered layout methodology for designing lateral MOSFETs. Gate pad not shown.

The on-resistance of the device decreased at high temperature, compared with room temperature (25°C). The minimum came at 125°C , but on-resistance continued to be lower than at room temperature in the range up to 200°C . Yun and Sung note: "The increase of $R_{\text{ON,sp}}$ from 125°C and onward could be due to the governance of other resistances at high temperatures such as JFET, contact, metal, and drift resistance"

Generally, the devices had a $5\mu\text{m}$ gate-drain distance. A source-centered device with smaller $2.5\mu\text{m}$ gate-drain spacing, and $0.3\mu\text{m}$ -channel length, still achieved a reasonable 450V breakdown voltage, along with the lowest $7.7\text{m}\Omega\text{-cm}^2$ $R_{\text{ON,sp}}$. The 450V corresponds to $180\text{V}/\mu\text{m}$ blocking, compared with $120\text{V}/\mu\text{m}$ for the $5\mu\text{m}$ gate-drain devices ($0.5\mu\text{m}$ channel). ■

<https://doi.org/10.1109/TED.2020.3027652>

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Mike Cooke

Smartphone production falls a record 11% to 1.25bn units in 2020 as Huawei exits top-six

This year will see a 9% rebound to 1.36 billion units, but Huawei will fall from third biggest smartphone maker to seventh, reckons **TrendForce**.

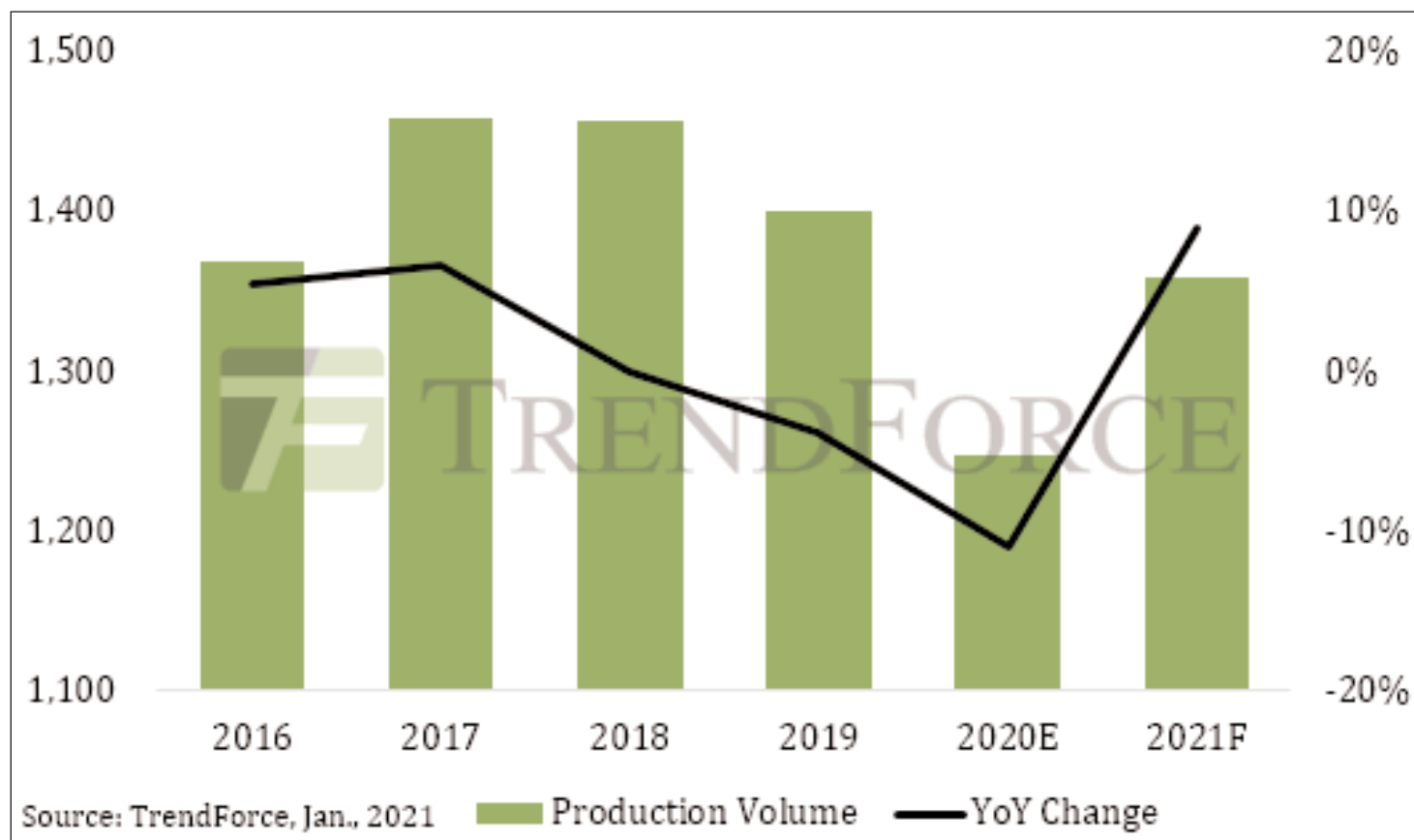
Due to the impact of the COVID-19 pandemic, global smartphone production fell by record 11% year-on-year (YoY) in 2020 to just 1.25 billion units, according to market research firm TrendForce.

The top six smartphone brands ranked by production volume for 2020, in descending order, are Samsung, Apple, Huawei, Xiaomi, OPPO and Vivo. The most glaring change from the previous year is Huawei's market share.

Honor will formally separate from Huawei and operate as an independent smartphone maker at the start of 2021, notes TrendForce. The aim behind this spin-off is to ensure the survival of Honor, which has become a major brand in the global smartphone market after years of labor. However, it remains to be seen whether

the 'new' Honor can capture consumers' attention without the support from Huawei. Also, Huawei and the new Honor will be directly competing against each other in the future, especially if the former is somehow freed from the US trade sanctions at a later time. With the new Honor seeking to ramp up production, Huawei will have more difficulty in regaining market share for smartphones, believes TrendForce.

Looking ahead to the rest of 2021, TrendForce forecasts that the global smartphone market will gradually recover as people become accustomed to the 'new normal' resulting from the pandemic. Moreover, this year will likely see a relatively strong wave of device replacement demand as well as demand growth in the emerging markets. Assuming that these conditions will materialize, annual global smartphone production for



Global smartphone production (in millions) and year-on-year change, 2016–2021.

Brand	2020E			2021F		
	Ranking	Production	5G Market Share	Ranking	Production	5G Market Share
Samsung	1	263	11%	1	267	13%
Apple	2	199	31%	2	229	35%
Xiaomi	4	146	8%	3	198	11%
OPPO	5	144	9%	4	185	14%
Vivo	6	110	9%	5	145	13%
Transsion	7	55	0%	6	60	0%
Huawei	3	170	30%	7	45	8%

Top 7 ranking of global smartphone brands by production volume (in millions) and 5G market share, 2020–2021.

2021 is forecasted to rise by 9% to 1.36 billion units.

Regarding the annual global ranking of smartphone brands for 2021, Huawei will see a further and significant decline in its device production due to the effects of the US export restrictions and the spin-off of Honor as a separate entity operating in the smartphone market, expects TrendForce. Huawei is projected to tumble from third place in 2020 to seventh place in 2021. The top six for 2021, in descending order, will be Samsung, Apple, Xiaomi, OPPO, Vivo and Transsion, collectively accounting for almost 80% of the global smartphone market.

Nevertheless, the pandemic will remain the central variable (or the biggest uncertainty) in the production projection because it will continue to exert significant influence on the global economy. Besides the pandemic, the performance of smartphone brands during 2021 could also be affected by geopolitical instabilities and the lack of available production capacity in the semiconductor foundry market.

Penetration of 5G smartphones forecasted to reach 37% in 2021, constrained by foundry capacity

Due to the Chinese government's aggressive push for 5G commercialization in 2020, global 5G smartphone production for the year rose to about 240 million units, a 19% penetration rate, with Chinese brands accounting for almost 60% market share. While 5G will remain a major topic in the smartphone market this year, various countries will also resume their 5G infrastructure build-out, and mobile processor manufacturers will continue to release entry-level and mid-range 5G chips. As such, the penetration rate of 5G smartphones is expected to rise rapidly to 37% in 2021, for annual production of about 500 million units.

Under the optimistic assumption that the pandemic can be resolved within the year, shipments for various end-products (including servers, smartphones and notebook computers) will grow year-on-year compared with 2020, notes TrendForce. In particular, the number of power management integrated circuits (PMICs) and

Looking ahead to the rest of 2021, TrendForce forecasts that the global smartphone market will gradually recover as people become accustomed to the 'new normal' resulting from the pandemic. Moreover, this year will likely see a relatively strong wave of device replacement demand as well as demand growth in the emerging markets. Assuming that these conditions will materialize, annual global smartphone production for 2021 is forecasted to rise by 9% to 1.36 billion units

CMOS image sensors (CIS) contained per handset will each double in order to meet increased smartphone specifications. On the other hand, major Chinese foundry Semiconductor Manufacturing International Corp (SMIC) has recently been added to the US Department of Commerce's Entity List once again. This is expected to exacerbate the foundry industry's already-strained production capacity. The recent bullish outlook of smartphone brands towards the 2021 market and their attempt to secure more semiconductor supplies by increasing their smartphone production targets can potentially lead these brands to overbook certain components at foundries, notes TrendForce. However, smartphone brands may adjust their component inventories from Q2/2021 to Q3/2021 and reduce their semiconductor procurement activities if actual sales performances fall short of expectations, or if component bottlenecks remain unresolved, leading to a widening inventory gap between bottlenecked and non-bottlenecked parts. Even so, TrendForce still forecasts an above-90% capacity utilization rate for foundries in 2021. ■

www.trendforce.com

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www.tek.com

15 Assembly/packaging materials**ePAK International Inc**

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

Gel-Pak

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

Wafer World Inc

(see section 3 for full contact details)

Materion Advanced Materials Group

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

16 Assembly/packaging equipment**CST Global Ltd**

4 Stanley Boulevard,
Hamilton International Technology
Park,
Blantyre, Glasgow G72 0BN, UK
Tel: +44 (0) 1698 722072
www.cstglobal.uk

Kulicke & Soffa Industries

1005 Virginia Drive,
Fort Washington, PA 19034,
USA
Tel: +1 215 784 6000
Fax: +1 215 784 6001
www.kns.com

Palomar Technologies Inc

2728 Loker Avenue West,
Carlsbad, CA 92010,
USA
Tel: +1 760 931 3600
Fax: +1 760 931 5191
www.PalomarTechnologies.com

PI (Physik Instrumente) L.P.

16 Albert St . Auburn ,
MA 01501,
USA
Tel: +1 508-832-3456,
Fax: +1 508-832-0506
www.pi.ws
www.pi-usa.us

TECDIA Inc

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

17 Assembly/packaging foundry**Quik-Pak**

10987 Via Frontera,
San Diego, CA 92127,
USA
Tel: +1 858 674 4676
Fax: +1 8586 74 4681
www.quikcpak.com

18 Chip foundry**CST Global Ltd**

4 Stanley Boulevard, Hamilton
International Technology Park,
Blantyre,
Glasgow, G72 0BN,
UK
Tel: +44 (0) 1698 722072
www.cstglobal.uk

United Monolithic Semiconductors

Route departementale 128,
BP46, Orsay, 91401,
France
Tel: +33 1 69 33 04 72
Fax: +33 169 33 02 92
www.ums-gaas.com

19 Facility equipment**RENA Technologies NA**

3838 Western Way NE,
Albany, OR 97321,
USA
Tel: +1 541 917 3626
www.rena-na.com

20 Facility consumables

PLANSEE High Performance Materials

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

W.L. Gore & Associates

401 Airport Rd, Elkton,
MD 21921-4236,
USA
Tel: +1 410 392 4440
Fax: +1 410 506 8749
www.gore.com

21 Computer hardware & software

Crosslight Software Inc

121-3989 Henning Dr.,
Burnaby, BC, V5C 6P8,
Canada
Tel: +1 604 320 1704
Fax: +1 604 320 1734
www.crosslight.com

Semiconductor Technology Research Inc

10404 Patterson Ave.,
Suite 108, Richmond, VA 23238,
USA
Tel: +1 804 740 8314
Fax: +1 804 740 3814
www.semitech.us

22 Used equipment

Brumley South Inc

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Mooresville, NC 28115, USA
Tel: +1 704 664 9251
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Decatur, GA 30035, USA
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Fax: +1 770 808 8308
www.ClassOneEquipment.com

23 Services

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Cheshire, CT 06410, USA
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Fax: +1 203-250-7389
www.riff-co.com

TECDIA Inc

2700 Augustine Drive, Suite 110,
Santa Clara,
CA 95054 ,
USA
Tel: +1-408-748-0100
Fax: +1-408-748-0111
Contact Person: Cathy W. Hung
www.tecdia.com

24 Resources

Al Shultz Advertising Marketing for Advanced Technology Companies

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7140 San Jose,
CA 95126, USA
Tel: +1 408 289 9555
www.alshultz.com

SEMI Global Headquarters

San Jose, CA 95134,
USA
Tel: +1 408 943 6900
www.semi.org

Yole Développement

69006 Lyon, France
Tel: +33 472 83 01 86
www.yole.fr

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CA 95134, USA
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IEEE International Solid-State Circuits Conference (ISSCC 2021)

San Francisco, CA, USA

E-mail: Issccinfo@yesevents.com

www.isscc.org

17–18 February 2021

PHOTONICS+ Virtual Exhibition & Conference, in partnership with EPIC

E-mail: photonicsplus@fleet-events.de

www.photonicsplus.com/epic

23 February 2021

ITF Photonics 2021

E-mail: oliver.wittig@wittig-marcom.de

www.imecitf.com/2021/photonics

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

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

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](http://www.epic-assoc.com/epic-annual-general-meeting-2020)

19–20 April 2021

(postponed from 26–29 April 2020)

2nd International Conference on UV LED Technologies & Applications (ICULTA 2021)

Online

E-mail: contact@iculata.com

www.ICULTA.com

20–22 April 2021

(postponed from 21–23 April 2020)

24th Annual Components for Military & Space Electronics Conference & Exhibition (CMSE 2021) – now a virtual, online event

E-mail: info@tjgreenllc.com

www.tjgreenllc.com/cmse

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9–14 May 2021**2021 Conference on Lasers & Electro-Optics (CLEO)**

San Jose Convention Center, San Jose, CA, USA

E-mail: CLEO@compusystems.comwww.cleoconference.org**11–14 May 2021****10th World Congress of Nano S&T 2021**

Venetian Macao Resort Hotel, Macao, China

E-mail: esther@bitcongress.comwww.bitcongress.com/nano2021-macao**6–10 June 2021****(postponed from 28 March –1 April 2021)****OFC 2021:
Optical Networking and Communication
Conference & Exhibition**

Moscone Center, San Francisco, CA, USA

E-mail: OFC@csreg.zohodesk.comwww.ofcconference.org**9–13 June 2021****(postponed from 21–25 June 2020)****IEEE Applied Power Electronics Conference
and Exposition (APEC 2021)**

Phoenix, AZ USA

E-mail: registration@apec-conf.orgwww.apec-conf.org**20–24 June 2021****International Congress on Photonics in Europe
— co-located with LASER World of PHOTONICS**

ICM (Internationales Congress Center München), Germany

E-mail: info@photonics-congress.comwww.photonics-congress.com/en**21–24 June 2021****LASER World of PHOTONICS 2021**

Messe München, Munich, Germany

E-mail: info@world-of-photonics.comwww.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.comwww.strategiesinlight.com**4–9 July 2021 (postponed from 14–19 June 2020)****ICMOVPE XX:
20th International Conference on Metal
Organic Vapor Phase Epitaxy**

Stuttgart, Germany

E-mail: info@icmovpexx.euwww.icmovpexx.eu**1–5 August 2021****SPIE Optics + Photonics 2021
— Conference and Exhibition**

San Diego Convention Center, San Diego, CA, USA

E-mail: customerservice@spie.orgwww.spie.org/opstm**1–3 September 2021****CIOE 2021 (23rd China International
Optoelectronic Exposition)**

Shenzhen World Exhibition & Convention Centre, China

E-mail: cioe@cioe.cnwww.cioe.cn/en**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.orgwww.icscrm2021.org**13–15 September 2021****ECOC 2021 (47th European Conference on
Optical Communication)**

Bordeaux Exhibition Centre, Bordeaux, France

E-mail: sales@ecocexhibition.comwww.ecocexhibition.com/ecoc-exhibition-2021**22–24 September 2021****LASER World of PHOTONICS INDIA 2021**

Bengaluru, India

E-mail: info@world-of-photonics-india.comwww.world-of-photonics-india.com**10–14 October 2021****27th International Semiconductor Laser
Conference (ISLC 2021)**

Potsdam, Germany

E-mail: islc@fbh-berlin.dewww.islc2021.org**10–15 October 2021****24th European Microwave Week (EuMW 2021)**

ExCel, London, UK

E-mail: eumwreg@itnint.comwww.eumweek.com**24–28 October 2021****(postponed from 13–17 September 2020)****13th European Conference on Silicon
Carbide and Related Materials
(ECSCRM 2020-2021)**

Vinci International Convention Centre, Tours, France

E-mail: ecscrm-2020@univ-tours.frwww.ecscrm-2020.com



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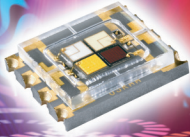


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