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COMPOUNDS & ADVANCED SILICON

Vol. 16 • Issue 2 • March 2021

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Silicon carbide power electronics gaining traction

Cree completes sale of LED business • Imaging center for ams
Rockley to go public • NeoPhotonics' non-Huawei revenue grows

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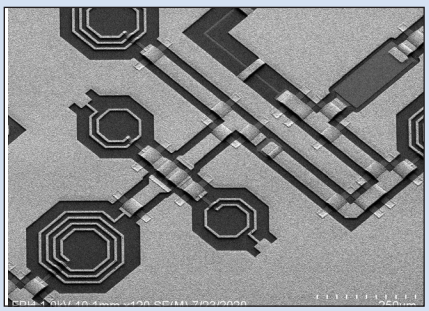
p20 Swansea University has been awarded £4.8m in UK Government funding to establish a 6–8"-wafer SiC power device pilot line at CISM.



p18 Ka-band GaN-on-SiC MMICs for satcoms and radar will be developed by the ESA-funded Kassiopeia project.

p21 GaN Systems' low-current, high-volume GaN transistors — as adopted for fast chargers and AC adapters — have fallen below $1 in price.

Cover: Japan's Toshiba has launched the MG800FXF2YMS3 silicon carbide MOSFET module (for volume production from May), which integrates newly developed dual-channel SiC MOSFET chips with ratings of 3300V and 800A, for industrial applications including trains and renewable-energy power generation. **p16**

editorial

Wide-bandgap powering electronics

Following on from last month's editorial, the global shortage of chips has continued to hamper production of cars and consumer electronics, and has now affected not only trucks but also electric vehicles (EVs).

This has been exacerbated by a fire in a Renesas fab in Japan, and by mid-February's winter storm in Texas that caused prolonged power outages. Samsung's Austin fab was still not back to full production over a month later. Since the foundry produces Qualcomm 5G RFICs, TrendForce forecasts that second-quarter 2021 will see worldwide declines in production of 30% for 5G smartphones and hence 5% for smartphones overall, lowering the penetration rate of 5G in 2021 from the previously forecasted 38% of total smartphones to 36.5% (see page 10). However, TrendForce maintains its forecast for smartphone unit production of 1.36 billion in 2021, with 4G making up for the 5G shortfall.

Nevertheless, the increasing penetration of wide-bandgap materials silicon carbide (SiC) and gallium nitride (GaN) into power electronics (in place of silicon) and the growing popularity of EVs is amplifying demand.

TrendForce expects rapid growth in GaN & SiC markets in 2021, driven by: (1) widespread vaccinations curbing the pandemic, galvanizing a stable rise in demand for base-station components as well as for components used in power inverters and converters; (2) adoption of SiC MOSFETs for EV inverters by Tesla; (3) China's 14th five-year plan (starting this year) investing in expanding its wide-bandgap semiconductor production capacity (targeting semiconductor independence) — see page 9.

Specifically, for 2021, TrendForce expects revenue growth of 30.8% in GaN RF devices (e.g. for RF front-ends in 5G base-stations) and 90.6% in GaN power devices (driven by fast chargers for smartphones, notebooks etc).

In Q4/2020, MOCVD system maker Aixtron saw orders rise 30% (to its highest quarterly intake since 2011). This was driven partly by demand for manufacturing GaN- and SiC-based power electronics, "addressing the growing end-market of efficient GaN chargers for consumer electronic devices such as smartphones and notebooks as well as efficient GaN power management solutions for servers and data centers... In 2020, we have clearly seen the tipping point of broad GaN power adoption, and we are now in the volume ramp phase," says the firm (see page 13).

Since SiC substrates are used for GaN RF & power devices, a short supply of 6" SiC wafers will constrain SiC power device revenue growth to 32% in 2021. However, Cree, II–VI and STMicroelectronics are planning to make 8" SiC substrates (although the short supply is unlikely to be resolved until 2022, reckons TrendForce — in light of this, the Swansea University in South Wales has gained £4.8m in UK funding to develop a 6–8" SiC power device pilot line — see page 15).

According to Yole Développement, the power semiconductor market for EVs is tripling between 2020 and 2026, rising at a 25.7% compound annual growth rate (CAGR) to $5.6bn (see page 72). "SiC modules are presently still about three times the cost of a 650V IGBT [silicon] module, but this difference will shrink when larger volumes are produced, with the transition to 8" wafers, and with the penetration of 1200V devices for higher battery voltages," says the firm. "Many semiconductor players are targeting SiC modules for EV applications, and the SiC module market is expected to reach 32% of the total EV/HEV semiconductor market by 2026, Yole adds.

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

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Automotive LED revenue to grow 13.7% to nearly $3bn in 2021

High demand for headlights and display panels, driving recovery from 3.7% decline in 2020

The COVID-19 pandemic heavily impacted the global automotive market and in turn damaged the automotive LED industry in first-half 2020, according to TrendForce's latest investigations. In second-half 2020 however, the gradual recovery of vehicle sales as well as the development of NEVs (new energy vehicles) provided some upward momentum for the automotive LED market, which reached $2.572bn for full-year 2020, down 3.7% year-on-year.

Automotive LED revenue for 2021 is projected to grow 13.7% year-on-year to $2.926bn, due to the increasing demand for automotive headlights and display panels. As auto-makers continue to incorporate LED lighting solutions into new car models, the penetration rate of automotive LEDs will continue to see a corresponding increase too.

Ranking	Company	Revenue		Market Share	
		2019	2020	2019	2020
1	OSRAM OS	920	926	34.4%	36.0%
2	Nichia	673	608	25.2%	23.6%
3	Lumileds	318	315	11.9%	12.2%
4	Stanley	228	212	8.5%	8.3%
5	Seoul Semiconductor	126	130	4.7%	5.1%
6	Dominant	120	123	4.5%	4.8%
7	Samsung LED	60	71	2.3%	2.8%
8	Everlight	43	67	1.6%	2.6%
9	CREE	31	29	1.2%	1.1%
10	Hongli	17	17	0.6%	0.7%
	Other	136	74	5.1%	2.9%
	Total	2672	2572	100%	100%

Revenue ranking of automotive LED suppliers, 2019–2020 (US$m).

TrendForce analyst Joanne Wu indicates that, in the ranking of automotive LED players by revenue for 2020, Osram Opto Semiconductors, Nichia, and Lumileds remained the top three largest automotive LED suppliers, respectively, with a combined market share of 71.9%. In particular, European and American auto-makers favored Osram's solutions for their high-end vehicle models and NEVs due to the high quality of Osram products. Adoption by these auto-makers subsequently became the main revenue driver of Osram's automotive LED business.

On the other hand, the pandemic caused Japanese auto-makers to suspend their operations and therefore had a direct impact on the revenues and market shares of Japanese LED suppliers in 2020. Nichia and Stanley saw their revenues decline by 9.8% and 7% year-on-year, respectively, and they were the two suppliers among the top 10 last year to have shown relatively noticeable declines.

Seoul Semiconductor's nPola and Wicop LED products were adopted by Chinese auto-makers, including CCAG, SAIC-GM and NIO, due to these products' high brightness and compact sizes. Seoul Semiconductor's market share reached 5.1% in 2020.

Finally, not only did other suppliers, including Samsung LED and Cree, deliver consistent performances in the automotive aftermarket (AM) and performance market (PM) segments, but they also gradually began to enter the automotive original equipment manufacturer (OEM) lighting market. Samsung LED and Cree each took seventh and ninth place in the 2020 ranking, with market shares of 2.8% and 1.1%, respectively.

On the whole, TrendForce finds that automotive demand has been recovering since fourth-quarter 2020. Accordingly, LED suppliers indicate that their order bookings appear bullish throughout 2021, meaning that most LED suppliers now need to extend their product lead-times in response. At the same time, LED players indicate that double booking may occur in the near future. They will hence take decisions in the light of the actual order booking quantity to see the possibility of increasing prices.

www.trendforce.com

VCSEL market to reach $5bn by 2027

Makers developing longer-wavelength VCSELs to meet data demand

The proliferation of data centers on globally — coupled with the rising adoption of digital solutions — is generating enormous amounts of data, accelerating the adoption of technologies offering high-speed and efficient data transmission, according to a study from market research firm Global Market Insights. This includes vertical-cavity surface-emitting lasers (VCSELs), which are seeing rising demand across various industry verticals such as healthcare, automobile, defense, aerospace, etc. The VCSEL market is hence forecasted to grow to $5bn by 2027.

For example, in 2020 Lumentum Holdings Inc introduced three new technical breakthroughs in terms of high-speed datacom laser chips aimed at widening its product portfolio for aiding the development of hyperscale data centers as well as 5G wireless applications. One of these is its 50G PAM4 VCSEL, designed especially for high-speed short-reach optical networks.

By material type, the gallium nitride (GaN) segment had a market share of about 6.5% in 2020 but is expected to grow as GaN-based VCSELs are gaining considerable attention due to features such as low threshold current, high efficiency, array formation capability, and lower manufacturing costs. They can hence potentially replace conventional LEDs in projectors, optical storage, laser printers, biosensors, solid-state lighting and several optical communications applications.

In terms of wavelength, VCSELs with wavelengths up to 1050nm are gaining popularity due to their ability to transmit large amounts of data across data centers and enterprise networks. The growing size of data centers has driven demand for higher-wavelength VCSELs for transmitting data over distances of more than 500m. This has boosted the adoption of 1050nm VCSELs for high-speed operation over multi-mode fiber.

Further, VCSEL manufacturers are aiming to develop innovative long-wavelength VCSELs to meet the high consumer demand. In 2020, ThorLabs announced that its 1060nm-wavelength VCSEL is being used in Atria Optical Coherence tomography, which includes scanning electronics, interferometer and control software. Considering these factors, the <1050nm VCSEL segment (which had a market share of 5.5% in 2020) is expected to record a compound annual growth rate (CAGR) of 11.5% through 2027.

By application, the heating & laser printing segment had 9% market share in 2020 and is projected grow at a CAGR of 20.6% through 2027 due to the increasing demand for VCSELs based on the benefits they offer. VCSEL can be used even without additional optics and they provide intense and highly directed infrared light, which has fueled adoption in industrial heating systems.

VCSELs also offer improved optical efficiency and a smaller footprint, and they are cost-effective, which is instigating their application in high-definition and high-speed printing. In addition, growing digitalization in the industrial sector, along with the emerging trend of digital image processing, is favoring the installation of VCSELs in offset printers, as they help in cleaning narrow lines and producing vivid images.

Based on industry vertical, the automotive segment will see a robust CAGR of 15% through 2027, it is forecasted, due to a significant rise in in-cabin sensing applications in vehicles, favoring the development of autonomous technology. Several prominent automotive OEMs are increasingly focusing on the incorporation of autonomous technology in upcoming vehicle models to gain a competitive advantage in the industry.

For example, in 2021 leading automobile manufacturer Honda announced a collaboration with the USA's General Motors and its spinoff Cruise to accelerate its autonomous vehicle mobility business in Japan. Such strategic initiatives are positively influencing the VCSEL market space. As another example, ams AG has this year launched the TARA2000-AUT series of VCSELs, offering 3D time-of-flight (ToF) sensing in autonomous applications.

In terms of geographic region, the VCSEL market in Europe comprised 18% market share in 2020 and is expected to grow at a CAGR of about 19.5% through 2027, driven by the thriving semiconductor industry in the region and supported by government initiatives. As a result of the COVID-19 pandemic, the region's supply chain was affected, which has motivated market players to reduce their dependency on Asian countries. This in turn increased investment activities in the region's semiconductor industry, which is complementing VCSEL business across Europe.

As an example, in 2020 the European Union introduced a joint initiative to augment the processor and semiconductor ecosystem in the region. In addition, government has announced plans to invest $176bn over the next 2–3 years in R&D activities pertaining to semiconductor technology.

Key companies covered in the report include Alight Technologies ApS, ams AG. Broadcom, FLIR Systems Inc, II-VI Inc, Inneos LLC, Inphenix Inc, IQE plc, Leonardo Electronics US Inc, Lumentum Operations LLC, Ophir Optronics Solutions Ltd, OSRAM Opto Semiconductors GmbH, ROHM Co Ltd, SANTEC Corp, TRUMPF, TT Electronics, Ushio America Inc, VERTILAS GmbH, Vertilite, and WIN Semiconductors.

www.gminsights.com

Smartphone shipments to grow 5.5% in 2021, driven by strong 5G push and pent-up demand

5G smartphones to exceed 40% of volume in 2021 then 69% in 2025

Global smartphone shipments will grow 13.9% year-on-year in first-quarter 2021 and 5.5% for full-year 2021, forecasts the International Data Corporation (IDC) Worldwide Quarterly Mobile Phone Tracker. This growth will be driven by continued recovery in demand and a supply-side push of 5G devices. IDC expects the smartphone market to deliver a compound annual growth rate (CAGR) of 3.6% over the 2020-2025 forecast period.

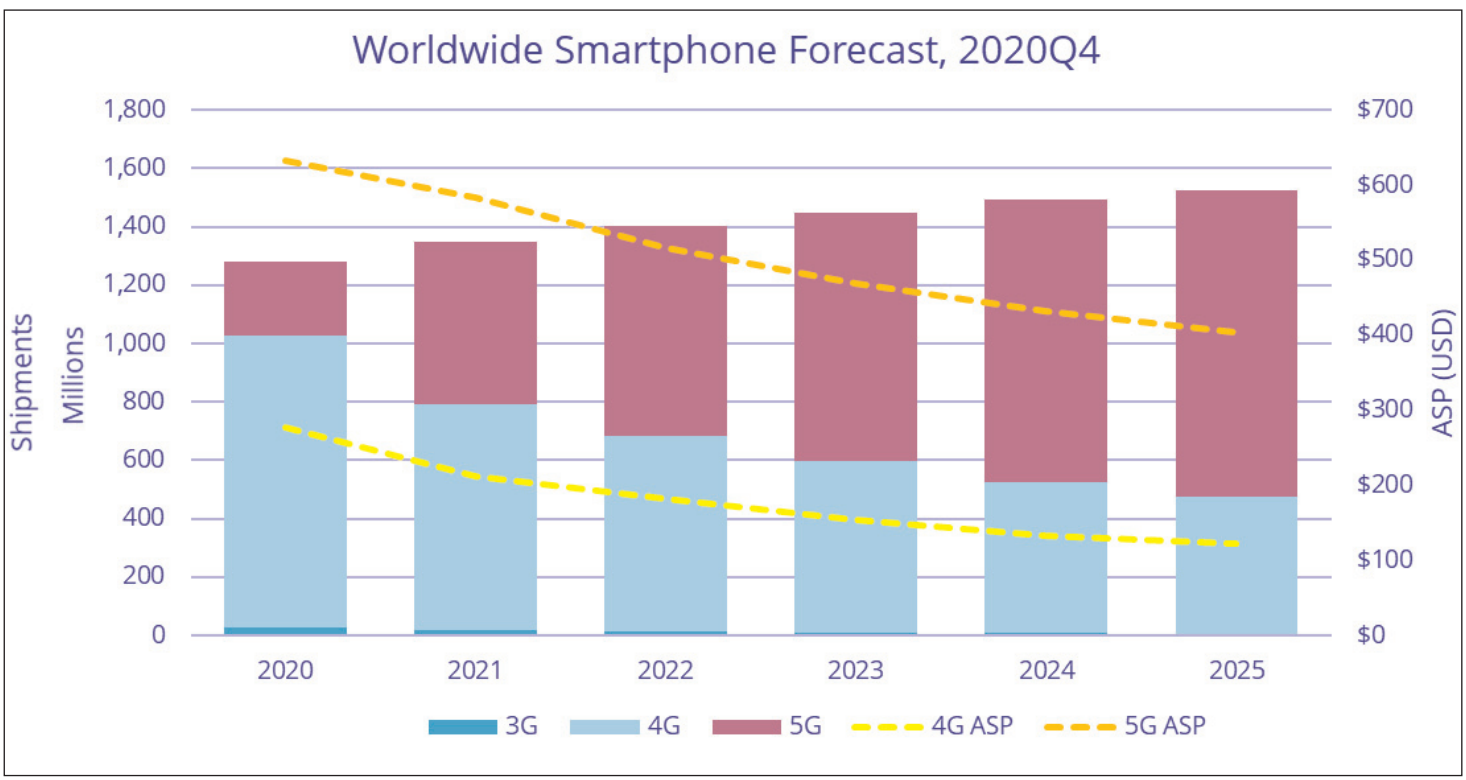
"Despite ongoing lockdowns and economic concerns, IDC continues to see strong demand for smartphones. We are also seeing that everyone in the value chain — from supply chains, OEMs and channels to consumers — is better prepared to handle any further lockdowns," says Nabila Popal, research director with IDC's Worldwide Mobile Device Trackers. "IDC has seen accelerated growth in online channels, climbing to 27% share in 2020 from just 20% the prior year, as channels adapt to the pandemic lifestyle. Ramp ups in production and improved channel planning combined with strong pent-up demand are all pointing to healthy growth in the months ahead."

China and the USA, the two largest geographic markets, are forecast to grow by 5% and 3.5% in 2021. The outlook for China remained stable despite several city-level lockdowns in January, reflecting the strength of consumer confidence there. Despite a 10–11% year-on-year decline for both markets in 2020 amidst the pandemic, 5G development and the success of the recently launched iPhones are expected to boost shipments in 2021.

5G remains the driving factor in the industry, accelerated further by the success of Apple's full 5G iPhone 12 line up. IDC expects 5G smartphone shipments to account for more than 40% of global volume in 2021 and grow to 69% in 2025. Both factors have helped to increase the overall average selling price (ASP) for smartphones in 2021 from IDC's previous forecast of $349 to $363. Regarding 5G ASP specifically, increasing competition in the 5G Android space, particularly from Chinese vendors, will bring downward pressure on 5G ASPs, which are expected to drop to $404 by 2025.

"The strong performance in the last quarter of 2020 has led to a huge push from all OEMs to increase production. Although this may create some temporary challenges in production, we do not foresee any significant gap as the manufacturers successfully cope with the ramp up," says Sangeetika Srivastava, senior analyst with IDC's Worldwide Mobile Device Trackers. "On the other hand, this is likely to intensify the pressure on smaller vendors as larger vendors are given priority by ODMs, making it harder for them to obtain targeted volumes."

www.idc.com/tracker/showproductinfo.jsp?containerId=IDC_P8397



Worldwide mobile phone shipments by air interface (3G, 4G, 5G) along with average selling prices for 4G and 5G phones.

GaN power device market to grow 90.6% to $61m in 2021

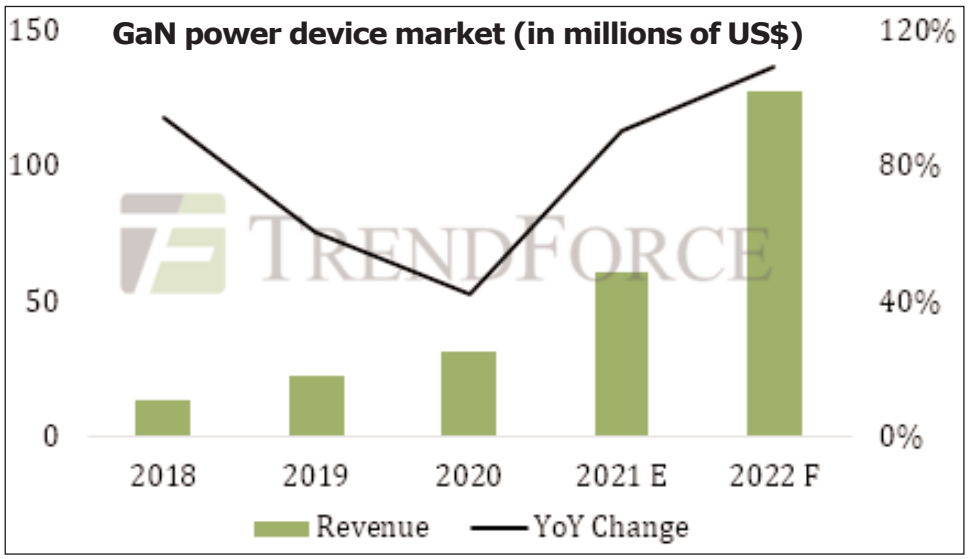
GaN RF device sector to grow 30.8% to $680m

The silicon carbide (SiC) and gallium nitride (GaN) 'third-generation' semiconductor industry was impaired by the US–China trade war then the COVID-19 pandemic from 2018 to 2020, according to TrendForce. During this period, the semiconductor industry on the whole saw limited upward momentum, in turn leading to muted growth for the third-generation semiconductor segment as well. However, due to high demand from automotive, industrial and telecom applications, this segment is likely to enter a rapid upturn. In particular, the GaN power device market will see the fastest growth, of 90.6% year-on-year to $61m in 2021.

TrendForce expects three factors to drive the rapid growth in the GaN and SiC markets in 2021: First, widespread vaccinations are projected to drastically curb the spread of the pandemic, galvanizing a stable increase in demand for base-station components, as well as for components used in industrial energy transition, such as power inverters and converters. Secondly, as Tesla began adopting SiC MOSFET designs for its in-house inverters used in Model 3 vehicles, the automotive industry has started to place increasing importance on third-generation semiconductors. Finally, China will invest enormous capital into its 14th five-year plan starting this year and expand its third-generation semiconductor production capacity to ultimately achieve semiconductor independence.

Resurgent demand from EV, industrial and telecom sectors

Although certain foundries, such as Taiwan Semiconductor Manufacturing Company (TSMC) and Vanguard International Semiconductor (VIS), have been attempting to manufacture GaN devices on 8" wafers, 6" wafers are still the mainstream. As the pandemic shows signs of a slowdown, the demand for RF front ends in 5G base stations, for smartphone chargers and for automotive on-board



chargers has now gradually risen. Total annual revenue from GaN RF devices is hence projected to grow by 30.8% to $680m in 2021 (compared with the 90.6% growth to $61m for GaN power devices).

In particular, the remarkable rise in GaN power device revenue can be attributed primarily to the launch of fast chargers from smartphone brands such as Xiaomi, OPPO and Vivo, starting in 2018. Thanks to their effective heat dissipation and small footprint, these chargers enjoyed excellent market reception. Some notebook computer manufacturers are currently looking to adopt fast-charging technology for their chargers too. Going forward, TrendForce expects more smartphone and notebook chargers to feature GaN power devices, leading to a peak year-on-year increase in GaN power device revenue in 2022, after which there will be a noticeable slowdown in its upward trajectory as GaN power devices become widely adopted by charger manufacturers.

On the other hand, 6" wafer capacities for SiC devices have been in relatively short supply, since SiC substrates are widely used in RF front-end and power devices. TrendForce expects annual SiC power device revenue to grow by 32% to $680m in 2021. Major substrate suppliers, including Cree, II–VI and STMicroelectronics, are planning to make 8" SiC substrates, but the short supply is unlikely to be resolved until 2022.

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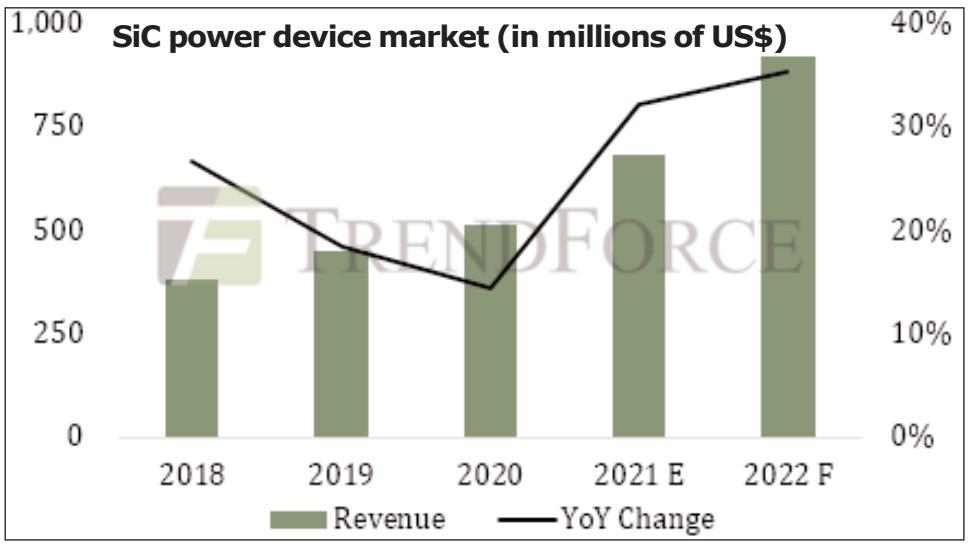


Storm-hit Qualcomm 5G RFIC shipments to reduce 5G smartphone production by 30% in Q2

Overall smartphone production to be reduced by 5% globally

Due to the impact of the winter storm in Texas, the Line S2 fab of Samsung in Austin sustained a power interruption that has forced it to suspend operation since mid-February. The latest investigations by TrendForce indicate that the capacity utilization rate for the entire fab is not expected to climb back to over 90% until the end of March. Samsung manufactures several products that are important for the production of smartphones, including the Qualcomm 5G RFIC, Samsung LSI OLED DDIC and Samsung LSI CIS Logic IC. Supply-wise, the first two products sustained the brunt of the winter storm's impact, and global smartphone production for second-quarter 2021 is therefore expected to drop by about 5% as a result.

According to TrendForce, Samsung was able to prepare for the power interruption ahead of time as the firm had been forewarned by the local utility. Hence, the loss of WiP (work in progress) wafers caused by the incident was minimal. However, the delay to the resumption of full operation at the plant is expected to last over two weeks, during which the fab will suspend its wafer input. The incident on the whole will have a definite impact on the global foundry industry that is already experiencing a serious capacity crunch. In terms of wafer input, the Qualcomm 5G RFIC, Samsung LSI OLED DDIC and Samsung LSI CIS Logic IC account for 30%, 20% and 15% of Line S2's monthly production capacity, respectively.

Of the three aforementioned products, the Qualcomm RFIC is primarily supplied to smartphone brands to be used in 5G handsets. This product is delivered to clients as part of either AP bundles or 5G modems. The winter storm's impact on the production of the Qualcomm RFIC is expected to take place in Q2/2021, resulting in a 30% decrease in 5G smartphone production for the quarter. However, TrendForce expects this incident to impair the Q2/2021 production of all smartphones by only about 5%, given smartphone brands' existing inventory of 5G AP bundles and 5G modems, in addition to the fact that smartphone brands are likely to keep up their quarterly smartphone production by increasing the production of 4G handsets to make up for the shortfall in 5G handsets. Furthermore, TrendForce expects the Line S2 fab to prioritize resuming the production of RF products ahead of other products, in turn further mitigating the winter storm's impact on global smartphone production.

On the other hand, the Samsung LSI OLED DDIC is primarily used in Apple's iPhone 12 series. The winter storm's impact on these DDICs will similarly take place by the end of Q2/2021. Even so, Apple likely possesses sufficient DDIC inventory, at least in the short term, since the period of peak DDIC demand for the firm's existing smartphone models has already passed. Moreover, the iPhone 12 mini may reach end-of-life (EOL) earlier than expected due to disappointing sales. Should Apple decide to cut iPhone 12 mini production, the firm will be able to further minimize the impact of OLED DDIC undersupply. Finally, as sales of the iPhone 11 (which is equipped with an LCD, instead of OLED, panel and therefore does not require OLED DDIC) have been resurgent recently, Apple may increase the share of iPhone 11 in its total smartphone production in order to keep up its quarterly production volume.

In light of these factors, TrendForce believes that the production volume of iPhones in Q2/2021 will suffer only limited impact from OLED DDIC supply disruptions.

On the whole, although the production of 5G smartphones will face a relatively considerable challenge in Q2, smartphone brands will be able to keep up their quarterly production volume by raising the production share of 4G smartphones instead. TrendForce thus projects that the winter storm will impair smartphone production for Q2/2021 by no more than 5%, while maintaining the previous forecast of 1.36 billion units produced for 2021. However, TrendForce also does not rule out the possibility that the winter storm will lower the penetration rate of 5G smartphones in 2021 from 38%, as previously forecasted, to 36.5%.

www.trendforce.com

Qorvo shipping RF Fusion20 RF front-ends to all major 5G smartphone makers

Qorvo Inc of Greensboro, NC, USA (which provides core technologies and RF solutions for mobile, infrastructure and defense applications) has announced increased shipments of its RF Fusion20 portfolio — an expansion of its family of integrated 5G RF front-end (RFFE) modules — to all major 5G smartphone makers. Fusion20 adds receive-path integration and RF shielding to deliver full transmit & receive coverage in a complete suite of configurations to match varying regional market needs.

"To support the rapid adoption of 5G in flagship and mass-tier handsets, manufacturers need greater integration and significantly higher performance, requiring best-in-class technologies throughout the RFFE," says Eric Creviston, president of Qorvo Mobile Products. "Fusion20 meets these challenges by combining Qorvo's world-class GaAs power amplifiers, advanced BAW multiplexing and integrated RF shielding, enabling our customers to introduce innovative new designs with enhanced performance and connectivity," he adds.

Qorvo's Fusion20 modules support all major baseband chipsets. Key advances include the integration of the receive path and low-noise amplifier (LNA), which increases receive performance and connectivity while saving valuable board space. Fusion20 also features Qorvo's MicroShield RF shielding on each module. This minimizes the potential for undesirable interactions between RFFE components, enabling manufacturers to simplify development and accelerate time to market, Qorvo says. Fusion20 helps to support the most stringent 5G bandwidth requirements of up to 200MHz, the firm adds.

Fusion20 includes the QM77048 mid/high-band, QM77043 low-band and QM78207/208/209 ultra-high-band modules, in regional configurations to meet specific market requirements. Qorvo has optimized Fusion20 as a full 5G front-end solution complemented by the firm's Wi-Fi 6/6E modules. When implemented as a system, the modules provide a robust path to rapid 5G handset development, the firm says.

The modules build on Qorvo's RF Fusion 5G portfolio, which provides a complete, highly integrated RFFE solution encompassing all major 5G and 4G bands, and has been adopted across multiple leading manufacturers, the firm notes.

www.qorvo.com/rf-fusion

Skyworks' chairman David Aldrich joins Mobix's board

Firm targets single-chip CMOS-based solutions at 5G mmWave market

Fabless semiconductor company Mobix Labs Inc of Irvine, CA, USA (which was founded in 2020 and develops ultra-compact, fully integrated, single-chip Bulk CMOS-based 5G mmWave beam-formers, antenna solutions and RF semiconductors) says that telecom chip veteran David J. Aldrich has joined its board of directors.

Aldrich is currently chairman of the board, and previously CEO and executive chairman, of Irvine-based Skyworks Solutions Inc (which manufactures analog and mixed-signal semiconductors). Previously he was president & CEO of Alpha Industries and held senior management positions at Adams-Russell and M/A-COM.

"Dave adds tremendous depth to our board, joining a stellar team of experienced technology leaders who have been instrumental in building highly successful companies in the semiconductor and telecom industries," says Mobix Labs' CEO Fabian Battaglia. "He brings to Mobix Labs a unique blend of technology, managerial and value-creating expertise that will help us deliver our high-performance, Bulk CMOS-based beam-formers, antenna solutions and RF semiconductors for the 5G mmWave market and beyond."

Aldrich's appointment follows Mobix recently naming former Microsemi Corp CEO James J. Peterson as chairman of the board, and closing a $10m round of new funding as part of an extended seed round.

"There is enormous opportunity in the 5G mmWave spectrum because of the overwhelming need for increased capacity and more bandwidth," says Peterson. "Dave's semiconductor and telecom experience brings a unique skill set to the Mobix board that will be extremely beneficial as the company markets its highly integrated, cost-effective technology across a wide range of global applications," he adds.

"Mobix Labs is at an exciting inflection point in its growth and development, providing innovative solutions to the 5G mmWave wireless market," comments Aldrich. "The company has extraordinary potential as it addresses a vast, global marketplace."

Aldrich received a bachelor's degree in political science from Providence College and a master's degree in business administration from the University of Rhode Island. He is a past recipient of the Ernst & Young New England Entrepreneur of the Year Award in the semiconductor category and was named CEO of the Year by the Massachusetts Technology Leadership Council.

www.skyworksinc.com
www.mobixlabs.com

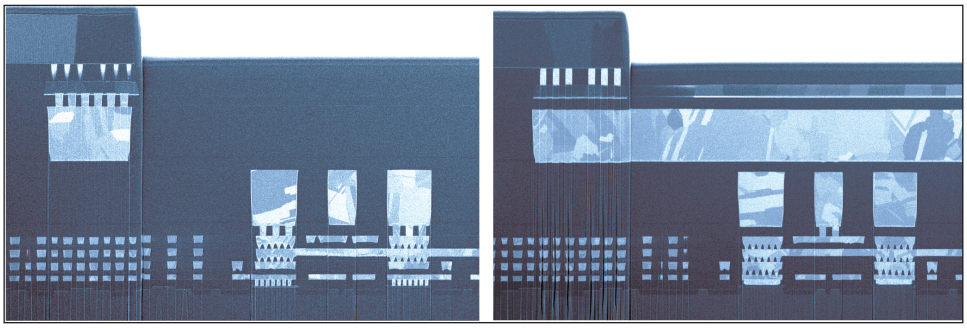
X-FAB and IHP collaborate on SiGe BiCMOS and RF-SOI

Prototyping to be offered through IHP and EUROPRACTICE

Analog/mixed-signal, micro-electro-mechanical system (MEMS) and specialty foundry X-FAB Silicon Foundries SE of Tessenderlo, Belgium and German government-funded IHP - Leibniz Institute for High Performance Microelectronics of Frankfurt (Oder) have announced an industry-academic partnership to bring together X-FAB's proficiency in semiconductor manufacturing with IHP's wireless communication expertise, to exchange knowledge, and to establish mutually beneficial engineering synergies.

IHP's active devices will be directly integrated into the backend of line (BEOL) of X-FAB's 130nm XR013 radio-frequency silicon-on-insulator (RF-SOI) process featuring copper (Cu) and thick-Cu based metallization, alongside high-performance passive elements such as inductors and transformers. This integration will mean that a wide array of next-generation wireless systems concepts can be experimented with.

Another key focus for the collaborative work that has been conducted is the development of silicon-germanium (SiGe) bipolar complementary metal-oxide-semiconductor (BiCMOS) technologies. At the foundation of this will be IHP's SiGe heterojunction bipolar transistors (HBTs). These offer strong performance parameters, with f_T/f_{max} figures of up to 250/340GHz for SG13S-Cu and up to 300/500GHz for SG13G2-Cu. The 3µm-thick low-loss copper interconnects employed are also certain to prove valuable in helping to boost RF performance levels.



Cross sections of SiGe BiCMOS wafer taken by scanning electron microscope.

Prototyping services for both the RF-SOI and SiGe BiCMOS technologies are offered through IHP and the EUROPRACTICE consortium. There will be opportunities for the technologies developed by IHP and X-FAB in relation to optoelectronics and 5G wireless communication systems, as well as for innovative radar implementations.

"SiGe BiCMOS remains an attractive prospect for a number of wireless applications, including 5G, because it enables the integration of high-performance RF on a silicon-based platform. IHP and X-FAB both recognize the huge potential here," says Dr Greg U'Ren, X-FAB's director of RF technology. "The technologies that we are working on are the fruit of a synergistic relationship that leverages the respective strengths of each partner," he adds.

"This partnership enables us to transfer first-class research into commercial applications laying ground for next-generation high-performance RF systems, such as 400G data communication, 60–300GHz radars and sub-THz imaging," comments IHP's scientific director professor Gerhard Kahmen.

www.ihp-microelectronics.com
www.xfab.com

pSemi opens design center in India, driven by 5G and IoT

Murata company pSemi Corp of San Diego, CA, USA — a fabless provider of radio-frequency integrated circuits (RFICs) based on silicon-on-insulator (SOI) — has opened a new design center in Chennai, India to support the growing demand for semiconductor products enabling 5G and Internet-of-Things (IoT) applications.

The India office will accelerate the scalability of its engineering team and the development of new design innovations for cellular RF front-end modules, sensor systems-on-a-chip and power management integrated circuits (ICs). Featuring labs and office space, the design center is located at Level 9, Olympia Teknos Park, No. 28 SIDCO Industrial Estate, Guindy, Chennai 600032. pSemi is now actively hiring staff.

"India is emerging as the largest mobile phone manufacturing hub in the world. With our new India design center, we want to attract top talent and further expand our engagements with customers, partners and the smartphone ecosystem," says CEO Sumit Tomar. "We have opened our first pSemi India design center in Chennai, but we will soon expand into other cities. We plan to scale up rapidly; our hiring plan is limited only by the availability of talent."

The establishment of the design center follows pSemi's recent product portfolio growth in 5G, wireless connectivity, power management and sensors along with increased IC content in smartphones and mobile applications. Furthermore, the pSemi India design center will serve as a close liaison between pSemi and Murata, strengthening the companies' operational growth with higher levels of integration and functionality in IC and package design.

www.psemi.com

Bosch using GF's 22FDX RF solution for mmWave automotive radar system-on-chip

GlobalFoundries (GF) of Santa Clara, CA, USA (the world's leading specialty foundry, with operations in Singapore, Germany and the USA) and Germany's Bosch are partnering to develop and manufacture next-generation automotive radar technology.

Bosch chose GF as its partner to develop a millimeter-wave (mmWave) automotive radar system-on-chip (SoC) for Advanced Driver Assistance Systems (ADAS) applications, manufactured using GF's 22FDX RF solution. ADAS applications help drivers to stay safe by keeping a vehicle in the correct lane, warning of collisions, initiating emergency braking, assisting with parking, etc.

"At GF, we have embraced excellence in automotive semiconductors as a core strategy, and our 22FDX is unbeatable as a high-performance, low-power solution," claims Mike Hogan, senior VP & general manager of Automotive, Industrial and Multi-market at GF. "In addition, GF is the only foundry with in-house mmWave test capability," he adds.

"Dependable radar and ADAS systems are of paramount importance to drivers and automakers around the world," says Oliver Wolst, senior VP heading Bosch's Integrated Circuit division. "We chose to partner with GlobalFoundries for their proven leadership in RF and mmWave technology, which is reinforced by their deep expertise in the automotive market. We carefully scrutinized the universe of available semiconductor solutions, and GF's 22FDX RF solution proved to be today's most attractive and most appropriate platform for our next generation of highly efficient and safe automotive radars."

GF's 22FDX chips are manufactured at its Fab 1 facility in Dresden, Germany. As part of the partnership, Bosch will also utilize GF's automotive turnkey solutions for mmWave testing and packaging development, which will assist in increasing design efficiency and speeding time to market. These post-fab and turnkey services will take place at GF's Fab 1 in Dresden and at GF's mmWave testing lab at Fab 9 near Burlington, VT, USA.

The first 22FDX-based radar SoCs for further testing of Bosch's new generation of automotive radars are targeted for delivery in second-half 2021.

GF says that, to date, its 22FDX solutions have realized $4.5bn in design wins, with over 350 million chips shipped to customers.

www.globalfoundries.com
www.bosch.com

Tower introduces galvanic isolation technology

Isolated SiC, GaN and MOSFET gate drivers and digital isolator ICs for EV, green power and industrial end-markets

Specialty foundry Tower Semiconductor Ltd (which has fabrication plants in Migdal Haemek, Israel, and at its US subsidiaries in Newport Beach, CA and San Antonio, TX, and at TowerJazz Japan Ltd) has announced a new galvanic capacitor technology integrated with its 0.18μm power management and mixed-signal platforms, enabling up to 12kV isolated gate driver and digital isolator ICs, which enhance safety and power efficiency for applications in the automotive, green power and industrial markets (addressing an estimated $1bn market).

The new technology is said to offer a cost and size advantage due to the integration of the galvanic isolator, saving the need for an additional device. Lead customers are prototyping initial products addressing applications such as battery chargers, power supplies and motor drivers for electric and hybrid vehicles (EV/HEVs), green power (solar inverters and wind turbines power converters) and industrial markets.

"We are very excited to announce this innovative technology as we partner with lead customers to bring new products to market, supporting the anticipated high growth in electrical vehicles and other applications for isolated power," says Shimon Greenberg, Tower's VP & general manager of its Mixed-Signal and Power Management Division, AIC business unit. "The new technology augments our widely deployed 0.18μm power technology, supporting applications from 5V to 200V".

UnitedSiC launches FET-Jet Calculator

On-line power design tool helps engineers to identify optimal SiC FET design solutions

Power semiconductor maker United Silicon Carbide Inc of Princeton, NJ, USA has launched the FET-Jet Calculator, a simple, registration-free online tool that facilitates selection and performance comparison in different power applications and topologies. The new tool is intended to allow engineers to make design decisions quickly and with confidence.

To identify the optimal UnitedSiC device for their power design, users can select their application function and topology, enter their design parameter details, and the tool automatically calculates switch current, efficiency and losses, categorized by conduction, turn-on and turn-off contributions. Operating temperature and heatsink rating are included as inputs, to show expected operating junction temperatures.

Users can explore the effect of changing conduction modes in the various topologies by varying storage inductor and switching frequency values. Additionally, single or paralleled devices can be selected to show relative overall performance of devices with various current ratings.

The tool warns if a selection is not appropriate, such as when voltage rating is insufficient for the conditions and topology chosen, helping the user to rapidly arrive at a viable solution.

All UnitedSiC FETs and Schottky diodes can be selected from sortable tables, which include devices in TO-220, TO-247, TO-247/4L and DFN8x8 packages and the recently launched Gen 4 750V devices.

"Selecting the right device in the right power topology shouldn't be a barrier to power designers considering the switch to SiC," says Anup Bhalla, VP engineering. "For engineers working with SiC for the first time, or those looking for the best SiC device to fit evolving designs, the calculator is a quick and easy way to evaluate UnitedSiC FETs in a variety of power topologies — speeding up R&D by avoiding any wasted time creating advanced simulations for inappropriate devices," he adds.

The UnitedSiC FET-Jet Calculator is free to use, with no registration required and can be found at: https://info.unitedsic.com/fet-jet

www.unitedsic.com

Swansea University gains £4.8m UK funding for 6" and 8" SiC power device pilot line

South Wales investment key part of Centre for Integrative Semiconductor Materials project

Swansea University has been awarded £4.8m in UK Government funding for equipment to manufacture silicon carbide (SiC) power semiconductor devices for more efficient power electronics in homes, transportation and industry, targeting the nation's net-zero-carbon ambitions.

The funding has been awarded as part of Driving the Electric Revolution (DER), which is part of the Industrial Strategy Challenge Fund led by UK Research and Innovation. DER is investing a total of £28.5m into equipment across the country for a competitive electrification supply chain to be built across sectors, including industrial, transport and energy.

The planned Centre for Integrative Semiconductor Materials at Swansea.

The investment will bring together a UK-wide network of over 30 academic, research and technology organizations based around four regional DER Industrialisation Centres, each supported by industrial clusters and bodies, in South West and Wales, Scotland, the North East, and the Midlands. The centers aim to coordinate and build on the UK's national capability to deliver long-term sustainable growth to achieve net-zero carbon emissions by providing open, easy access for businesses to find the expertise, facilities and manufacturing process technologies they need to scale up PEMD (Power Electronics, Machines and Drives).

The South Wales investment is a key component of Swansea University's new Centre for Integrative Semiconductor Materials (CISM) project involving multiple partners from the region's CS Connected semiconductor manufacturing community. The investment will fund the creation of a wide-bandgap power electronics component industrial pilot line with equipment at Swansea and Newport Wafer Fab, which will process 6" and 8" SiC substrates that can be used to manufacture efficient power electronics for sectors such as automotive, aerospace, medical and energy.

"We welcome this funding which will contribute to further developing Swansea University's power electronics capabilities," comments Mike Jennings, associate professor at Swansea University's College of Engineering. "Power electronics is a key enabling technology and is used in all sectors from domestic appliances, transportation, through to renewable energy generation. This new pilot line will manufacture new innovations in SiC semiconductor chips for use in the next generation of power electronic systems that will be more efficient, lighter and play a crucial role in helping the UK to meet its carbon reduction targets," he adds.

"We are very proud of the collaborative and truly innovative work of our power electronics research team led by Associate Professor Mike Jennings and their partners in the CS Connected manufacturing supply chain spearheaded by our new Centre for Integrative Semiconductor Materials," says professor Helen Griffiths, Swansea University's pro-vice-chancellor, Research and Innovation. "Successful award of the funding for the DER wide-bandgap component pilot line, with critical support from Welsh Government, signals our ongoing leadership and commitment to tackling climate change," she adds.

"This award further demonstrates the collective strength of the regional CS Connected community in key enabling technologies for electrification and connectivity," believes Dr Andrew Withey, Compound Process Integration Manager at Newport Wafer Fab (NWF). "The investment will allow NWF to develop next-generation SiC MOSFETs, devices at the heart of the green revolution, a critical component of our scale-up ambitions."

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

Toshiba launches 3300V, 800A SiC MOSFET module for industrial applications

High-power-density package enables high-efficiency, compact equipment

Tokyo-based Toshiba Electronic Devices & Storage Corp (TDSC) has launched the MG800FXF2YMS3 silicon carbide (SiC) MOSFET module (for volume production from May), which integrates newly developed dual-channel SiC MOSFET chips with ratings of 3300V and 800A, for industrial applications.

Features include: drain–source voltage rating V_{DSS}=3300V; drain current rating I_D=800A dual; high channel temperature range T_{ch}=175°C; low loss (E_{on}=250mJ, E_{off}=240mJ; and $V_{DS(on)sense}$=1.6V, typical); low stray inductance L_s=12nH (typical); and high-power-density small iXPLV package.

To achieve a channel temperature of 175°C, the new device adopts an iXPLV (intelligent fleXible Package Low Voltage) package with silver sintering internal bonding technology and high mounting compatibility The new module meet the needs for high-efficiency, compact equipment for industrial applications such as converters and inverters for railway vehicles, renewable-energy power generation systems, and industrial motor control equipment.

Toshiba's MG800FXF2YMS3, a SiC MOSFET module for industrial applications including railways vehicle and renewable-energy power generation systems.

www.toshiba.semicon-storage.com

Siemens Mobility using Infineon's 1200V CoolSiC MOSFETs for trains

Auxiliary converters improve efficiency of on-board power systems

Siemens Mobility GmbH (which is a separately managed company of Siemens AG) and Infineon Technologies AG, both of Munich, Germany, have jointly developed new auxiliary converters that use silicon carbide (SiC)-based power semiconductors to improve the efficiency of on-board power systems in trains.

The auxiliary converter makes use of power semiconductors (in a half-bridge topology) that are based on Infineon's CoolSiC MOSFET 1200V technology. Depending on the design, between 8 and 16 half-bridge modules are installed for each converter.

"Our vehicles should not only offer the highest level of passenger comfort but also enable our customers to operate them sustainably over the entire product life-cycle," says Albrecht Neumann, CEO of Rolling Stock at Siemens Mobility. "Energy-efficient on-board train power systems can make a major contribution to economical and environmentally friendly train operations."

Siemens Mobility uses the new converter for various train platforms, which are hence said to be maintenance-friendly, reliable, economical and power efficient. "With SiC, we achieve higher switching speed as well as efficiency to reduce the size of transformers, capacitors, cooling elements and the housing unit," says Dr Peter Wawer, president of Infineon's Industrial Power Control Division. "The advantages of this semiconductor material are evident and are now being leveraged in rail-bound vehicles," he adds.

In addition to providing the AC voltage (e.g. 3 AC 400V 50Hz) required for the vehicle power system, auxiliary converters also deliver the required battery voltage (e.g. 110V DC). To achieve this, they convert the DC voltage provided at the converter input. They ensure that train passengers can charge laptops and smartphones; the air conditioning and ventilation systems are running; and the on-board restaurant can offer hot and cold drinks and food. Without them, connectivity, information or entertainment services on trains would not be available. As part of the system, SiC reduces the overall costs in the on-board electrical system and the energy consumption of the auxiliary converter. It also enables more compact and lighter converter designs, along with a modular and service-friendly design to ensure lower maintenance costs, the firms say.

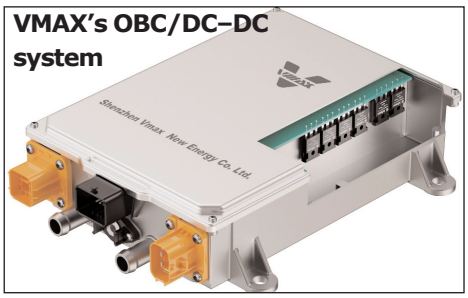
www.siemens.com

Infineon launches 650V CoolSiC Hybrid Discrete for Automotive

50A IGBT and CoolSiC Schottky enable cost-efficient performance boost plus high reliability for fast switching on-board chargers

Infineon Technologies AG of Munich, Germany has launched the 650V CoolSiC Hybrid Discrete for Automotive (available now). The device contains a 50A TRENCHSTOP 5 fast-switching insulated-gate bipolar transistor (IGBT) and a CoolSiC Schottky diode to enable a cost-efficient performance boost as well as high reliability. The firm says that this combination creates a cost-performance trade-off for hard-switching topologies and supports high system integrity in addition to bi-directional charging, making the device suitable for fast-switching automotive applications such as on-board chargers (OBC), power factor correction (PFC), and DC–DC and DC–AC converters.

The integrated fast-switching 50A IGBT enables MOSFET-like turn-off behavior outperforming pure silicon solutions. In contrast to regular silicon carbide MOSFETs, the



VMAX's OBC/DC–DC system

plug-and-play solution for a fast time-to-market achieves 95–97% system efficiency at a lower cost level, it is reckoned. Furthermore, the CoolSiC Schottky diode supports reduced turn-on and recovery losses. Compared with pure silicon designs, the device is suitable for hard commutation with 30% lower losses. With its low cooling requirements, the diode also provides what is claimed to be an excellent cost-performance trade-off at the system level.

As an OBC supplier focusing on the development of automotive power electronics and providing highly reliable OBCs and DC–DC converters, China-based Shenzhen VMAX New Energy Co Ltd is using Infineon's latest CoolSiC Hybrid Discrete in its next-generation OBC/DC–DC system.

"The partnership we have with Infineon is an essential cornerstone of our philosophy of consistently creating maximum value for our customers," says VMAX's R&D director Xu Jinzhu. "The CoolSiC Hybrid Discrete allows us to simplify driver design, accelerate product development, lower costs and increase system robustness," he adds. "The integrated silicon carbide diodes without reverse recovery charge further optimize the EMC characteristics of the system. This results in greater performance benefits and a better price/performance ratio in topologies such as totem-pole PFC and DAB."

www.infineon.com/coolsic
www.infineon.com/

CoolGaN 600V e-mode HEMTs used in Delta's rectifiers for telecom power applications

Infineon Technologies AG of Munich, Germany says that its CoolGaN 600V enhancement-mode (e-mode) gallium nitride high-electron-mobility transistor (HEMT) in the DFN8x8 package is a key component in Delta's DPR 3000E EnergE rectifiers, enabling energy efficiency of 98%.

"Delta's Telecom Power Solutions have built an unparalleled track record in the global market, especially by enabling lower energy consumption and CO_2 emissions in 4G and the next-generation 5G telecommunications," claims Eton Lee, general manager of Delta's Communication & Information Solutions business unit.

"We have achieved that success by collaborating with tier-one brands to develop our solutions. Moreover, Infineon's CoolGaN chips deliver excellent performance to Delta's 3000E rectifiers, which boast industry-leading efficiency up to 98% and an outstanding power density of 56.8W/in^3. It provides high performance while consuming little energy," he comments.

"At Infineon, we work closely with our customers to help them achieve ever-growing requirements towards energy efficiency and also power density," says Stefan Obersriebnig, product line head High Voltage Conversion of Infineon's Power & Sensor System Division. "With our complete portfolio of wide-bandgap solutions, i.e. CoolGaN and CoolSiC, we are paving the way towards a new era in the power industry."

Infineon says that, besides being suitable for industrial applications (e.g. industrial telecom and server SMPS), its family of CoolGaN devices (which are qualified according to JEDEC standards, offering lifetimes beyond 15 years) is also a match for consumer applications such as adapters, chargers, wireless charging and class-D audio amplifiers.

www.infineon.com/gan
www.infineon.com/cms/en/applications/communication/

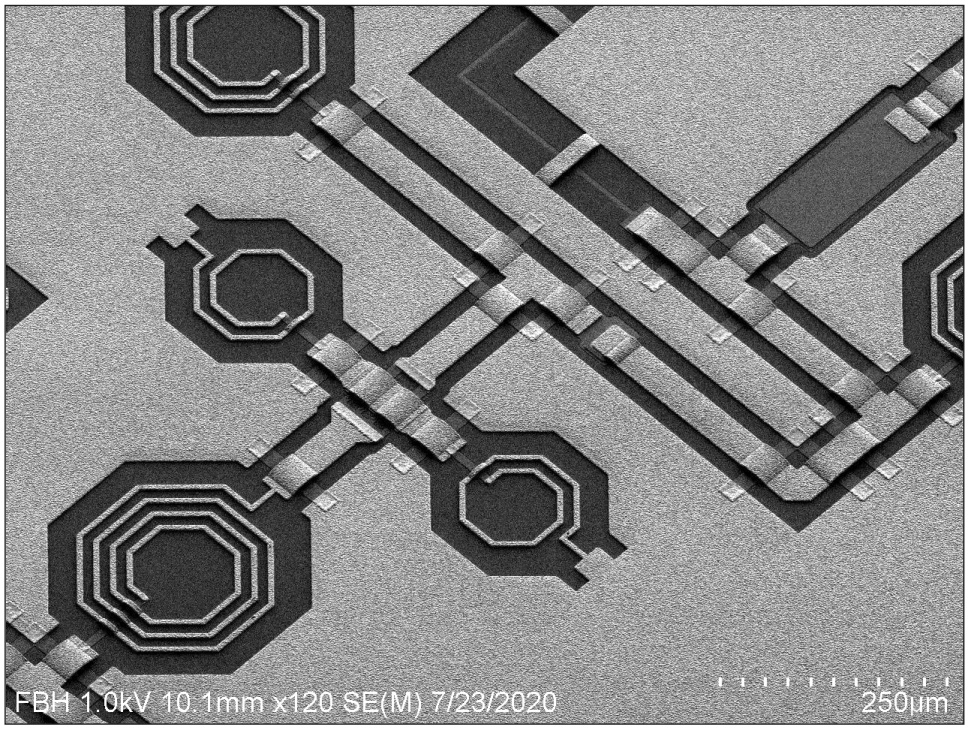
FBH, SweGaN and University of Bristol partner in European Space Agency's Kassiopeia project

Ka-band GaN MMICs to be develop for beam-steering antennas in satellite communications and radar

Funded under the European Space Agency (ESA) ARTES Advanced Technology Program 'European Ka-band high power solid-state technology for active antennas', in March the Kassiopeia project was launched to provide a value-added chain using technology only available in Europe.

Led by Ferdinand-Braun-Institut, Leibniz-Institut für Höchstfrequenztechnik (FBH) of Berlin, Germany and joined by epitaxial wafer foundry SweGaN AB of Linköping, Sweden and the UK's University of Bristol, the consortium aims to demonstrate a fully independent European supply chain, from silicon carbide (SiC) substrates, gallium nitride (GaN) epitaxy, GaN device processing up to power amplifiers. For this purpose, Ka-band monolithic microwave integrated circuits (MMICs) using novel epitaxy, processing and circuit concepts towards highly efficient GaN and aluminium nitride (AlN) devices will be developed and demonstrated. The Ka-band frequency band is used, for example, in satellite communications.

FBH is contributing its industry-compatible Ka-band MMIC technology on 100mm GaN-on-SiC wafers. "The unique selling point of our GaN MMIC technology is its highly reproducible and reliable iridium sputter-gate technology," says Dr Joachim Würfl, head of FBH's Power Electronics Department. "This technique reduces dynamic losses (gate lagging) to values up to two times less than competing institutional and industrial technologies," he claims. The technology also significantly improves device reliability, he adds. Together with new approaches in terms of process technology and circuit concepts both targeting parasitic loss reduction, highly efficient Ka-band MMICs will be developed. The technology should hence provide advantages in performance and reliability, which are particularly important for spaceborne devices.



SEM image of gallium nitride MMICs.

SweGaN is participating with its unique QuanFINE buffer-free solution for GaN-on-SiC epiwafers, bringing its expertise in epitaxial layer design and optimization to the project. The firm will also supply in-house-developed semi-insulating SiC substrates for evaluation. These activities are financially supported by the Swedish National Space Agency (Rymdstyrelsen). SweGaN is recognized for providing GaN epiwafers for sub-6GHz and millimeter-wave transistors with a significantly low thermal boundary resistance and limited trapping effects — based on its proprietary buffer-free approach. The company supplies epitaxial material to manufacturers of components and devices for satellite communications, telecom and defense applications, plus power electronics for electric vehicles (EVs), solar inverters etc.

"Conventional GaN-on-SiC materials for Ka-band applications still lack maturity, leaving significant room for innovation and improvement," says chief technology officer Jr-Tai Chen. "SweGaN will introduce its revolutionary epitaxial manufacturing process to address the challenge."

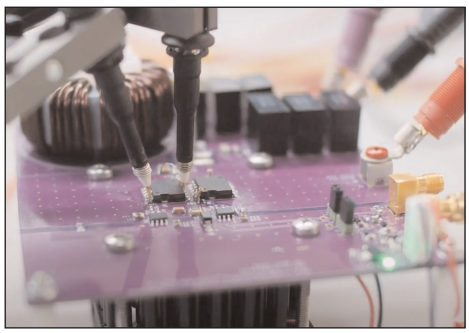
The University of Bristol's research in this program focuses on direct thermal measurements on active GaN transistors by using micro-Raman thermography and advanced device characterizations and modeling. This will provide continuous feedback to all device and epitaxial developments planned in Kassiopeia.

www.swegan.se
www.fbh-berlin.com
www.bristol.ac.uk/physics/people/martin-h-kuball/overview.html

Nexperia and UAES partner on GaN power devices

Program to address technical requirements for electric vehicle power systems

Nexperia BV of Nijmegen, Netherlands (which makes discrete and MOSFET components and analog & logic ICs) has announced a comprehensive partnership covering gallium nitride power semiconductor devices with United Automotive Electronic Systems Co Ltd (UAES) of Pudong District, Shanghai (a joint venture established in 1995 by China's Zhonglian Automotive Electronics Co Ltd and Germany's Robert Bosch GmbH). The program will focus on power systems for electric vehicles (EVs), with the aim to jointly develop automotive applications using GaN technology.



The electrification of cars, the increasing high power requirements of telecoms equipment for 5G and the rise of Industry 4.0 require power conversion efficiencies for which GaN is expected to become the mainstream technology. These trends underpin the growing demand for power semiconductors in 2021 and beyond. UAES has already started using Nexperia GaN FETs in R&D and collaborative projects including vehicle-mounted chargers and high-voltage DC-to-DC converters for electric cars. Nexperia says its GaN technology has good figures of merit ($R_{DS(on)}$ x Q_{GD}) and reverse recovery charge (Q_{rr}) metrics that support high switching frequencies and efficient power conversion. The firm produces GaN based on mature and reliable mass-production techniques, largely in its own global production facilities, to manufacture products according to automotive AEC-Q101 standards.

UAES provides car manufacturers with automotive powertrain and body control system solutions. It specializes in the development and production of gasoline engine management systems, transmission control systems, vehicle body electronics, and hybrid & electric drive control systems. Its five technology centers in China have laboratories for entire vehicles, engines, automatic transmissions and electric drive performance development. The equipment provides engineering services including system development, component development and calibration for various Chinese car manufacturers.

"The power density and efficiency of silicon-based GaN field-effect transistors will play key roles in the electrification of cars," believes Paul Zhang, senior VP sales & marketing & general manager, Nexperia China. "We recognize the broad offering, industry position and customer basis that UAES has in the automotive industry and we believe that our intensified collaboration in GaN will help both companies to deliver more advanced and efficient EV power system solutions to our customers. Earlier this month, we announced an increase in global production and R&D investment to fully support new product development. We intend to expand our investments and jointly to create a laboratory to develop automotive GaN technology applications."

"This partnership will help us reduce the number of devices used, reduce costs, increase power density and increase the reliability and effectiveness of the entire system," states a senior management spokesperson at UAES.

www.nexperia.com/gan-fets
www.uaes.com

GaN Systems launches smallest 100W GaN charger reference design

Turnkey reference design speeds design and rollout of smaller and more powerful and efficient GaN chargers

GaN Systems Inc of Ottawa, Ontario, Canada (a fabless developer of gallium nitride-based power switching semiconductors for power conversion and control applications) has released what it claims is the industry's smallest 100W dual USB-C intelligent PD GaN charger.

The turnkey reference design achieves what is reckoned to be the highest power density of any 100W charger on the market, while also having smart features. The charger can balance and appropriately power a variety of plugged-in device power-level combinations from a single 100W device, two devices at 65W and 30W, or two 45W or 30W devices. Additionally, when the power draw is below a certain threshold, the charger shifts to a higher efficiency mode to further maximize performance and reduce energy loss.

Available now, the charger reference design includes prototypes and documentation (schematics, PCB layout, bill-of-materials, and design guideline) to shorten design cycles and speed up product launches.

The 100W charger reference design uses GaN Systems' GS-065-011-1-L transistor, with the following key features:

- ultra-high power density (>16W/in3 with case and foldable prong);
- flexible and smart power distribution (Dual USB-C ports to support universal USB-C protocols and flexible plug-in end devices);
- peak efficiency (>92.5%);
- exceeds EN55032 Class B with >6dB margin;
- meets safety IEC62368-1 touch temperature requirement; and
- meets IEC61000-3-2 for power line harmonics with power factor correction (PFC) circuit.

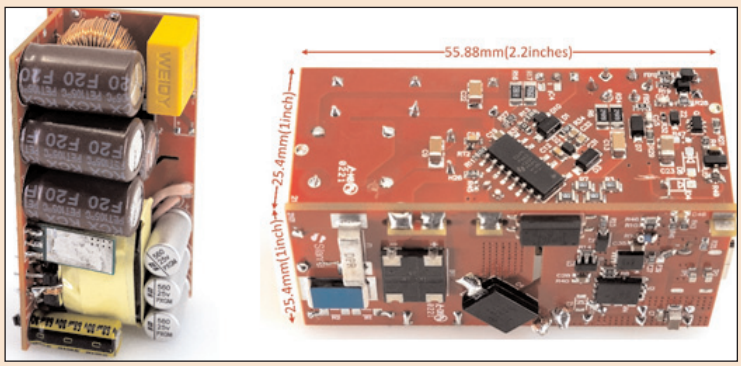
"Consumers have spoken, and they want GaN chargers. 65W was the start and now everyone wants 100W and multiple ports," says CEO Jim Witham. "Our design, validated by leading customers, is the highest-performance, smartest and smallest charger design that gets customers' products to market in record time."

www.gansystems.com/evaluation-boards/gs-evm-chg-100wpfcqr-gs1

GaN Systems & Silanna release 65W ACF GaN charger reference design

GaN Systems has announced a new reference design for the highest-power-density, high-efficiency GaN-based 65W Active Clamp Flyback (ACF) charger in collaboration with Silanna Semiconductor of San Diego, CA, USA, which makes AC/DC and DC/DC power converter ICs. The reference design is now available at Silanna and provides an easy design for ACF USB-C PD GaN chargers, reducing design cycles and product time to market for customers, GaN Systems says.

The solution removes the difficulties of an ACF topology design, which typically has two transistors in the high-side and in low-side configuration. The new charger reference design uses Silanna's SZ1130 ACF Pulse Width Modulator (PWM) controller and GaN Systems' GS-065-008-1-L 650V GaN power transistor, with the high-side FET integrated into the controller. GaN Systems says that this design results in lower bill of materials (BoM) costs by using a conventional RM8 transformer and 100V SR MOSFET on the secondary side.



Simpler ACF GaN charger design enabled by GaN Systems' transistor and Silanna Semiconductor controller.

Key benefits and features include:

- ultra-high density (30W/in^3 no case);
- high efficiency (>94%, peak);
- low temperature (<95°C maximum component temperature);
- better EMI design (clean waveforms with almost zero voltage spike or ringing); and
- supports for a wide range of applications (5V/3A, 9V/3A, 15V/3A and 20V/3.25A output voltages; USB-PD).

"Silanna Semiconductor's SZ1130 chip is a great fit for 65W ACF designs and is another example of a company developing an innovative solution in recognition of the growing importance of GaN to power engineers," says GaN Systems' CEO Jim Witham. "As GaN becomes the standard building block across markets, it's good to see that the ecosystem continues to grow."

www.powerdensity.com/reference-design/rd12
www.gansystems.com/gan-transistors/gs-065-008-1-l

GaN Systems' power transistor prices drop below $1

Milestone signals GaN's rapid global adoption

GaN Systems Inc of Ottawa, Ontario, Canada (a fabless developer of gallium nitride-based power switching semiconductors for power conversion and control applications) says its low-current, high-volume transistors have fallen below $1 in price.

The transistors are commonly used in GaN chargers and AC adapters for smartphones and laptop applications and a wide variety of consumer and industrial applications. With many consumers, enterprise, and industrial market customers worldwide ramping up production volumes, GaN Systems foresees further price reductions.

While GaN's performance advantages, including reductions in total system costs and improved power density and power efficiency, have been recognized for years, many power system manufacturers have chosen to wait for GaN to approach silicon prices, notes GaN Systems.

Philips charger with GaN Systems' power transistor.

"With volumes skyrocketing, GaN prices have approached, and even undercut, silicon MOSFET pricing," says CEO Jim Witham. "Within just a few years, we have seen GaN deliver on smaller, lighter, cooler, less expensive power systems. It is not a surprise that so many customers now have GaN in their products and designs."

Demand for GaN power semiconductors has been growing. Grand View Research forecasts that the global GaN device market will expand at a compound annual growth rate (CAGR) of 19.8% from $1.65bn in 2020 to $5.85bn in 2027. GaN Systems has been experiencing this growth, recently announcing the shipment of its 20 millionth GaN transistor and a 40x capacity expansion in 2021.

According to market analyst firm Yole Développement, the rise of GaN adoption has been driven by the high-volume consumer market, such as fast-charger applications. High growth in consumer and enterprise applications, coupled with continual process enhancements and a cost reduction focus at GaN Systems, has led to falling prices.

GaN Systems reckons that, in combination with its proven reliability and high-volume capacity, this trend positions it well for rapid GaN's adoption across many markets.

www.grandviewresearch.com/

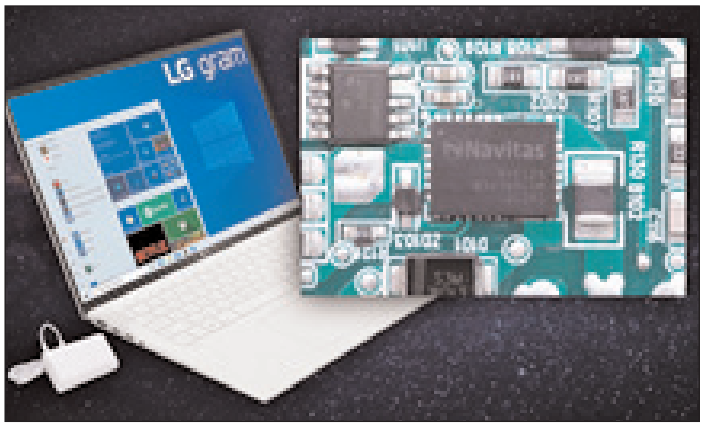
Navitas' GaNFast power ICs adopted by LG Electronics for lightest laptop

Adapter designed and built by Shenzhen Honor Electronics

Navitas Semiconductor Inc of El Segundo, CA, USA says that LG Electronics has adopted gallium nitride (GaN) technology for the first time, using its GaNFast power ICs.

While LG's gram laptop incorporates a heavyweight Intel i5-1135G7 Tiger Lake processor and an 80Wh battery, it is certified by the Guinness Book of Records as being the world's lightest 16" laptop, at only 2.62lbs (1190g). The gram is supplied with a matching powerful and lightweight 65W fast charger 'in-box', using the NV6125 GaNFast power IC. With the USB-C 'power delivery' (PD) functionality, the same 65W charger can also power tablets, smartphones and audio earbuds safely and quickly.

GaN is reckoned to run up to 20x faster than silicon, and enables up to 3x more power or 3x faster charging in half the size and weight. Founded in 2014, Navitas introduced what it claimed to be the first commercial GaN power ICs, which monolithically integrate GaN power field-effect transistors (FETs) with drive, control and protection circuits, enabling faster charging, higher power density and greater energy savings for mobile, consumer, enterprise, eMobility and new energy markets.



"As laptops and smartphones get more powerful yet thinner and lighter, it's time for fast chargers to upgrade from old, slow and heavy silicon 'bricks' to new, fast and lightweight gallium nitride technology," says Navitas' CEO & co-founder Gene Sheridan. "LG's adoption of fast-charging, lightweight GaN is a perfect match for the world-record gram laptop."

The cool-running NV6125 GaNFast power IC is used in a high-frequency quasi-resonant (HFQR) circuit. The adapter was designed and built for LG by Shenzhen Honor Electronics Company, with support from local Navitas application engineering.

"Gallium nitride is the future of fast charging for all of us," believes Albert Wang, vice chairman of the board & vice general manager of Shenzhen Honor Electronic Co Ltd. "Honor is excited to partner with Navitas to take the lead in adopting GaNFast power ICs in the global laptop market and successfully create this future-facing, faster, lighter and more efficient laptop charging solution. GaNFast power ICs are fast and efficient, so we can design a great charger, and they're also easy-to-use, so our development cycle is more dependable, with maximized chance of 'first-time right' and faster time-to-market," he comments.

GaNFast power IC used in Xiaomi's 55W fast charger

Fast charger supplied 'in-box' with every Mi 11 smartphone

Navitas says that its gallium nitride (GaN) power ICs are being used in the Xiaomi 55W fast charger (model MDY-12-EQ), supplied 'in-box' with every Mi 11 smartphone.

The Mi 11 is the first smartphone with the Qualcomm Snapdragon 888 5G processor, has a Gorilla Glass 6.81" AMOLED screen with 1440p resolution, plus a large 4600mAhr battery. Using the GaNFast 55W, the Mi 11 charges from 0–100% in only 45 minutes (half the time of competitor flagships, it is claimed) and is also highly compact (at half the size of typical silicon-based chargers).

The Xiaomi 55W fast charger uses an NV6115 GaNFast power IC in a high-frequency quasi-resonant (HQFR) flyback converter with the On Semiconductor NCP1342 controller at 200kHz to enable a slimline, planar transformer with shrunk core, plus smaller EMI filter and output capacitors.

"One of the best things about the 55W GaN charger is that it's capable of charging more of your gear, including laptops, gaming consoles and smartphones," notes Shou Zi Chew, partner, senior VP & president of International, Xiaomi Corp.

"Following the Mi 10 accessory GaNFast charger in February 2020 and the excitement over our 'Little Star' GaN twins at the Xiaomi Technology & Investment Day in October, we are now very excited to go global with Xiaomi with the Mi 11 55W 'in-box' GaNFast charger, now with the European 2-pin AC option," says Navitas' CEO & co-founder Gene Sheridan. "This is a major commitment to mainstream adoption of gallium nitride technology."

www.navitassemi.com

EPC launches 200V, high-current pulsed laser diode driver demonstration board for LiDAR

EPC2034C eGaN FETs enable current pulses up to 220A and widths under 3ns

Efficient Power Conversion Corp (EPC) of El Segundo, CA, USA — which makes enhancement-mode gallium nitride on silicon (eGaN) power field-effect transistors (FETs) and integrated circuits for power management applications — has announced the availability of the EPC9150, a 200V, high-current pulsed laser diode driver demonstration board priced $414 each.

In a light detection & ranging (LiDAR) system, used to create 3D maps for autonomous vehicle (AV) applications, speed and accuracy of object detection is critical. As demonstrated by the new board, the rapid transition capability of the EPC2034C eGaN FETs provides power pulses to drive the laser diodes, vertical-cavity surface-emitting lasers (VCSELs) or light-emitting diodes (LEDs) up to ten times faster than an equivalent MOSFET and in a small fraction of the area, energy and cost, enhancing the overall performance (including accuracy, precision and processing speed) as well as the price of a LiDAR system.

eGaN FETs and integrated circuits are said to provide the high-current pulses, extremely narrow pulse widths and small size that make affordable, high-performance LiDAR possible. Using the 200V, 12mm x 12mm EPC2034C eGaN FET, the EPC9150 can generate a 220A laser pulse peak in a pulse width that is only 2.9ns wide. The high current increases the range of the LiDAR system, while the short pulse width leads to higher resolution, and the tiny size and low cost make eGaN FETs and ICs suitable for LiDAR applications from automotive to industrial robotics and security.

The EPC9150 ships with an interposer board. The interposer board is a collection of breakaway 5mm x 5mm interposer PCBs with footprints to accommodate different lasers, RF connectors, and a collection of other footprints designed for experimentation with different loads. The use of the interposers allows many different lasers or other loads to be mounted, allowing users to test the performance with the load requirements that are appropriate to their application.

www.epc-co.com/epc/Products/DemoBoards/EPC9150.aspx

EPC adds automotive-qualified 65V eGaN FET for higher-resolution LiDAR

EPC has expanded its AEC Q101-qualified product family with the addition of the EPC2219 65V GaN transistor with integrated reverse gate clamp diode optimized for high-resolution light detection & ranging (LiDAR) systems in the automotive industry and other harsh environments.

eGaN technology has been in mass production for more than a decade, accumulating billions of hours of successful field experience in automotive applications, such as LiDAR and radar for autonomous vehicles (AVs), 48V–12V DC–DC converters for mild hybrid power, ultra-high-fidelity infotainment systems, and high-intensity headlamps for trucks.

The EPC2219 has completed rigorous automotive AEC Q101 qualification testing including humidity testing with bias (H3TRB), high-temperature reverse bias (HTRB), high-temperature gate bias (HTGB), temperature cycling (TC), as well as several other tests. The new GaN device will be followed with several more discrete transistors and integrated circuits designed for the harsh automotive environment.

In addition to LiDAR in demanding automotive applications, the EPC2219 — a 65V, 3.3Ω, eGaN FET with integrated reverse gate clamp diode and tiny 0.81mm^2 footprint — is suitable for driving GaN FETs in radar and ultrasonic sensors, satellite reaction wheels, high-frequency DC–DC conversion, wireless power, and class-D audio.

To complete AEC Q101 testing, EPC's eGaN FETs undergo rigorous environmental and bias-stress testing. EPC notes that its wafer-level chip-scale (WLCS) packaging passes all the testing standards created for conventional packaged parts, demonstrating that the superior performance of chip-scale packaging does not compromise ruggedness or reliability. eGaN devices passing AEC Q101 testing are produced in facilities certified to the Automotive Quality Management System Standard IATF 16949.

"This new automotive product is the latest addition to a growing family of EPC transistors and integrated circuits designed to enable autonomous driving and improve fuel economy and safety," says CEO & co-founder Alex Lidow.

The EPC2219 eGaN FET is priced at $0.54 each for 2.5Ku/reel and is available for immediate delivery from distributor Digi-Key.

www.epc-co.com/epc/Products/eGaNFETsandICs/EPC2219.aspx

Teledyne e2v HiRel and Integra partner on high-voltage GaN devices

Integra's GaN-on-SiC technology to be applied to high-rel space markets, including LEO/GEO applications

Teledyne e2v HiRel Electronics of Milpitas, CA, USA (part of the Teledyne Defense Electronics Group that provides solutions, sub-systems and components to the space, transportation, defense and industrial markets) has announced a new high-reliability partnership with Integra Technologies Inc (ITI) of El Segundo, CA, USA (which makes high-power RF & microwave transistors and power amplifier modules for mission-critical applications including radar, electronic warfare and advanced communications systems). Teledyne will leverage Integra's portfolio of gallium nitride on silicon carbide (GaN-on-SiC) RF power transistor products to deliver optimized power solutions for the space market.

With Integra, Teledyne e2v HiRel will specialize in providing high-power RF devices for emerging space applications in the LEO and GEO payload market. Teledyne will also offer high-reliability options for Integra's GaN-on-SiC power devices and pallets targeted at the defense market.

"Our space customers are requesting RF power devices at higher power density levels and operating at higher frequencies," says Brad Little, VP & general manager of Teledyne e2v HiRel. "The combination of our expertise in providing space RF components along with Integra's high-performance RF GaN device technology and product portfolio will provide space payload engineers state-of-the-art power devices for insertion in their applications."

"Integra has decades of proven success enabling a variety of defense and commercial radar systems with our world-class RF power products," says Integra's CEO Suja Ramnath. "We are excited to partner with Teledyne e2V, a market leader in hi-rel with deep domain expertise, to extend the application of our unique GaN-on-SiC technology and products into the growing space market."

www.integratech.com
www.e2v.com/products/

AKHAN hires chief marketing officer from Forbes

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 added Thomas P. Davis as its new chief marketing officer (CMO).

The firm says that Davis is an experienced marketer with a track record of building teams to achieve business goals and stakeholder growth. He was most recently CMO and chief growth officer at Forbes, where he worked to expand the reach of the business beyond the legacy magazine's efforts into dozens of global partnerships and new audience platforms around the world.

AKHAN reckons that Davis' experience in developing global partnerships and knowledge of how business needs to keep pace with the rate of change will be instrumental for it as it expands its Miraj Diamond Technology product line to address essential verticals, including consumer electronics, aerospace, military and defense. As AKHAN's technology continues to develop and advance, Davis will rely on his experience using new tools to build communities, increase engagement, corporate revenue and profitability while keeping pace with the rapid growth that the firm is currently experiencing.

"AKHAN Semiconductor and its breakthrough Miraj Diamond Technology provides me with a unique opportunity to join a burgeoning company with products that will change all aspects of the way we live our lives, from more efficient cell phones to technologies that help keep our nation safe," says Davis. "Adam Khan and the executive leadership team at AKHAN has developed game-changing technology, and I look forward to bringing it to the masses."

AKHAN expects that Davis will draw on intellectual capital gained from working closely with a network of business partners and colleagues to expand the firm globally, develop new product lines, and further transform the organization to explore new possibilities.

"Tom will play a key role in developing market outreach and customer acquisition strategies across our entire Miraj Diamond portfolio to ensure we're continuing to meet the key growth metrics our stakeholders have come to expect," says CEO & founder Adam Khan.

Before joining Forbes in 2008, Davis held multiple roles at International Data Group (IDG), including associate publisher of Network World and general manager of IDG's Customer Access Group. In 2016, he joined the Ad Council board of directors. He was also recognized by the Advertising Club of New York in 2016 with the Action Award, honoring advocates for the importance of diversity and inclusion through MEDIACTION. Additionally, he received the 2016 Revvie Award as Marketing Executive of the Year along with the 2014 Min Award for Sales Leader of the Year.

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Inseto supplies K&S Asterion wedge bonder to CIL

Electronic solutions provider performing packaging of WBG materials for electric vehicle projects

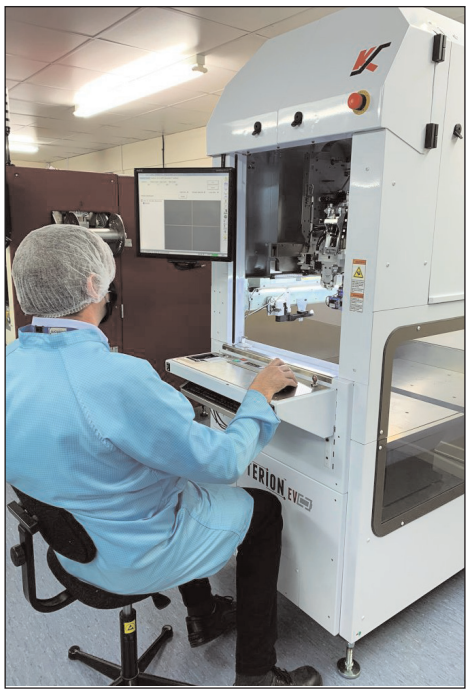
Inseto (UK) Ltd of Andover, UK (a distributor of equipment and materials to the semiconductor, microelectronic & advanced technology sectors) has supplied Custom Interconnect Ltd (CIL) with a Asterion large-diameter wire/ribbon wedge bonder made by Singapore-based chip assembly & packaging equipment and materials supplier Kulicke & Soffa Industries Inc (K&S) for use in the production of wide-bandgap (WBG) semiconductor-based power modules and the assembly of battery packs.

The Asterion is to play a crucial role in two major electric vehicle (EV) projects in which CIL is extensively involved.

In the first project, CIL is engaged with BMW on APC15@FutureBEV to maximize the potential for future battery electric vehicle (BEV) systems. The project is one of 10 projects by the Advanced Propulsion Centre (APC) in its latest round of Government and industry funding for low-carbon emissions research.

In the second project, CIL is the project lead on GaNSiC — a project that stems from the UK Research and Innovation's (UKRI) 'Driving the Electric Revolution' challenge and brings together CIL and Compound Semiconductor Applications Catapult (CSA Catapult, a not-for-profit organization headquartered in South Wales). It is set to develop novel ways of applying silver sinter pastes to WBG semiconductors, such as silicon carbide (SiC) and gallium nitride (GaN) devices, to optimize their thermal coupling and solve complex power module assembly challenges.

"Because of the high currents EV power modules handle, both projects require the placement of heavy-gauge wire or ribbon, of between 150μm and 600μm diameter or width compared to fine-wire bonding, which tends to be about 25μm," says CIL's managing director John Boston.



Kulicke & Soffa Asterion wedge bonder installed at CIL's new BEV facility.

SiC-based power module designs are aiming to switch up to 800V_{DC} and handle up to 600A. "You need heavy gauge, but heavy-gauge wire bonding of wide-bandgap materials is a relatively new technology," notes Boston. "More than ever before, there's a need for collaboration and trust within the industry. Also, with keeping costs low such an imperative in the automotive sector, the use of advanced manufacturing tools likely to produce the best results is essential, particularly when some vehicle manufacturers are demanding zero defects and stipulating that reworks are not allowed."

As an electronic solutions provider, CIL has the largest independent 'chip and wire' facility in the UK and its microelectronics packaging facility is regarded as being at the forefront of the EV power revolution, says Inseto.

"In addition to APC15@FutureBEV and GaNSiC, we're the manufacturing partner on many other EV projects, plus we have many customers in the aerospace sector — active under initiatives like the More Electric Aircraft and the All-Electric Aircraft," Boston says.

The K&S Asterion is located in CIL's BEV facility, and joins an automatic die bonder and high-pressure silver sinter press (both of which are for the packaging of WBG materials) and a scanning acoustic microscope used to detect voids. The Asterion will also be used in the manufacture of EV batteries, specifically for bonding between cells and busbars/plates.

Inseto is exclusive distributor for Kulicke and Soffa's range of wire bonding and die bonding equipment & materials in the UK, Ireland and Nordic regions.

Established in 1986 and ISO9001:2015, ISO13485:2016 (Medical) and AS9100D (Aerospace) certified, CIL is also on the path to ISO/TS 16949:2009 (Automotive) certification. The firm has transitioned from a conventional electronics manufacturing services (EMS) company into an electronic solutions provider and currently manufactures some of the most complex mission-critical electronic assemblies in the UK. A combination of six SMT lines, 3D AOI, Flying probe test and laser depanelling enables it to manufacture complex SMT PCB assemblies. CIL also has one of the largest independent die and wirebond facilities in the UK. Three automatic die bonders, and six automatic wire bonders and various encapsulation systems are available. It is now entering a WBG power module manufacturing era to support both UK- and EU-based companies deploy SiC- and GaN-based assemblies.

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Gelest's founder & CEO elected to US NAE

Barry Arkles recognized for contributions to organosilicon materials and organometallic and biochemical reagents

Dr Barry Arkles — chair, founder & CEO of Gelest Inc of Morrisville, PA, USA (a subsidiary of Mitsubishi Chemical Corp that manufactures silicones, organosilanes, metal-organics and specialty monomers) — has been elected to membership of the US National Academy of Engineering (NAE) in recognition of his "contributions to organosilicon materials and organometallic and biochemical reagents."

Arkles is said to have contributed scientific advances and inventions with positive impacts extending beyond the professional community to the global public. His record of innovation and accomplishments in applied materials science, surface chemistry and biotechnology is demonstrated by his contributions to medical devices (such as contact lenses) and semiconductor fabrication, particularly ILD (interlayer dielectrics) and interconnect metallization.

NAE membership recognizes outstanding individuals who have contributed to "engineering research, practice, or education, including … significant contributions to the engineering literature" and to "the pioneering of new and developing fields of technology, making major advancements in traditional fields of engineering, or developing/implementing innovative approaches to engineering education".

"Arkles's election to NAE membership recognizes the value of the characteristic hybrid chemicals technology he and Gelest have cultivated," comments Mitsubishi Chemical Corp (MCC) president & CEO Masayuki Waga.

"Gelest's technology, led by Dr Arkles, combines organic and inorganic chemistry and has great potential as an approach to various problems that could not be solved by organic or inorganic chemistry alone," says Waga, who expects to grow Gelest's technology by combining it with MCC's specialty technology related to organic chemistry.

Gelest's founder & CEO Barry Arkles.

"Barry Arkles is a very rare combination of technical excellence, entrepreneurial acumen and research management expertise which was evident early in his career and has continued to date," comments NAE member Dr Robert D. Miller, IBM emeritus at IBM Almaden Research Center and adjunct professor of material science & engineering at Stanford University.

Arkles formed Gelest Inc in 1991 to develop and manufacture silicon and metal-organic based chemicals and polymers for applications in microelectronics, optoelectronics, diagnostics (including DNA array devices), medical devices and pharmaceuticals

"Companies either founded or co-founded by Arkles currently generate nearly $1bn in revenue," says Miller. "In each of his ventures, he has remained the technical face of the business, with more than 150 technical publications and more than 75 US patents. The marriage of broad technical expertise and business impact is refreshing and is uncommon in today's world of specialization," he adds.

"Election to Academy membership validates my life's work and the collective mission of Gelest and now MCC scientists to customize materials solutions that benefit society at large," says Arkles.

Arkles formed Gelest Inc in 1991 to develop and manufacture silicon and metal-organic based chemicals and polymers for applications in microelectronics, optoelectronics, diagnostics (including DNA array devices), medical devices and pharmaceuticals. Prior to launching Gelest, he was VP, corporate development at Hüls America/Evonik. Arkles came to Hüls via its acquisition of Petrarch Systems, which he founded to develop advanced silicon and silicone products for medical devices. Early in his career at LNP Engineering Plastics (now part of SABIC) he was manager of advanced development of thermoplastic composites, a materials technology introduced into many consumer items, including cameras and photographic equipment, tool and appliance housings, and sports equipment.

Arkles is a recipient of the American Chemical Society 2020 Frederic Stanley Kipping Award in Silicon Chemistry and a fellow of the British Royal Society of Chemistry. He holds a B.S. in chemistry and Ph.D. in biochemistry at Temple University in Philadelphia.

Arkles is one of 106 newly elected NAE members and 23 international members. The recent election brings the total US membership to 2355 and international membership to 298.

www.gelest.com
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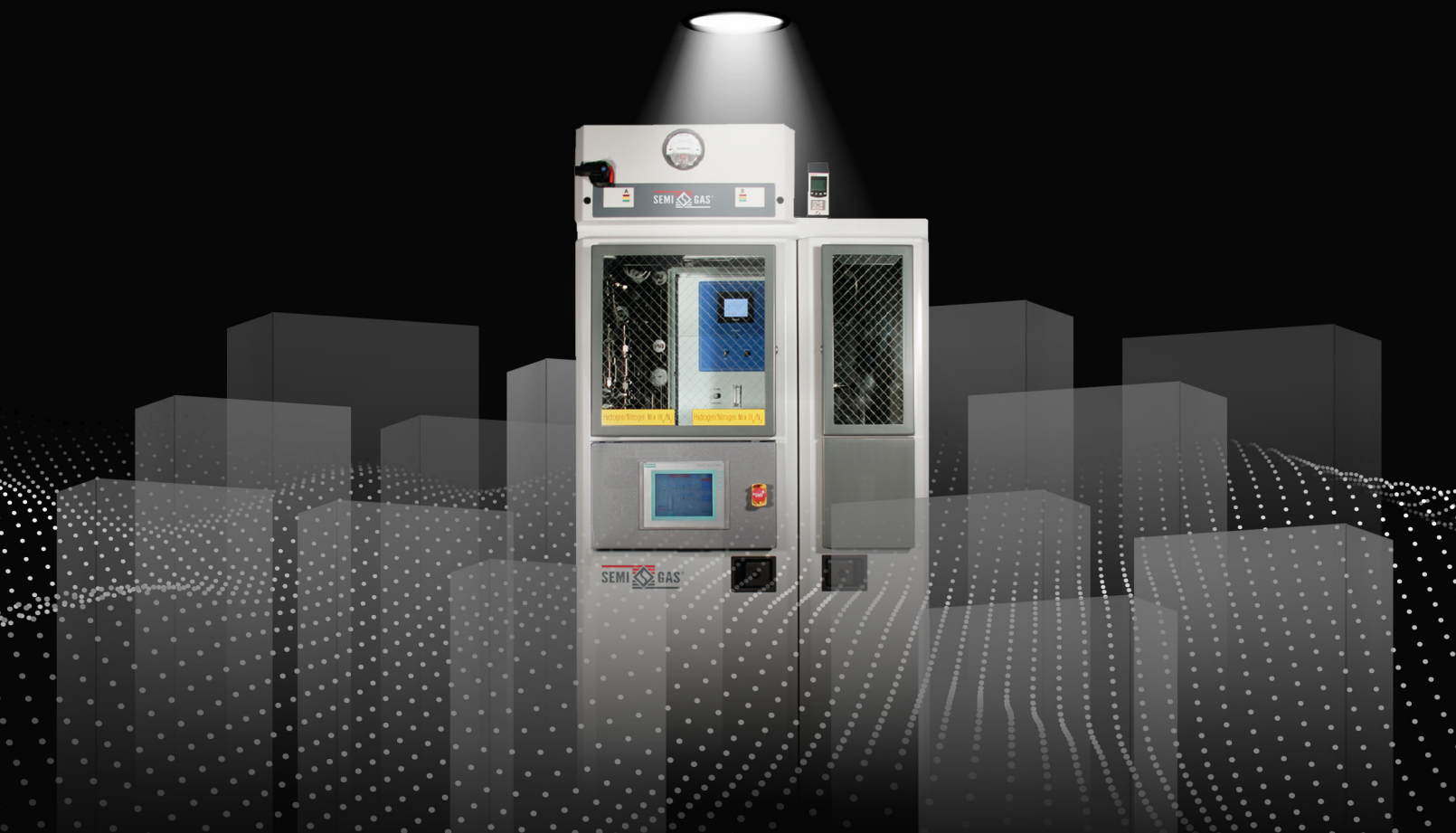

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LayTec adds t-PearL for time-resolved PL of thin films

Combined PearL/t-PearL used by ZSW in MBE of CIGS PVs

The transfer of copper indium gallium diselenide ($Cu(In,Ga)Se_2$, CIGS) thin-film photovoltaics from R&D to the gigawatt production scale leads to a growing demand for fully automated process control methods. To support this, in-situ metrology system maker LayTec AG of Berlin, Germany has extended its portfolio of photoluminescence (PL) products for thin-film semiconductor characterization.

The spectral PL (sPL) product PearL has been applied for several years for in-line production control of CIGS thin-film photovoltaic modules. Here, sPL allows spectral analysis of the effective CIGS bandgap energy, which is directly correlated to the [Ga]/([Ga]+[In]) atomic ratio (GGI). Furthermore, the PL signal also reveals information about the electronic quality of the CIGS thin films. Now, t-PearL has been designed especially for complementary characterization of semiconductor thin films by means of time-resolved photoluminescence (TRPL). In contrast to sPL, TRPL investigates the time-resolved decay of the PL intensity at a fixed wavelength range, therefore directly delivering key figures on the charge carrier lifetime of the semiconductor.

In particular, for thin-film photovoltaic materials such as CIGS, cadmium telluride (CdTe) and perovskites, this method has been well established in recent years in the research community but, until today, no commercial setup for integrated measurements in deposition chambers or production lines has been available. With t-PearL, this metrology method can now be integrated directly into the deposition environment for the measurement of carrier lifetimes as low as 5ns. By vacuum integration it is also possible to investigate pristine thin films that have not yet been exposed to ambient conditions.

For a most complete sample characterization, PearL and t-PearL can be combined into a single system. Additionally, both methods are available as metrology components in LayTec's integrated combined in-line metrology stations ILMetro as well as in the stand-alone mapping stations EpiX. Modified versions for longer lifetime materials such as silicon are available on request.

In February, the first combined PearL/t-PearL system was installed and commissioned at Zentrum für Sonnenenergie- und Wasserstoff-forschung Baden-Württemberg (ZSW) in Stuttgart, Germany. The materials research team at ZSW will use this fully integrated metrology system in combination with various in-situ and in-line metrology methods to monitor and control the process development of CIGS solar cells.

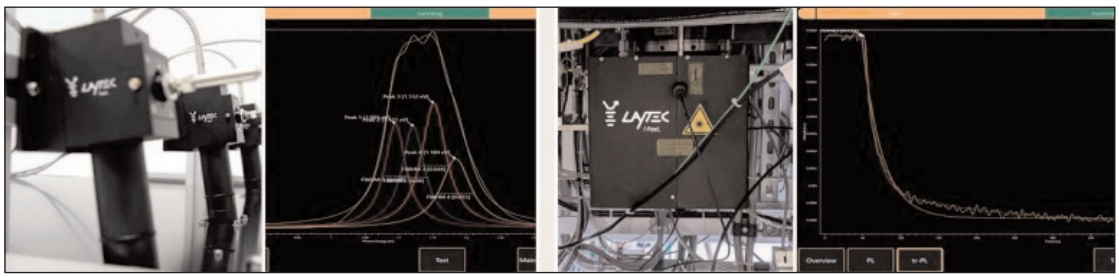
The target is to further develop and improve the solar energy conversion efficiency of CIGS thin-film solar cells to values above 25% — i.e. beyond the existing record of 23.4% — and to understand the mechanisms governing the performance of these devices.

A new vacuum cluster system combining two MBE 412 molecular beam epitaxy (MBE) chambers made by Riber of Bezons, France and a physical vapor deposition (PVD) chamber made by Von Ardenne of Dresden, Germany has hence been designed. Riber's vacuum cluster system is a fully automated system that includes a central UHV cluster robot for transferring samples between all chambers.

All LayTec systems have been fully interfaced into Riber's Crystal XE control software for acquisition control and data recording. That enables for quick and easy access to the relevant analytic parameters of each processed sample in Crystal XE software during or after thin-film deposition for real-time monitoring or for later analysis.

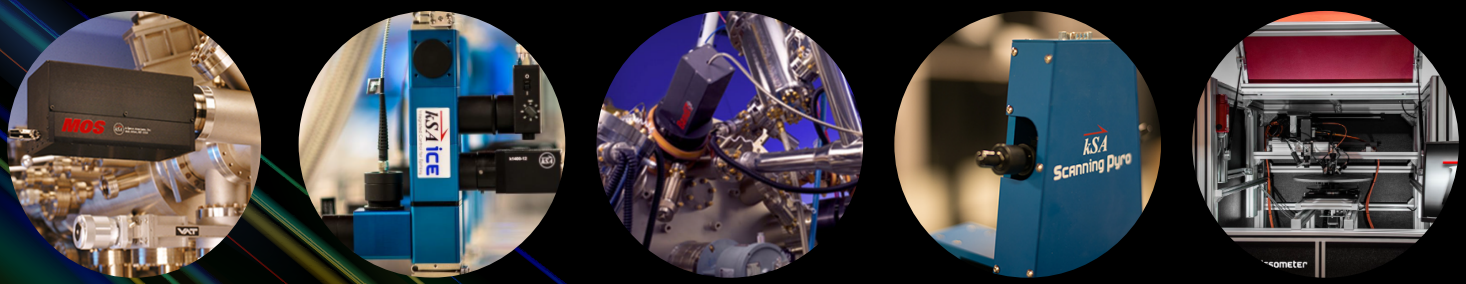
Regarding metrology methods, this cluster system employs LayTec`s InspiRe system for in-situ reflectance measurements in the MBE chamber during CIGS co-evaporation. Moreover, two EpiTT systems are integrated for monitoring the CIGS co-evaporation and the post-deposition treatment in-situ. Additionally, a combined PearL/t-PearL has been integrated into the transfer chamber between the Riber MBE chamber and the Von Ardenne PVD chamber. As a result, samples can be analyzed by both PL methods directly after CIGS deposition or post-deposition treatments as well as before and after transparent conducting oxide (TCO) deposition. The resulting in-depth understanding of the CIGS material should enable further improvement of CIGS solar cells, targeting even more efficient CIGS devices.

www.zsw-bw.de
www.laytec.de/solutions/industries/photovoltaics/cigs



Left: Production-integrated in-line PearL metrology system for spectral PL measurements and exemplary data for CIGS measurements. Right: Vacuum-integrated combined PearL/t-PearL setup for in-vacuo CIGS analysis at ZSW. Additionally, exemplary transients for CIGS time-resolved PL measurements are shown.

When Accurate Real-Time Measurement Matters



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Aixtron's growth accelerates in Q4

Strong order, sales and earnings growth expected for 2021

For full-year 2020, deposition equipment maker Aixtron SE of Herzogenrath, near Aachen, Germany has reported 4% revenue growth, from €259.6m in 2019 to €269.2m for 2020. However, growth accelerated in fourth-quarter 2020, with revenue of €108.1m up 69% on Q3's €64.1m and 44% on €75.1m a year ago.

Aixtron's revenue development benefited from the growing need for higher energy efficiency and data transmission speeds, as well as the growing use of innovative display technologies in consumer electronics.

Of full-year equipment revenue, power electronics manufacturing nearly doubled from 2019, rising from 18% to 31% of total revenue, driven by strong demand for gallium nitride (GaN) power equipment. Metal-organic chemical vapor deposition (MOCVD) systems for manufacturing optoelectronic components (i.e. lasers and solar, excluding LEDs) still comprised the largest contributor, but fell back from 43% of total revenue to 33% (although order intake almost doubled in 2020, driven by strongly increasing demand towards the end of the year). Equipment for LED production fell from 35% to 27% of revenue.

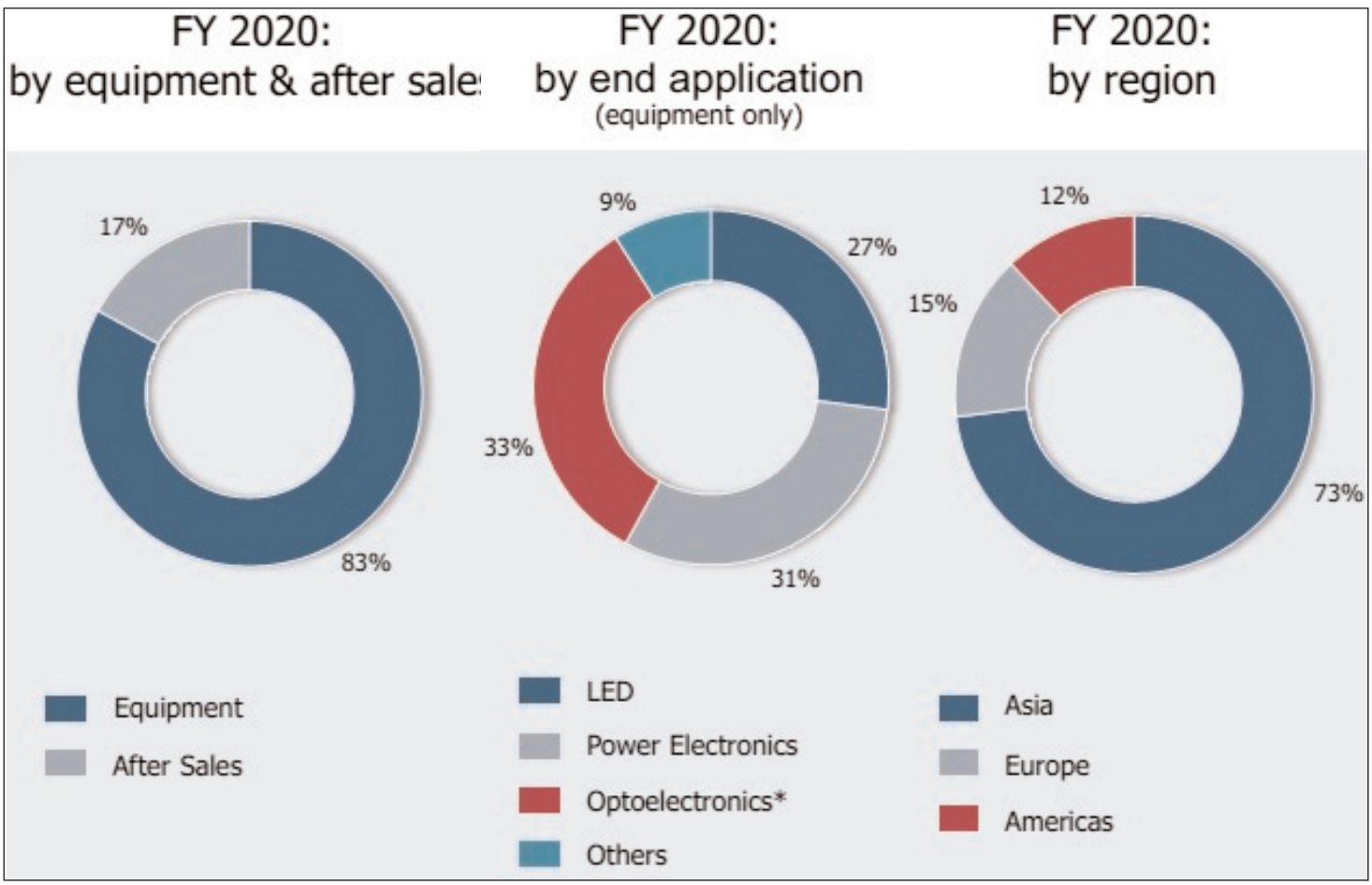
On a geographic basis, Asia rose from 68% to 73% of revenue, while Europe fell from 16% to 15% and America from 16% to 12%.

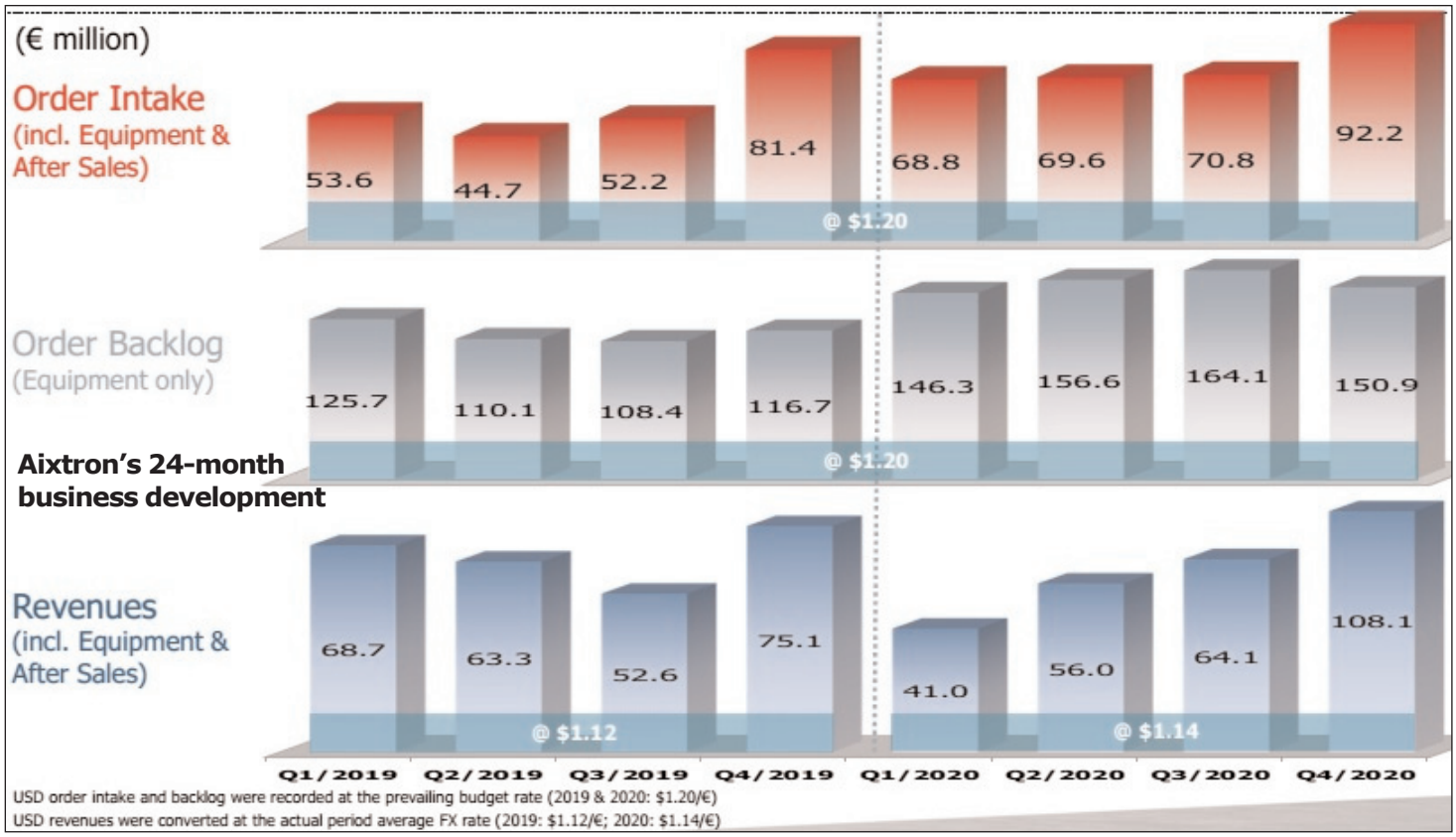
Full-year gross margin has fallen from 42% in 2019 to 40% for 2020, attributed to the US dollar–euro exchange rate effect between the two years. However, quarterly gross margin rose from 40% in Q3 to 42% in Q4/2020.

Full-year operating expense rose from €70m in 2019 to €73m in 2020. General & administrative (G&A) expenses increased from €16.5m in 2019 to €18m in 2020, due mainly to increased recruitment costs and other variable expenses. R&D expenses rose from €55m in 2019 to €58.4m in 2020 (22% of revenue), due to product development for next-generation MOCVD systems for various applications, including power electronics and mini- and micro-LEDs.

Aixtron's staffing rose during 2020 from 688 to 728 (more than a third of whom are engaged in R&D).

"We will start to ship first systems [for mini- and micro-LEDs] to test customers worldwide," notes VP of finance & administration Charles Russell. Spending on organic light-emitting diode (OLED) development reduced towards the end of the year, but €17m for the full year remained similar to 2019. Following completion of the Gen 2 OLED development project, customer





discussions are currently being held on the final qualification phase of this technology.

Full-year operating result (EBIT, earnings before interest and taxes) has fallen from €39m in 2019 to €34.8m (with margin falling from 15% to 13% of revenue). Quarterly EBIT almost tripled from €8.2m (13% margin) in Q3 to €24.5m (23% margin) in Q4/2020.

Full-year net income rose slightly from €32.5m in 2019 to €34.5m for 2020 (remaining 13% of revenue, although rising from €0.29 per share to €0.31 per share). Q4 net income was €24.9m (23% of revenue, €0.22 per share), more than tripling from Q3's €7.1m (11% of revenue, €0.07 per share).

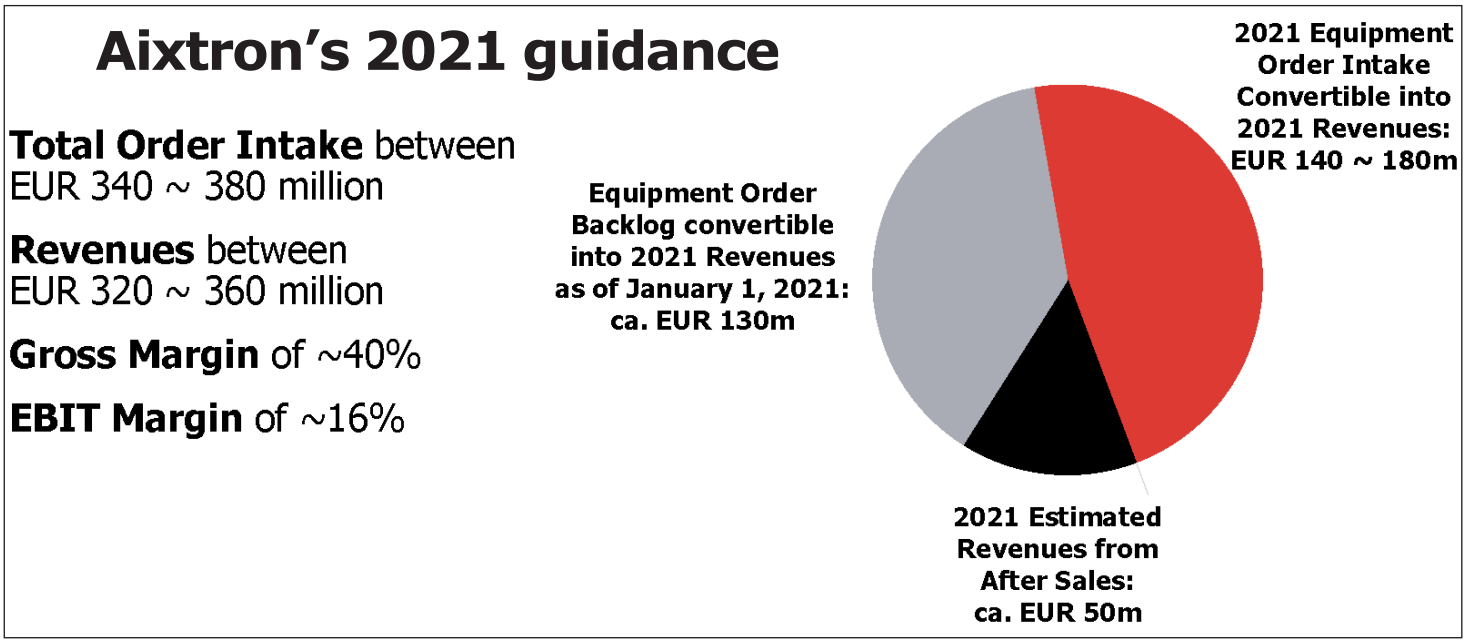
Operating cash flow more than doubled from €8.1m in Q3 to €18.4m in Q4. However, full-year operating cash flow was still down, from 2019's €42.8m to €23.3m for 2020, because of the increase in receivables at the end of 2020.

Capital expenditure (CapEx) rose from 2019's €7.7m to €9.3m in 2020 after an increase in demonstration equipment for the expanded product range and investments in facilities needed for expanding business activity.

Full-year free cash flow fell from €35.1m in 2019 to €14m for 2020 (although quarterly free cash flow rose from €5m in Q3 to €17.3m in Q4). Cash and cash equivalents (including financial assets) has changed from €298.3m at the end of 2019 and €292.8m at the end of Q3/2020 to €309.7m at the end of Q4 (or €249.7m, excluding €60m shown in other non-current assets).

Full-year order intake has grown by 30%, from 2019's €231.9m to €301.4m in 2020, exceeding the €270–300m guidance range. In Q4/2020, new orders were €92.2m, up 30% on €70.8m in Q3, the highest order intake in a single quarter since 2011. Growth is driven by demand for manufacturing:

- gallium nitride (GaN)- and silicon carbide (SiC)-based power electronics — "We continue to receive orders from customers to address the growing end market of efficient GaN chargers for consumer electronic devices such as smartphones and notebooks as well as efficient GaN power management solutions for servers and data centers," says executive board member & president Dr Felix Grawert. "In 2020, we have clearly seen the tipping point of broad GaN power adoption, and we are now in the volume ramp phase for GaN power solutions that replace the incumbent silicon-based power management systems," he adds. "At the same time, we see increasing momentum in the area of gallium nitride and gallium arsenide RF solutions, driven by the 5G build-out," Grawert continues. "In silicon carbide, we have achieved the qualification of our fully automated, high-throughput system from two customers and we continue to work hard to achieve the same with additional customers."
- optoelectronics — orders were particularly strong in Q4, driven by datacom lasers (for the 5G infrastructure build-out) as well as lasers for 3D sensing (due to growing adoption for both sides of the smartphone and other devices).
- specialty LEDs for displays — "Customer inquiries for tools to make ROY LEDs are strong, driven by demand from the areas of full-color mini-LED displays and backlighting units," notes Grawert. "For the first time in 2020, we have received significant orders



for ROY [red-orange-yellow] LEDs targeting the horticulture market [indoor farming]," he adds. "In micro-LEDs, we have seen the transformation of the industry from pure R&D to the manufacturing feasibility stage, making the adoption of this technology more probable than before. At this stage, the order volumes for this segment are still comparatively small."

Order backlog was €150.9m at the end of Q4/2020, down 8% from €164.1m at the end of Q3/2020 but up 29% from €116.7m at the end of 2019.

The high level of sales in Q4 drove a substantial reduction in inventory, from Q3's €101.6m to €79.1m and an increase in trade receivables from €19m to €41.3m (most of which will be collected in Q1/2021). Advance payments received from customers in Q4 were €50.8m (equivalent to 34% of the order backlog), down on €63.2m last quarter but similar to €51.1m a year ago.

In view of the positive business development in 2020, at the Annual General Meeting of shareholders on 19 May, Aixtron's executive board and supervisory board will propose to pay a dividend of €0.11 per share (a payout ratio of 36% of the firm's net income of €34.5m). Aixtron last distributed a dividend to shareholders for 2011.

Accelerating growth in 2021

For 2021, Aixtron expects a strong upturn in business. Based on its current corporate structure, the assessment of the order situation and the budget rate of $1.25/€ (versus 1.20$/€ in 2020), it anticipates significant growth in order intake volume to €340–380m.

Based on equipment order backlog (convertible into 2021 revenue) of €130m as of 1 January joined by an expected €140–180m of order intake that should be converted into revenue during 2021, plus €50m of spares & services revenue, for 2021 Aixtron expects revenue to grow significantly to €320–360m. In particular, Aixtron expects demand for equipment for the manufacture of energy-efficient power components made of GaN to make an increased contribution compared with 2020.

The executive board has set itself the goal of ensuring continued high profitability in 2021. Despite the adverse US dollar–euro currency effect, gross margin should remain about 40%, while EBIT margin should rebound to about 16% of revenue. This is despite increased R&D expenses for completing the development of Aixtron's next-generation products for lasers, µLEDs, GaN power & RF, and 8" SiC. "With this large portfolio initiative, we expect to secure our leading market position in our rapidly growing core market," says Grawert.

The expectations for 2021 fully include the results of Aixtron's South Korea-based OLED-focused subsidiary APEVA (including all necessary investments). "We have achieved customer acceptance of our Gen2 in December 2020 and we are now in customer discussions related to a scale-up of the system to larger size, which would be the final part of the qualification process," notes Grawert.

The 2021 also remains subject to the COVID 19 pandemic not having a significant impact on the development of business.

"In 2020, we have taken a major step forward in strengthening our competitive position in the relevant growth markets for our MOCVD technology," says executive board member & president Dr Bernd Schulte. "With our ambitious and focused investment program to further develop our leading-edge technologies, we are setting the stage for progress in clearly aligning our product portfolio with the growing demands of our customers' future markets," he believes.

"These markets include, in particular, e-mobility, the expansion of the 5G mobile network, and the growing demand from our customers in the semiconductor industry to be able to deploy energy-efficient solutions," adds Grawert. "We will again increase our growth rate in 2021."

www.aixtron.com

Epiluvac supplies CVD reactors to Polish institute

Multi-reactor 8-inch system designed for SiC and GaN

Epiluvac AB of Lund, Sweden — which was founded in 2013 and produces silicon carbide (SiC) chemical vapour deposition (CVD) systems used in power device research — has received the first order for two new CVD systems in a double configuration. Designed with Epiluvac ER3 reactors for 8" wafer epitaxy of silicon carbide (SiC) and gallium nitride (GaN), the CVD systems will be used by Lukasiewicz Research Network Institute of Microelectronics and Photonics in Warsaw, Poland, for research & development on new materials technology.

"The reactor development started years ago in cooperation with Linköping University," says Epiluvac's chief technology officer Roger Nilsson. "During the last years, we have refined the design into a brand-new platform. From the beginning, it is designed for 8-inch wafers; that requires new solutions for controlling the temperature profile and gas flow concentration over the large wafer," he adds. "It has also the unique feature that it allows two or more systems to be put together to a WBG [wide-bandgap] multi-reactor CVD system. This multi-system approach allows the user to optimize the chemistry in each and every reactor, thereby achieving a very high yield."

The systems are equipped with an automatic robotic wafer handler interfacing both reactors. To increase production capacity, the wafers are pre-heated and cooled down outside the reactor. Epiluvac offers a turnkey solution, including support to get the system up and running with basic epitaxial growth. The new ER3 also includes a patented feature where the wafer bow is minimized. Optionally, customers can add in-situ measurements for GaN.

"There is a huge potential for sales of this new platform to the semiconductor industry," reckons chairman Dr Rolf Elmér. "The new wide-bandgap (WBG) semiconductor materials are used to produce more efficient power electronics devices. These devices are used in, for example, electrical vehicles, transformers for solar cells and smart micro-power grids."

https://epiluvac.com

Eta unveils GaN wafers for laser diode manufacturing

Si-doped n-type or C-doped semi-insulating 2" and 4" free-standing gallium nitride, with backside polished or etched

Eta Research of Shanghai, China, which was founded in 2015 to develop free-standing gallium nitride (GaN) wafers, is now producing free-standing GaN wafers at sizes of 2" and 4", with conductivity available in either silicon (Si)-doped n-type or carbon (C)-doped semi-insulating. The properties of the GaN wafers have been engineered to meet the requirements for laser diode manufacturers.

The wafer orientation flat must be closely aligned to the GaN m-plane, since lasers may be manufactured by cleaving on the crystallographic plane. Eta has therefore developed the process to achieve 0.0±0.1° alignment of the orientation flat to the crystallographic plane.

The typical x-ray diffraction (XRD) rocking curve full width at half maximum (FWHM) for both (002) and (102) are in the range 40–50 arcsec. The dislocation density was measured by both cathodo-luminescence (CL) and etch pit methods, and was found to be in the range 5E5–9E5/cm^2.

Eta's standard offcut is 0.5° toward the m-direction and 0.0° toward the a-direction at the center point of the wafer. The center point offcut can be customized in the range 0.2–0.6°.

The lattice radius specification is >10m, and typical values range from 20m to 60m with the shape as concave. The offcut variation can be calculated from the lattice radius. However, since there is a small concave wafer bow, the actual offcut variation is less than would be calculated from the lattice radius. The offcut was measure by XRD with x-ray reflection alignment to the real wafer surface. The offcut variation over a 4" wafer was measured to be 0.06° for both the m-direction offcut and a-direction offcut. For example, the m-direction offcut was 0.47° on one edge and 0.53° on the other edge over the entire 100mm of the wafer.

The gallium (Ga)-face is polished to an average roughness of 0.15nm measured by a 10μm x 10μm atomic force microscope (AFM) scan. The wafer is cleaned in a special process to remove any contamination from the polishing procedure. Removal of trace-metal impurities from the surface was confirmed by total reflection x-ray fluorescence (TXRF).

The backside finish is available in either polished or etched versions. The average roughness of the backside surface measured by 3D profiler over 239μm x 318μm is 1nm for polished and 1μm for etched. The wafers with polished and etched backside finish are shown in the figures.

www.etaresearch.com

5N Plus renews $79m syndicated credit facility

Contingent and accordion options could expand facility to $154m

Engineered materials and specialty chemicals producer 5N Plus Inc of Montreal, Québec, Canada has renewed its US$79m senior secured multi-currency, revolving and syndicated credit facility. The agreement includes a contingent option to expand the facility to US$124m.

The renewed credit facility has a two-year term, bearing interest and a margin based on the company's senior consolidated debt-to-EBITDA ratio. In addition to its contingent option, 5N Plus can exercise a $30m accordion feature to increase the total size of the facility to $154m, subject to lender approval. The syndicate consists of five banks and financial institutions, with HSBC Bank assuming the role of lead arranger and book runner.

5N Plus provides purified metals such as bismuth, gallium, germanium, indium, selenium and tellurium, and also produces related II-VI semiconducting compounds such as cadmium telluride (CdTe), cadmium sulphide (CdS) and indium antimonide (InSb) as precursors for the growth of crystals for solar, LED and eco-friendly materials applications.

"We are pleased to have the support of leading financial institutions as we continue to execute our strategic transformation toward deepening our position as a global material technology company," says chief financial officer Richard Perron. "We continue to make significant progress along this path and have been consequently rewarded with enhanced return on capital employed, recurrent cash flows and a solid balance sheet."

5N Plus says that it continues to remain competitive through its sustainably optimized cost structure, selection of promising growth initiatives and portfolio of customers that continue to be essential for the company's transformation. The capital made available through its credit facility and associated contingent and accordion options are expected to finance both organic and inorganic growth initiatives.

"We continue to focus on accelerating our long-term growth story and will look beyond our current organic initiatives to support this trajectory," says Perron. "The additional flexibility to our credit facility will be a notable asset in realizing these ambitions."

www.5nplus.com

Signify's UV-C lighting validated for disinfecting air

UV-C disinfection upper air luminaires inactivated 99.99% of SARS-COV-2 within 10 minutes

Signify of Eindhoven, The Netherlands has conducted research that validates the effectiveness of UV-C disinfection upper air luminaires on the inactivation of SARS-CoV-2, the virus that causes COVID-19.

In a test chamber with overall dimensions of about 8'x8'x10' (compliant with Biosafety Level 3 standards) and sufficient air circulation, Philips UV-C disinfection upper air wall-mounted luminaires inactivated 99.99% of SARS-CoV-2 in the air within 10 minutes, and the virus was below detectable levels after 20 minutes, according to results obtained from a laboratory test conducted by Innovative Bioanalysis (a CAP-, CLIA- and AABB-certified safety reference laboratory in Costa Mesa, CA, USA).

"Based on the understood method by which UV-C exposure deactivates pathogens, we would expect UV-C disinfection lighting to have a similar impact on the various genetic mutations of SARS-CoV2," says Innovative Bioanalysis' chief scientific officer Sam Kabbani.

"These test results illustrate the effectiveness of our UV-C disinfection upper air luminaires and the important contribution they can make towards fighting the coronavirus and future viruses," says Harsh Chitale, division leader Digital Solutions at Signify. "It shows how UV-C lighting for upper air applications can be a successful preventive measure for organizations as they seek ways to provide their guests, customers and employees virus-free environments."

In 2020, Signify increased production of its UV-C light sources eightfold in support of the fight against the coronavirus and acquired GLA to complement its portfolio with luminaires for upper-room air disinfection. Since then the firm has installed UV-C disinfection upper air luminaires in several locations, including retailers EDEKA Clausen in Germany, dm in Slovakia, and Rugby Union Club Harlequins in the UK.

In combination with the luminaires' design, the height at which the luminaires are installed allows the system to disinfect air as it circulates a space, even when there are people present. Mechanical ventilation and/or natural convection moves the disinfected air back into the lower part of a space. The germicidal effectiveness of UV-C light sources is proportional to the exposure time of the micro-organism to the UV-C light source and the intensity of the UV-C light source. Therefore, sufficient air flow in the room (which may be achieved through forced air flow or natural convection) is required for effective operation of Signify's UV-C upper air disinfection luminaire solutions. Additionally, shielding and optics in the luminaires are designed to prevent accidental exposure to UV-C radiation for the people beneath them.

www.signify.com

Nitride Semiconductors files complaint against Lite-On

On 26 February, Japan's Nitride Semiconductors Co Ltd (which was spun off from Tokushima University in 2000 and claims to have developed the first highly efficient ultraviolet light-emitting diode) has filed a complaint against Lite-On Technology Corp and its three US-based affiliated companies in the US District Court for the Western District of Texas, Waco Division, asserting infringement of Nitride's UV LED patent.

Nitride first filed a patent infringement suit against Digi-Key in the US District Court for the District of Minnesota in September 2017.

With professor emeritus Shiro Sakai at Tokushima University, Nitride developed highly efficient UV LEDs as early as 2000. It has continued to manufacture and sell UV LEDs, and says that it has invested in R&D to develop and enhance its UV-LED technology.

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

Further, the lawsuit that Nitride Semiconductors has filed against global electrical components distributor Digi-Key Corp is pending before the US District Court for the District of Minnesota. Nitride is asserting that UV LED products being supplied by various LED companies — such as American Opto Plus LED Corp, Crystal IS Inc, Lite-On Semiconductor Corp, Luminus Devices Inc, Kingbright Electronic Co Ltd., QT-Brightek Corp and Vishay Intertechnology Inc — have been infringing Nitride's UV LED patent.

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

www.nitride.co.jp

Cree completes sale of LED business to SMART

Cree LED brand name to be licensed and incorporated into SMART portfolio; Cree to change name to Wolfspeed

Cree Inc of Durham, NC, USA, which provides silicon carbide (SiC) technology through its Wolfspeed business, has completed the sale of its LED Products business unit (Cree LED) to SMART Global Holdings Inc. SMART will now license and incorporate the Cree LED brand name into the SMART portfolio of businesses, and Cree will change its corporate name to Wolfspeed later this year.

Under the terms of the transaction, Cree will receive up to $300m, consisting of a $50m cash payment at close and a $125m seller note issued by SMART to Cree (to be paid upon maturity in 2023). Cree also has the potential to receive an earn-out payment of up to $125m based on the revenue and gross profit performance of Cree LED in the first full four quarters after the transaction's completion, also payable in the form of a three-year seller note.

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

Cree LED's product families include blue and green LED chips, high-brightness LEDs and lighting-class power LEDs targeted for indoor and outdoor lighting, video displays, transportation and specialty lighting applications.

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

"The completed sale of Cree LED represents a major milestone in our transformational journey, establishing the company as a pure-play global semiconductor powerhouse, well positioned to lead the industry transition from silicon to silicon carbide," believes Cree's CEO Gregg Lowe. "As industries across the globe look to increase efficiency and performance with smaller, more scalable power systems, this evolution sharpens our focus and strengthens our continued investments to capitalize on multi-decade growth opportunities for Wolfspeed silicon carbide and gallium nitride (GaN) solutions across electric vehicles (EVs), 5G and industrial applications," he adds.

Cree's ongoing capacity expansion plans include its materials factory at its North Carolina headquarters and its Mohawk Valley Fab construction in Marcy, NY which, upon completion, will be the world's largest silicon carbide manufacturing facility, as well as the first 200mm silicon carbide fabrication facility, with production expected to begin in 2022.

www.cree.com

ALLOS' GaN-on-Si epi used by Toyohashi University for in-vivo neural applications

Nitride micro-LEDs combine with silicon to provide medical brain/machine interface

Professor Hiroto Sekiguchi's team at Japan's Toyohashi University of Technology together with IP licensing & technology engineering firm ALLOS Semiconductors GmbH of Dresden, Germany have collaborated to realize high-efficiency nitride-based micro-LED chips for novel in-vivo neural applications.

Since their development in the 1990s, nitride LEDs have been saving energy and enabling many new applications, being used ubiquitously in numerous illumination applications and now emerging as micro-LEDs for use in super-large TVs or augmented reality (AR) displays as well as robust automotive displays.

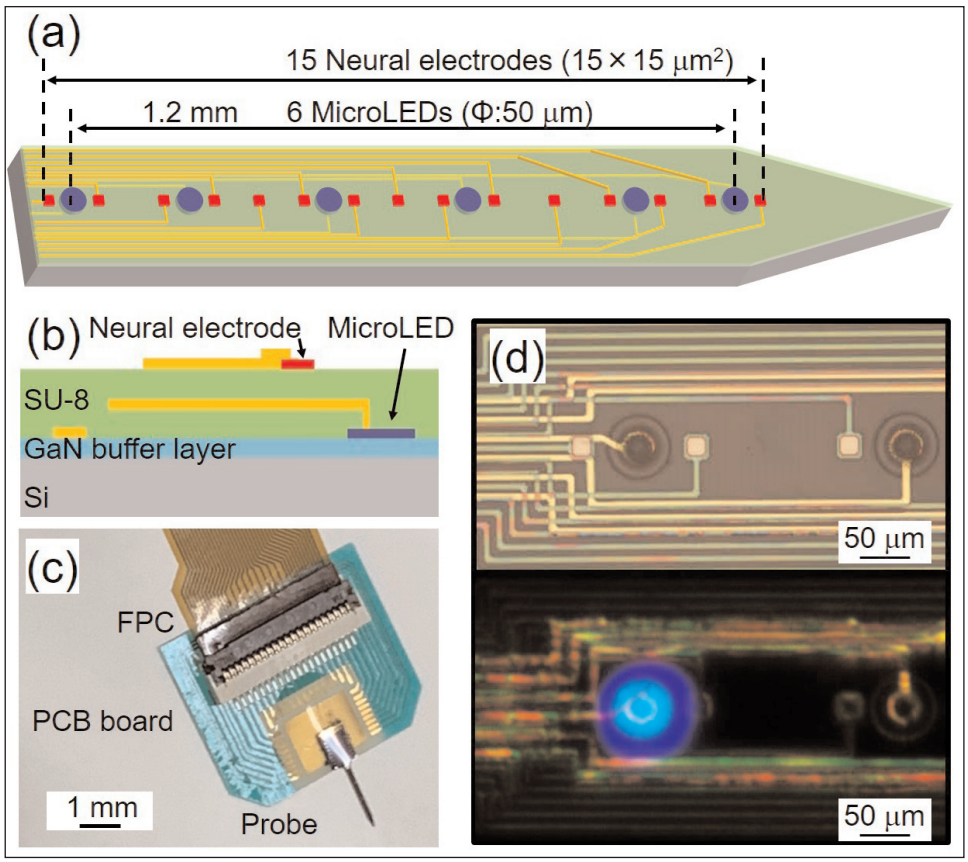
Nitride LEDs for medical applications

Beyond the obvious illumination applications, nitride LEDs are also increasingly proving helpful in medical applications. For example, nitride LEDs emitting ultraviolet light are employed to fight viruses like COVID-19 by disinfecting surfaces.

Another example is Toyohashi University of Technology using nitride micro-LED technology to build medical brain/machine interfaces. Professor Sekiguchi's group has developed a neural probe to study brain functions using ALLOS' micro-LED epiwafer. To avoid brain damage, the high efficiency of micro-LEDs is key in order to reduce the harmful impact from heat coming from conversion losses. Furthermore, for micro-LEDs, extreme precision is needed.

GaN-on-Si to overcome manufacturing challenges

For this novel medical application, manufacturing challenges had to been overcome, where ALLOS' gallium nitride on silicon (GaN-on-Si) technology plays a key role. In particular, it was important to integrate nitride LED technology with mature and precise silicon industry processes in order to achieve highest accuracy and reliability standards.



Micro-LED neural electrode probe fabricated by professor Sekiguchi's group integrating ALLOS' strain-engineering epiwafer technologies.

"We need to achieve extreme precision and reliable results," says Sekiguchi. "Only industry-grade silicon processing equipment — as we fortunately have at our university — can deliver such processing results. Thus, using ALLOS' GaN-on-Si epiwafers, which can be processed on silicon lines, was the right choice," he adds.

"With our CMOS-line-ready GaN-on-Si technologies we unlock the benefits those silicon lines bring — including scalability to 200mm and 300mm for low cost and the exceptionally high reliability and yield levels required for all micro-LED applications," says ALLOS' chief technology officer Dr Atsushi Nishikawa.

At Toyohashi, Sekiguchi has been working on the development of nitride semiconductor for over 10 years. Currently he is considering micro-LEDs as a new optogenetic tool for brain science. Using their silicon process technology and ALLOS' GaN-on-Si technology, he and his research team are developing a new neural probe that has micro-LEDs for manipulating neural activity and a neural recording electrode for recording neural activity (Hiroki Yasunaga et al, Jpn. J. Appl. Phys. 60, 016503 (2021)). They believe that such a device development will be a powerful tool for opening up new fields of neuroscience.

https://iopscience.iop.org/article/10.35848/1347-4065/abcffa
www.tut.ac.jp/english
www.allos-semiconductors.com

Lumileds launches LUXEON SkyBlue for human-centric lighting

BIOS' circadian lighting expertise aids LED efficacy, color consistency and melanopic ratios

LED maker Lumileds LLC of San Jose, CA, USA has announced the immediate availability of its new LUXEON SkyBlue LED human-centric lighting solution. In partnership with NASA-spinoff BIOS (Biological Innovations and Optimization Systems LLC) of Carlsbad, CA, Lumileds has engineered a circadian lighting solution that delivers what are claimed to be superior melanopic ratios at comfortable correlated color temperatures (CCTs) — 3000K, 3500K and 4000K — with high efficacy and uniformity at low solution cost. Consisting of LUXEON SkyBlue and white LUXEON 3030 HE Plus LEDs, the new solution eliminates the challenging technical and spectral analysis and engineering and enables a single-channel driver to support circadian lighting.

LUXEON SkyBlue is specified by CCT for melanopic ratio, CRI and R9, efficacy and luminous flux and produces light within a 3 MacAdam ellipse space. Lumileds says that its unique knowledge eliminates the complex analysis, binning and supply chain issues that typically challenge a luminaire manufacturer and add to the cost and complexity of developing a solution.

"Integrating BIOS Lighting's expertise in circadian lighting spectral requirements with Lumileds expertise in LED and solution development enabled this breakthrough approach to luminaire development," says Willem Sillevis-Smitt, Lumileds' head of marketing. "Our direct access to the full production from our factories and the detailed information we have about every LED allows us to dramatically simplify engineering for OEMs. LUXEON SkyBlue is simply the fastest, simplest and most cost-effective path to producing a circadian lighting luminaire," he claims.

"As the science has progressed, HCL (human-centric lighting) has quickly risen in importance for both lighting designers and end-users," notes Mark McClear BIOS Lighting's chief operating officer. "Only spectrally optimized circadian lighting delivers the specific and measurable physiological impact that is desired in schools, offices, factories, health-care settings, and similar locations."

www.bioslighting.com
www.lumileds.com/LSB

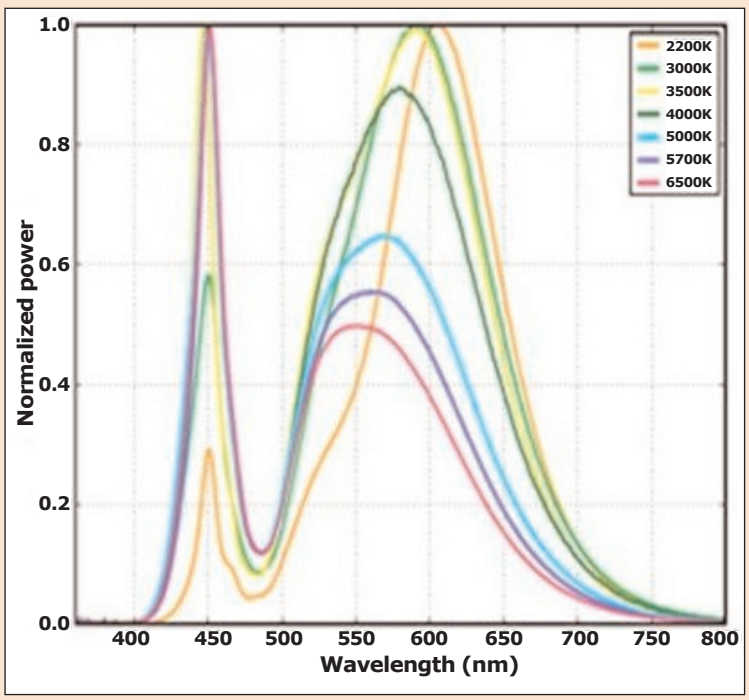
Lumileds launches LUXEON 3030 HE Plus Horticulture

Broad spectrum white LEDs are widely available

Lumileds has announced immediate high-quantity availability of its LUXEON 3030 HE Plus Horticulture LEDs. Based on its 3030 LED portfolio and characterized for horticulture, the new options offer high-PPF/W broad-spectrum white light that enable grow lights which are productive and economical, says the firm.

"In horticulture applications growers are looking for time-tested, top performance and reliability; the LUXEON 3030 HE Plus Horticulture delivers the photons that enable consistent and high growth output with the highest of efficiencies," says product manager Mei Yi.

The new LEDs are engineered for robust sulfur protection — critical for long and stable lifetime in warm and humid environments — and are specified for horticulture at 65mA and T_j= 25°C with correlated color temperatures (CCTs) ranging from 2200K to 6500K and a color rendering index (CRI) of 70, 80 or 90. When matched with LUXEON Deep Red and Far Red options, a complete horticulture illumination solution is at hand.



Available now in manufacturing quantities, the LUXEON 3030 HE Plus Horticulture offers a 0.1V forward voltage bin, quadrant color bin inside 3SDCM, and a maximum drive current of 480mA.

www.lumileds.com/3030Horticulture

evatec process systems

EDITION 5

LAYERS

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

Stefan Seifried, Head of BU Optoelectronics

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Vector to work with QD Laser in BLOODLINE project

Innovate UK and Japan's NEDO collaborate on commercializing PCSELs for 3D metal laser printing

The project BLOODLINE (Bright Laser diOdes fOr aDvance metaL addItive maNufacturing systEms) is part of the first funding of UK Government agency Innovate UK to be allocated to a collaborative research initiative with Japan. The £1.5m project will commercialize the all-semiconductor photonic-crystal surface-emitting laser (PCSEL) technology of Vector Photonics Ltd (which was spun off from Scotland's University of Glasgow in March 2020) for 3D metal laser printing. The 3D metal laser printing market is forecasted to quadruple to $10bn by 2025, according to the report 'Additive Manufacturing with Metal Powders 2019' from SmarTech Analysis.

The project is guided by the Eureka Network international development program, in conjunction with Innovate UK's Japanese counterpart, the Japan National Research and Development Agency's New Energy and Industrial Technology Development Organization (NEDO).

Vector Photonics is leading the collaboration, which is supported by Japan-based laser epitaxy firm QD Laser Inc (which was spun of from Fujitsu Laboratories Ltd). Device reliability testing is provided by the UK's Compound Semiconductor Applications (CSA) Catapult. A leading Japanese industrial equipment manufacturer will assess the generic laser chips for production.

"The opportunity for Vector Photonics to lead the UK side of BLOODLINE, with Japan, is an honour," says Vector Photonics' chief technology officer Dr Richard Taylor. "Professor Richard Hogg, chair of Vector Photonic's Advisory Board, and I are the co-inventors of the PCSEL technology," he adds. "We have both participated in research at the University of Tokyo and both lived in Japan. My research post was under professors Nakano and Tanemura. Professor Hogg's research was in professor Arakawa's Laboratory and at NTT Basic Research Laboratories in Tokyo. We have also already been involved in research projects with QD Laser Inc. All this has given us the essential collaborative experience, critical to winning this project."

www.qdlaser.com
www.vectorphotonics.co.uk

Lynred invests €2.8m in small-pixel-pitch near-IR detectors

Lynred of Palaiseau (near Paris) and Veurey-Voroize (near Grenoble), France, which designs and makes infrared (IR) detectors for aerospace, defense and commercial applications, is investing €2.8m ($3.37m) in developing next-generation infrared (IR) detectors. Lynred will receive €900,000 ($1.08m) in R&D funding from the French government as part of a program to revamp the microelectronics ecosystem in France.

In developing the next generation of small-pixel-pitch near-infrared (NIR) detectors, Lynred aims to establish a new market sector in France. The national ecosystem aims to address demand for IR imaging in industrial process control — such as sorting plastics — and for the spectral imaging market.

As well as creating about 20 new jobs, Lynred's R&D program also responds to the imperatives of France's industrial renewal strategy by bringing selected development and production steps back to the nation, reinforcing the internal supply chain.

"Our core mission is to supply state-of-the-art infrared detectors at the international level, while supporting an independent and sovereign infrared industry in France," says CEO Jean-François Delepau. "The investment we will be making here will drive us forward in near-infrared technology and support the French government's target of strengthening the nation's strategic infrared detector industry."

The small-pixel-pitch NIR detectors that Lynred will develop will be highly sensitive, fast-frame-rate devices that deliver the accuracy and throughput required for industrial process control scenarios.

Lynred says that the R&D program showcases its innovation at a time when the government is revamping its strategy roadmap for the electronics industry. This includes a recent amendment (enacted by France's deputy economy minister Agnès Pannier-Runnacher on 4 March) to a previous government initiative involving the Nano 2022 program. Each underscores how strategic the electronics industry is to the French economy and its industrial sovereignty. Lynred says it has played an active role in developing the nation's electronics industry roadmap and bringing artificial intelligence into the industry's key technologies.

France's economic stimulus package 'Plan France Relance' is administered by the nation's Ministry of the Economy and Finance. It includes financing instruments to support specific industries deemed strategic to the nation's economic recovery and industrial sovereignty. Microelectronics is one of these industries. This stimulus package aims to make France's industrial economy more competitive by modernizing production facilities and securing the supply chain.

www.lynred.com

Fraunhofer IAF researches compact on-chip photon pair sources for quantum technologies

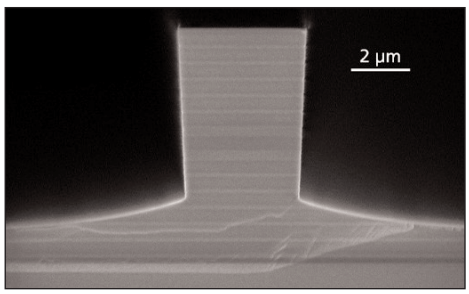
QuoAlA project targets quantum entangled photon pair source at telecom wavelength based on AlGaAs Bragg reflection waveguides

Fraunhofer Institute for Applied Solid State Physics (IAF) of Freiburg, Germany has started a project on compact on-chip sources for entangled photons, which are an important component for the realization of industrial quantum technology applications.

In the project named QuoAlA ('Quantum entangled photon pair source at telecom wavelength based on AlGaAs Bragg reflection waveguides'), scientists are researching waveguides based on aluminium gallium arsenide (AlGaAs) as sources for generating entangled photons. AlGaAs enables a particularly compact design and chip integration.

The project started in February and is funded by the German Federal Ministry of Education and Research (BMBF) within the framework program of the Federal Government 'Quantum technologies — from basic research to market' as WiVoPro (Scientific Preliminary Project) (FKZ: 13N15480). The aim of these preliminary projects is to study scientific issues with regard to future industrial applications in photonics and quantum technology. They are intended to complement existing research funding and build a bridge between basic research and industry-led collaborative funding.

Applications of quantum technology are based on various quantum phenomena and physical laws to which elementary particles are subjected. These include the effect of entangled photons, on which promising concepts for high-precision sensor technology and secure quantum communication are based. To bring these technologies into application, compact and efficient sources of entangled photon pairs are needed that can be integrated into photonic circuits.



Simulated profile of a Bragg reflection light wave mode in an AlGaAs Bragg reflection ridge waveguide.

The main components of quantum photonic systems (such as mirrors, beam splitter and phase shifters) can now all be realized in integrated form. However, this does not yet apply to the light sources and detectors that are required as well. "Our goal is now to integrate all the functions needed for quantum communication, i.e. the generation, manipulation and detection of single and entangled photons, into just one chip," says Dr Thorsten Passow, project manager at Fraunhofer IAF. With the project QuoAlA, the researchers are taking a first step with regard to light sources.

AlGaAs Bragg reflection waveguides as photon pair sources

The focus of QuoAlA is on fundamental research of AlGaAs-based photon sources and their epitaxial fabrication. The aim is to generate photon pairs with a high quality of entanglement at an exactly defined wavelength. The target wavelength is 1550nm, i.e. within the telecom range (1500–1600nm).

AlGaAs is a promising material for photon pair sources for several reasons. For example, it has nonlinear properties. In a material with nonlinear properties, a photon can spontaneously split into two photons at high light intensity due to an optical effect. Such light particle pairs can be quantum mechanically entangled.

Potential for particularly compact design

Furthermore, AlGaAs Bragg reflection waveguides allow the integration of other optical and electronic components at the chip level. "A unique feature of the technology used in the project QuoAlA is the potential to integrate a pump laser diode," says Passow. "This makes a particularly compact design possible," he adds. Reducing the size, weight and power of the components would satisfy an essential requirement for the realization of practical applications.

For use as a source in telecommunications, it must be possible to adjust the wavelength of the photons very precisely because the wavelength spacing of the channels is less than 1nm. The wavelength of the generated photons depends very sensitively on the epitaxially produced layer structure of the waveguides. Therefore, the project focuses on the accuracy of the epitaxy of AlGaAs-based Bragg reflection waveguides with regard to the wavelength of the generated entangled photons.

The AlGaAs waveguide structures in the project benefit from Fraunhofer IAF's decades of experience in the epitaxy of high-quality GaAs-based heterostructures as well as in process technology for the realization of waveguide structures in various III-V semiconductor materials. In addition, the scientists are using software for the optical simulation of Bragg reflection waveguides that they previously developed in the project NESSiE ('Nonlinear waveguides for quantum entangled sources at telecom wavelength'), which ran during 2019–2020 and was coordinated by the Fraunhofer Centre for Applied Photonics CAP.

www.iaf.fraunhofer.de/en/researchers/optoelectronic-devices/quoala.html

NUBURU establishes advisory board

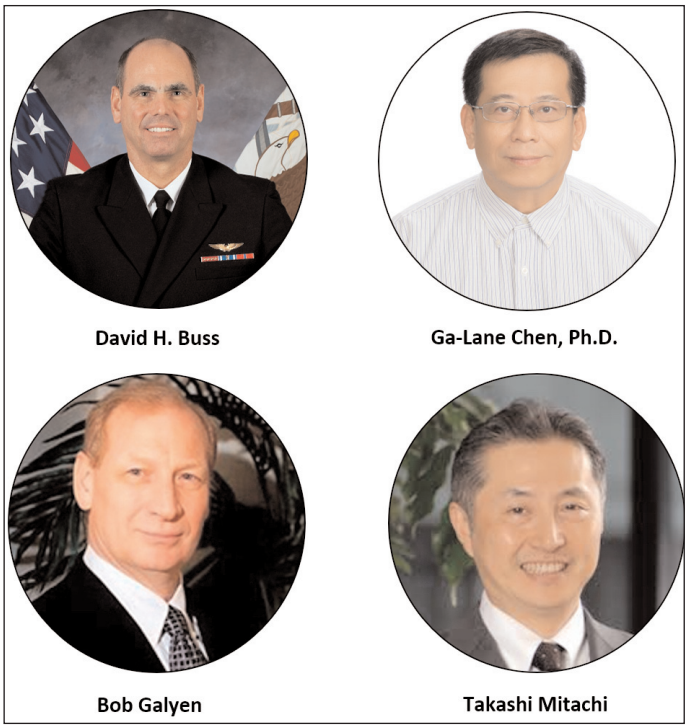
Experts across energy storage, defense, and consumer electronics to provide strategic insight across key markets

NUBURU Inc of Centennial, CO, USA, which was founded in 2015 and develops and manufactures high-power, high-brightness industrial blue lasers, has formed an advisory board, whose strategic insight should enable it to better understand and support customers and strengthen its market position.

Bringing global expertise across battery and e-mobility, consumer electronics, 3C and defense to guide NUBURU's business and product development, the founding members are as follows:

● Vice Admiral (ret.) David Buss held numerous leadership positions throughout his 37-year career in the US Navy. Most recently he served as the Commander, Naval Air Forces (the Navy's 'Air Boss'), where he had global responsibilities for the operational readiness of the Navy's aviation force. He is currently CEO of Los Angeles-based data storage technology company OpenDrives Inc. He was previously president of Cubic Global Defense Inc (a unit of Cubic Corp), where he led all aspects of its global military training business. Admiral Buss earned his bachelor's degree in Physics from the US Naval Academy and is a graduate of the Navy's Nuclear Power Training program.

● Dr Ga-Lane Chen is currently the chief technology officer & chief information officer of Foxconn. He manages the global R&D on optics, lens, mobile phone camera, nano-technology, robot, automation, autonomous driving, and biomedical technology. He also oversees the firm's investment in high-tech companies from funding to IPO, including Invensense, GoPro, Berkeley Light, Habana Labs (2.2 Billion merged by Intel). Prior to Foxconn, Chen worked at Varian, Komag, Hitachi Metal, and Seagate. He also founded two firms: Oerdex (1989, magnetic media), GLC Communication (1999, fiber optics, acquired by Foxconn in 2000). Chen holds a BS in Mechanical Engineering from National Taiwan University and a Ph.D. in Materials Science/Electrical Engineering from the University of Minnesota. He also holds 2094 granted patents (US 454, China 828, Taiwan 812).



NUBURU's new advisory board.

● Takashi Mitachi is currently a senior advisor and was a co-chairman of the BCG Japan office from 2005 to 2015 and was a member of BCG's Worldwide Executive Committee from 2006 to 2013. He was vice chairman of the Japan Association of Corporate Executives and has been a chief executive director for the Ronald McDonald House Charities Japan. He currently serves as an outside director to several Japanese companies including DMG Mori Co Ltd, Tokio Marine Holdings, Rakuten Inc, and Unicharm Corp. He is also a professor at the Graduate School of Management, Kyoto University. Mitachi holds a Master of Business Administration with high distinction (Baker Scholar) from Harvard Business School and a Bachelor of Arts in American literature from the University of Kyoto.

● Robert (Bob) L. Galyen is recognized as one of the top executives in the battery energy storage world and science/engineering-based communities. His former positions as CTO of CATL (the world's largest battery maker), chairman of SAE International Battery Standards Steering Committee, SAE Fellow, chairman emeritus & CTO of NAATbatt International, have given him a unique leadership perspective in the global battery industry. He also holds patents and publications and participates on multiple BODs (boards of directors and TABs (technical advisory boards). His nearly 50 years of international work experience has given him a visionary perspective on world-wide business, says NUBURU, making him uniquely qualified as a global energy storage and scientific/engineering community thought leader.

"The understanding of market trends and customer perspectives will be key in enhancing our market approach and strategic direction moving forward," reckons NUBURU's CEO Dr Guy Gilliland.

www.nuburu.net

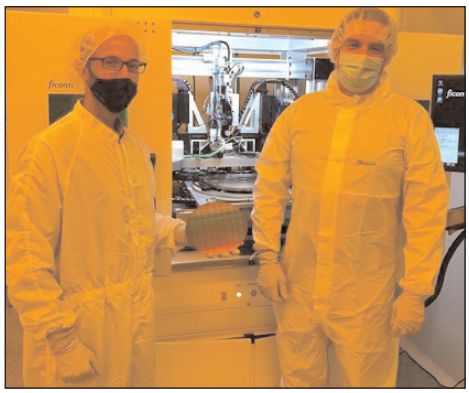
VLC Photonics receives new wafer-level test system from ficonTEC

PIC testing to aid customers' product development

To support the growth of the photonic integrated circuit (PIC) market and be able to timely serve the scaling of its customers when moving to engineering and pilot production stages, in November PIC design house VLC Photonics S.L. (a spin-off of Spain's Universitat Politècnica de València) took delivery of a new wafer-level test (WLT) system from ficonTEC Service GmbH of Achim, Germany, which provides automated packaging and testing machine systems for high-end optoelectronic components and integrated photonic devices. The WLT tool is now in production in VLC's UPVfab cleanroom.

The WLT delivered to VLC incorporates dual alignment of optical pick-ups that can be fast-actively aligned to optical I/O ports at on-wafer PIC devices. The addition of the system to VLC's in-house portfolio of equipment and tools for PIC characterization and testing will complement the services offered up to now on a die level.

Acquired last November by Tokyo-based Hitachi High-Tech group, VLC offers services for organizations seeking to exploit the advantages of photonic integration. These services now cover all aspects of PIC development, from initial consultancy to design, manufacturing, test and packaging. For this purpose, VLC has grown a global portfolio of customers and additionally partnered with foundries and packagers to serve a broad spectrum of applications in communications, sensing, quantum optics, biophotonics, instrumentation and other sectors.



VLC Photonics' CTO David Domenech and ficonTEC production engineer Tim Kluge after installation of the new WLT system.

As for its other services, the new WLT capability can be offered for a comprehensive range of on-wafer component types, irrespective of the material system. This includes integrated photonics-enabled elements and devices based on the silicon-on-insulator (SOI), silicon nitride (SiN) and indium phosphide (InP) material systems, as well as components based on planar lightwave circuits (PLCs). Component size can lie anywhere from 2mm x 2mm to 20mm x 20mm, while the wafer-handling system in the WLT is compatible with single dies and wafer sizes from 3" up to 12".

Having already worked with several Fortune 500 and equivalent corporations, as well as emerging start-ups and researchers, VLC's CEO Iñigo Artundo foresees particular benefits emerging through the addition of the WLT system: "Back-end packaging and test has always been acknowledged to be the main bottleneck when industrializing PIC-based products, and most of our developments and acquisitions in recent years are designed to help our customers succeed in facing the challenges associated with PIC testing," he says.

"We have worked intensively on our WLT capability over the last two years, and we are really excited to see this technology finding acceptance amongst commercial PIC service sector leaders such as VLC Photonics," comments ficonTEC's CEO Torsten Vahrenkamp. "Notwithstanding, this is just a momentary snapshot of where we are going with the WLT systems, and we are continuing to collaborate with leading partners in specific technology areas to provide efficient mixed-signal electro-optical testing and high-volume capability in the near-term."

www.vlcphotonics.com
www.ficontec.com

IQE reaches power and reliability milestones with IQDN-VCSELs for long-wavelength sensing on 150mm GaAs

Tier-1 customer-funded development programs to optimize technology for qualification in future 3D sensing applications

Epiwafer foundry and substrate maker IQE plc of Cardiff, Wales, UK has achieved key power and reliability milestones for its IQDN-VCSEL vertical-cavity surface-emitting laser technology for advanced sensing applications at longer wavelengths (1100–1600nm) on 150mm gallium arsenide (GaAs) substrates. IQE is currently supplying wafers to tier-1 partners and collaborating with them to refine the technology for next-generation advanced sensing applications.

Currently, the longest achievable wavelength for GaAs-based VCSEL technology is limited to wavelengths of ~1100nm. It is desirable to raise this to >=1380nm, allowing the technology to be applied to below-screen (BOLED) consumer applications such as facial recognition systems for mobile devices. There is significant customer demand for technologies like these because they enable new applications and improve device performance while at the same time reducing cost, says IQE. Additionally, the move to longer wavelengths can make it even simpler to safely deliver emerging technologies, such as light detection & ranging (LiDAR) for automotive applications.

IQE has addressed demand for a 150mm GaAs-based long-wavelength VCSEL with its IQDN-VCSEL technology. IQE has demonstrated that this dilute-nitride-based technology delivers VCSELs with ~1mW per emitter, each having more than several hundred hours of reliability. This has met the development requirements for multiple tier-1 3D sensing customers. Because IQDN-VCSEL is based on the GaAs materials system, it offers a longer-wavelength 'drop in' solution for IQE's customers, enabling them to use the same equipment and processes that were developed for shorter wavelengths to achieve longer wavelengths.

IQE is currently engaged in customer-funded development programs with key tier-1 customers to refine the technology for qualification in future 3D sensing applications. Coupled with its IQGeVCSEL 150 technology, IQE says that it has demonstrated a path to the volume manufacture of long-wavelength VCSELs on 150mm and ultimately 200mm substrates.

"IQE has been able to rapidly develop an offering that exceeds what was previously possible, and our partner engagements are a testament to the potential for this technology for next-generation 3D sensing applications," says chief technology officer Dr Rodney Pelzel. "IQDN-VCSEL technology is a key component of a unique VCSEL portfolio that enables IQE's customers to serve a diverse range of high-volume market opportunities."

www.iqep.com

II–VI Inc unveils VCSEL flood illuminator modules for driver and occupancy monitoring systems

AEC-Q102 automotive certification expected in Q2/2021

II–VI Inc of Saxonburg, PA, USA has launched vertical-cavity surface-emitting laser (VCSEL) flood illuminator modules for driver and occupancy monitoring systems in vehicles.

US and European transportation safety regulators are increasingly recommending or requiring driver and occupancy monitoring systems in vehicles, spurring the demand for next-generation 2D and 3D infrared cameras designed with higher-performance infrared illuminators. II-VI says that its new VCSEL flood illuminator modules emit higher optical power and with a narrower spectral width than infrared LEDs currently used in existing driver monitoring systems, enabling substantial improvements in system performance. The infrared light emitted from II–VI's flood illuminator modules can be modulated to frequencies greater than 100MHz, making them suitable for 3D time-of-flight (ToF) cameras for driver and occupancy monitoring.

"Our new VCSEL flood illumination modules integrate VCSEL chips, photodiodes and diffuser optics, achieving a greater level of vertical integration and value for our customers," says Dr Julie Eng, senior VP, Optoelectronic & RF Devices business unit. "We leveraged our in-house 6-inch gallium arsenide technology platform to successfully scale production of our VCSEL arrays for consumer electronics, and we look forward to ramping production of flood illumination modules for in-cabin sensing in automotive as the demand grows."

II-VI says its VCSELs achieve very high power-conversion efficiency and are available with up to 2.5W or 5W of continuous power output. The flood illuminator modules are available in surface-mount packages integrated with diffuser optics with either a narrow (60° x 45°) or wide (110° x 85°) field of view. The modules are expected to be AEC-Q102 certified for automotive applications in second-quarter 2021.

www.ii-vi.com/product/940-nm-vcsel-flood-illumination-module

POET reports progress on Super Photonics Xiamen JV

Permanent facility to supplant temporary Sanan IC facilities by end-2021

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 reported progress made on Super Photonics Xiamen (SPX), its joint venture with Sanan Integrated Circuit Co Ltd of Xiamen City, Fujian province (a subsidiary of Sanan Optoelectronics, China's first 6-inch pure-play compound semiconductor wafer foundry).

Since signing the definitive joint venture agreement on 21 October, progress has been made in forming, locating, staffing and equipping SPX, whose mission is to create an assembly, test and sales operation for the production of optical engines based on the POET Optical Interposer platform. Specifically, POET has:

- completed official registration of Super Photonics Xiamen;
- nominated and appointed POET and Sanan IC members to the SPX board of directors;
- appointed a general manager, chief financial officer, director of R&D, two engineering and one general administrative staff (and five additional engineering staff have been made offers for appointment in April);
- completed temporary cleanroom and office facilities of 5000ft^2 (co-located with Sanan IC in Xiamen) and committed to completion of a permanent 15,000ft^2 facility in a high-tech industrial park outside Xiamen by the end of the year;
- ordered key capital equipment for delivery, installation and qualification in April-May; and
- received investment from Sanan IC of about US$5m to cover initial operating and capital expenditures.

Representing POET on the five-member SPX board is president & general manager Vivek Rajgarhia. Recruited and nominated by POET for the second position on the board is Dr Xiaozhong Zheng, general manager of SPX and former senior executive in the photonics industry (including, most recently, W.L. Gore, Huawei and Oclaro). Sanan IC has appointed its chief technology officer Dr Weizhong Sun as chairman and member, and Ruyan (Rita) Zheng of the Sanan Group corporate office as board member and part-time chief financial officer of SPX. With unanimous support of the board and both partners to the JV, Dr Yong-Zhen Huang, professor of the Institute of Semiconductors of the Chinese Academy of Sciences (CAS) and the University of the Chinese Academy of Sciences, has been appointed as the independent member on the board. Sun has designated Rajgarhia to serve as vice chairman.

Key initial appointments to the management team of SPX also include Dr Yonghong Hu (formerly with HiSilicon, Huawei and Oclaro) as head of R&D. Under the direction of general manager Zheng, SPX's business plan calls for the recruitment and appointment of an additional 25 personnel, which should bring the headcount to about 30 by the end of 2021.

"Progress on the formation of SPX has been remarkably fast compared to the normal time that it takes to get a complex joint venture with a foreign owner officially registered in China, especially with the travel constraints accompanying the COVID-19 pandemic," reckons Rajgarhia. "The benefits to POET of this joint venture are notable, as it provides a means for POET to bring products based on the Optical Interposer platform to market with a partner that is able to scale production quickly and efficiently," he adds. "We have received remarkable support from Sanan IC and from key staff in POET's Shenzhen office to prepare the SPX operation for what is expected in the coming months, including qualification of equipment and processes, assembly & testing of several product prototypes, establishing good initial customer relationships and making preparations for scaling production early next year," Rajgarhia comments.

www.sanan-ic.com
www.poet-technologies.com

II–VI presents new product and technology capabilities

At the SPIE Photonics West Digital Forum and BiOS Digital Marketplace 2021 (6–11 March), II–VI Inc of Saxonburg, PA, USA showcased its portfolio of products and technology capabilities that are enabling next-generation photonics applications in diverse markets such as materials processing, life sciences, automotive, consumer electronics, and communications.

Recent new product introductions announced by II–VI included the following:

- 1060nm seed laser in a 3-pin miniature package for pulsed fiber lasers;
- double-junction vertical-cavity surface-emitting laser (VCSEL) arrays;
- VCSEL flood illuminator modules for in-cabin monitoring in automotive;
- multi-wavelength laser module product line for life sciences.

Also during Photonics West, II–VI participated in a special industry event focused on the business side of photonics: Dr Julie Sheridan Eng, senior VP & general manager, Optoelectronic and RF Devices business unit, gave a presentation in the session 'Applications of sensing and imaging solutions'.

http://spie.org/photonics-west.xml
www.ii-vi.com

POET's board authorized to consolidate shares

Firm targets additional listing on NASDAQ Capital Market and/or graduation to TSX Exchange

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 — says that, in a Special Meeting held virtually on 19 February, its shareholders authorized the board of directors to consolidate issued and outstanding common shares (on the basis of one post-consolidation common share for a number of pre-consolidation common shares ranging between two and 14).

During the meeting, chairman & CEO Dr Suresh Venkatesan drew attention to the increase in the firm's stock price and its current liquidity resulting from the recently completed brokered private placement and exercise of warrants.

Consolidation of the issued and outstanding common shares will only take place at a time when the board deems appropriate and in the best interest of the company. Venkatesan reiterated that the purpose of the consolidation was in furtherance of the firm's goal to seek an additional listing on the NASDAQ Capital Market and/or a graduation to the TSX Exchange in order to gain access to a larger pool of shareholders, including additional institutional investors.

POET reports on financing activities

POET has added about C$24m (US$18.8m) to its cash balance as a result of the closing of a brokered private placement, warrants and stock options exercised since 1 October.

Exercise of options and warrants

The firm has received about C$10m from the exercise of options and warrants since 1 October. Approximately C$2.7m (US$2.1m) came from the exercise of about 7 million options by former employees and directors at prices ranging from C$0.28 to $0.52. About C$7.3m (US$5.7m) came from the exercise of warrants from its public offering in November 2016 in which 34.8 million units, consisting of one common share and one common share purchase warrant with an exercise price of C$0.52 per share, were placed.

Most of those warrants remained unexercised until recently. From 2 November 2016 through 30 September 2020 only 2.8 million had been exercised. However, since the start of fourth-quarter 2020, warrant holders have exercised about 14 million of the 32 million warrants outstanding, with about 18 million still unexercised. The firm believes the outstanding warrants are held mainly by Canadian investors. If fully exercised, the remaining warrants would result in proceeds of about C$9.4m (US$7.3m) being realized by the firm. If unexercised, the warrants will expire on 2 November.

Warrants associated with convertible debentures

POET also issued warrants in connection with its private placement of 2-year convertible debentures in the period April through September 2019. Holders of the debentures have the option of redeeming for cash or converting into units consisting of one common share and one common share purchase warrant. The common share purchase warrant forming a part of such unit has an exercise price of C$0.50 per share. Approximately C$5m (US$3.75m) worth of the debentures were issued, representing about 12.5 million warrants that would be issuable upon conversion into units.

Since being issued, the firm's debt has been cut by C$750,000, resulting in the issuance of 1.875 million shares and an equal number of warrants. Assuming that all of the remaining debentures are converted and the associated warrants exercised, the remainder of the debt would be extinguished, and the firm would issue an additional 10.6 million units. Upon exercise of the associated warrants, POET would receive an extra C$5.3m (US$4.1m). Depending on the purchase date, holders of the debentures have 2–7 months remaining to convert or redeem the convertible debentures.

www.poet-technologies.com

POET's LightBar-C targets new markets for co-packaged optics and optical sensing

Optical Interposer platform extended for C-band lasers

POET Technologies has extended its Optical Interposer into new applications and markets with LightBar-C, a fully integrated, multiplexed light-source for optical computing chipsets and sensing applications.

The Optical Interposer platform has been extended and validated with the intrinsic features to support conventional-band (C-band) and long-band (L-band) lasers that produce light in the 1530–1625nm frequency range. POET has designed, developed and demonstrated cooled lasers for the Optical Interposer platform with up to 90mW of power operating at room temperature. In addition, the firm has designed and demonstrated a dense wavelength division multiplexer (DWDM) embedded in the Optical Interposer waveguide layer that allows channel spacings of 200GHz, providing the high density and broadband requirements needed for high-performance optical sensing and co-packaged optics (CPO) applications, such as optical computing chipsets for artificial intelligence (AI).

The firm's first product to incorporate all of these features is the POET LightBar-C, which includes integrated spot-size converters that minimize coupling losses and increase power efficiency of components, such as multiplexers and detectors. The product provides low-loss fiber and free-space coupling, all specifically developed for highly integrated solutions within the C-band frequencies. The LightBar-C also utilizes a versatile and integrated laser source with multiple wavelengths (from 2 up to 8) multiplexed in the C-band.

The optical bandwidth in the C-band is in the 'eye-safe' region, which makes it suitable for free-space sensing applications. Consequently, C-band light solutions are expected to be foundational to the next generation of light detection & ranging (LiDAR) solutions where high sensitivity, high power, reduced atmospheric influence and eye safety are presumed to be essential requirements.

"The mega trends of cloud computing, 5G communications and the rapid growth of artificial intelligence are spawning numerous applications and driving increasing volume demands for both high-performance lasers and integrated photonics solutions. These applications require a step-function improvement in packaging and scalability," says chairman & CEO Dr Suresh Venkatesan. "Current photonics products are still assembled and tested using conventional and esoteric packaging technologies that ultimately limit production scalability. POET's Optical Interposer addresses key integration and scalability challenges with a unified wafer-scale hybrid integration platform that seamlessly merges the benefits of planar lightwave circuits (PLCs) and electrical interposer functionality for co-packaging electronics and optics within a single chip-scale package."

As with previously announced Optical Interposer-based solutions, POET's unique method of hybrid integration enables products with small form factors and high performance. The firm's wafer-scale hybrid integration approach is said to simplify the manufacturing, assembly and testing of the passively assembled optical sub-system while simultaneously maximizing power efficiency with reduced coupling losses through the complete link.

The firm says that the extensibility to the C-band frequency range consisting of 15xx wavelengths of light further exemplifies the value of its hybrid platform approach, as the same fundamental Optical Interposer manufacturing process and design kits can be utilized to deliver solutions across a wide range of applications.

www.poet-technologies.com

Lumentum launches five-and six-junction 940nm and 905nm VCSEL arrays

Multi-junction VCSEL arrays targeted at consumer, automotive LiDAR and other 3D sensing applications

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 launched high-power and high-efficiency five-and six-junction vertical-cavity surface-emitting laser (VCSEL) arrays for consumer, automotive light detection & ranging (LiDAR) and other 3D sensing applications.

With LiDAR and 3D sensing expanding into new applications in consumer electronics, automotive and industrial markets, new functionality is driving the need for higher power and higher efficiency from smaller-form-factor devices. Lumentum says that its five- and six-junction VCSEL arrays enable much lower power dissipation, very high slope efficiencies and record optical peak powers compared with existing devices. Optical powers exceeding 2W per individual VCSEL emitter have resulted in over 800W of peak power from a compact 1mm^2-sized VCSEL array. The peak optical power, low thermal dissipation and small die size of the new multi-junction VCSELs arrays are important to extending their use to high-performance all-solid-state medium- and long-range LiDAR.

"Automotive, consumer and industrial customers increasingly need higher-performance VCSEL arrays to drive increased functionality and adoption of LiDAR and 3D sensing enabled products," says Dr André Wong, VP of 3D Sensing product line management. "Our latest multi-junction VCSEL arrays continue our long history of pioneering innovative optical solutions in close collaboration with customers," he adds. "These new products leverage the well proven high-volume, 6-inch wafer supply that we established more than four years ago."

Lumentum's multi-junction VCSEL arrays emit at 940nm and 905nm and are manufactured on the same production lines as existing high-volume VCSEL array products serving the consumer electronics market. In addition to these new high-power VCSEL array illuminators, Lumentum also offers a wide variety of optical solutions for 3D sensing, automotive and LiDAR applications. These include VCSEL solutions for vehicle in-cabin monitoring, high-performance gallium arsenide (GaAs) and indium phosphide (InP) edge-emitting laser chips for 3D sensing and LiDAR, and 1550nm narrow-linewidth distributed Bragg reflector (DBR) diode lasers for long-range frequency-modulated continuous-wave (FMCW) coherent LiDAR.

Lumentum showcased its product line of lasers and optics for 3D sensing and LiDAR at the SPIE Photonics West 2021 Digital Forum (6–11 March), along with giving several technical presentations and participating in industry panel discussions.

www.lumentum.com

BluGlass presents RPCVD laser paper at Photonics West

Firm showcasing laser product development and custom GaN epi

At the virtual SPIE Photonics West 2021 conference (8–11 March), BluGlass Ltd of Silverwater, Australia — which develops remote-plasma chemical vapor deposition (RPCVD) — showcased its latest laser diode product development progress and custom GaN epitaxy services with customers and industry participants.

RPCVD is a low-temperature, ammonia-free approach to GaN-based epitaxial growth, with advantages not possible with conventional metal-organic chemical vapour deposition (MOCVD), it is claimed.

Also at the virtual conference, head of epitaxy Dr Josh Brown presented a new paper 'InAlGaN based ridge-guide laser diodes using RPCVD for enhanced performance' outlining recent laser diode development work, utilizing both MOCVD technology and low-temperature RPCVD technology to enhance the performance of laser diodes.

The paper highlights the benefits of BluGlass' proprietary RPCVD technology for the manufacture of both traditional and novel structure laser diodes. It features the firm's latest MOCVD laser diode development results and progress on the development of enhanced laser diode structures utilizing RPCVD.

BluGlass says that its RPCVD technology offers laser diode makers a number of performance and cost advantages for the growth of high-brightness GaN laser diodes, including higher-performing devices.

High-brightness GaN laser diodes are used in a growing number of applications including industrial lasers (cutting and welding), scientific applications, automotive, and general lighting and displays.

BluGlass says that it continues to advance its MOCVD standard laser diode product suite ahead of its first product launches (405nm and 420nm laser diodes) in early 2021. It also continues to advance its RPCVD low-resistivity p-GaN and tunnel-junction laser diode designs for enhanced laser products.

http://spie.org/photonics-west.xml
www.bluglass.com.au/laser-diodes

ams setting up imaging center of excellence in Rochester

R&D and design to boost sensor-enabled consumer imaging expertise

High-performance sensor designer and manufacturer ams AG of Premstaetten, Austria is establishing an imaging center of excellence producing consumer image sensors and product validation to support key US customers from the Riverwood Tech Campus in Rochester, NY, USA. The new R&D and design center aims to continue the tradition of consumer imaging innovation into the sensor-enabled era.

A concentration of photonics expertise in R&D in the Rochester area means that there is talent base to create a center of excellence for optical imaging, notes ams. The firm is keen to expand its engineering capacity, drawing on its global position in consumer imaging and sensing in the smartphone market and the regional heritage and ecosystem in imaging and photonics.

"Rochester is the perfect choice for ams to expand its research and development in the transformative fields of consumer imaging and photonics, to create design innovations that make an impact on our world," says David Sackett, senior director R&D, Consumer Image Sensors at ams and the site manager. "We look forward to collaborating with institutions such as the NYS American Institute for Manufacturing for Integrated Photonics, and renowned local universities and institutes."

The Rochester location is in the renovated Riverwood Tech Campus near the Genesee River, and will be used for collaboration with customers and partners.

ams' says that its position in optical sensing is built on its broad portfolio for 3D sensing including vertical-cavity surface-emitting laser (VCSEL) illumination, high-quality display management including behind-OLED (BOLED) sensing, micro-scale proximity sensing, spectral and bio-sensing, and other optical applications. Continuous R&D investments allows it to drive innovation in new optical and optical/sensor module technologies, the firm adds.

Going forward, ams expects that camera-enhancing technologies to offer adoption opportunities as camera-related features will drive key value propositions for smartphone users. This includes areas such as automatic white balancing (AWB), laser-detect autofocus (LDAF)/1D time-of-flight (ToF), wide-range flicker detection and augmented reality (AR)-oriented camera support functions.

www.ams.com

Rockley selects Synopsys for silicon photonics design and verification

Rockley to use Synopsys software to design and optimize devices, create PDKs and tape-out photonic integrated circuits

Synopsys Inc of Mountain View, CA, USA — which provides electronic design automation (EDA) software, semiconductor IP and services for chip and electronic system design — says that integrated optical chip and module supplier Rockley Photonics of Oxford, UK and Pasadena, CA, USA has adopted its solutions to accelerate the design and verification of silicon photonics for sensing and datacom applications. Specifically, Rockley is using tools from Synopsys' Photonic Solutions platform, including OptoCompiler, OptoDesigner, OptSim Circuit, RSoft Photonic Device Tools and IC Validator. Rockley plans to use Synopsys solutions to design and optimize photonic devices, create process design kits (PDKs) and tape out photonic ICs.

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

Rockley was an early adopter of Synopsys' OptoCompiler tool following its commercial launch in September. OptoCompiler is said to be the first unified electronic and photonic design platform, combining mature and dedicated photonic technology with Synopsys' industry-proven custom and analog-mixed signal tools to enable engineers to produce and verify complex photonic IC designs quickly and accurately.

"Rockley's unique photonic chipset technology with silicon photonics at its core is driving the growth of integrated optical components in healthcare, machine vision and data communications," says Rockley's chief executive Andrew Rickman. "The PDA platform Rockley has created by utilizing OptoCompiler allows our engineers to define, simulate, lay out and verify photonic ICs quickly and efficiently to meet our quality and schedule goals. Synopsys' technical support has been instrumental in ensuring Rockley met its tape-out goals," he adds. "We look forward to additional efficiency gains by expanding our use of Synopsys' Photonic Solutions tools."

The Synopsys OptoCompiler design platform is a schematic-driven layout flow that speeds design time with automated features such as assisted waveguide routing and auto-alignment of photonic circuits. OptoCompiler helps to ensure accuracy through the use of comprehensive photonic layout versus schematic (LVS) checking and native photonic simulators that work in conjunction with industry-standard SPICE electrical simulators.

"Rockley is a valued partner and this purchase is the latest step in a longstanding relationship," says Tom Walker, group director of Synopsys' Photonic Solutions. "Rockley's choice of Synopsys validates our model of providing a unified design platform and expert support. Our intuitive photonics design flow integrated in a familiar EDA environment allows traditional IC designers to be productive in the emerging field of integrated photonics."

www.rockleyphotonics.com
www.synopsys.com/photonic-

Rockley to go public via SC Health

Founder Dr Andrew Rickman to remain CEO & chairman

Rockley Photonics Ltd of Oxford, UK and Pasadena, CA, USA, which develops integrated silicon photonic chipsets and supplies modules for high-volume sensor and communication products, has entered into a definitive agreement to combine with SC Health Corp, a publicly traded special-purpose acquisition company. The transaction will result in Rockley becoming a publicly traded company on the New York Stock Exchange (NYSE) under the symbol RKLY and values the firm at a pro forma enterprise value of $1.2bn.

Rockley was formed in 2013 by a management team that has previously had success with two silicon photonics companies. Founder & CEO Dr Andrew Rickman founded the first firm to commercialize silicon photonics, Bookham Technology (which had an IPO in 2000, became Oclaro in 2009 and is now a part of Lumentum), and later became chairman of Kotura (sold to Mellanox in 2013).

Aiding healthcare through 'clinic-on-the-wrist' monitoring technology

The transaction is intended to accelerate the commercial launch of Rockley's sensing platform, which is tailored for consumer health and wellness by enabling continuous, non-invasive monitoring of multi-modal biomarkers such as lactate, glucose, hydration, blood pressure and core body temperature.

Based on its silicon photonics platform, Rockley's 'clinic-on-the-wrist' technology is claimed to be significantly more accurate than LED sensors commonly used today in wearables such as smart watches and fitness bands and allows for continuous monitoring of key vitals in a way that was previously possible only with clinical machines. By bringing laboratory precision diagnostics to wearables, Rockley aims to enable consumers to detect diseases earlier, to better manage nutrition, and to focus on preventive healthcare.

Rockley says that it is working closely with some of the world's largest consumer electronics and wearables companies to provide them with a full-stack solution, including co-packaged hardware devices, biosensing algorithms, firmware and data analytics to enable them to provide meaningful and actionable insights to their users.

Beyond consumer electronics, Rockley is partnering with clinicians and medical technology companies to expand the application of its monitoring platform to medical devices in order to improve disease detection and prevention.

Rockley says that its platform supports cost-effective, high-volume manufacturing. Its manufacturing ecosystem (with capacity reserved) and proprietary process flows can enable rapid scale-up for volume production of its highly integrated optical/electronic devices, the firm adds.

Rockley has also applied its integrated photonics technology to deliver chipsets for high-speed datacoms and machine-vision applications, including light detection & ranging (LiDAR). Its technology is protected by over 120 patents and the company has raised $390m in funding from over seven years of product development from non-recurring engineering, investors, government grants, subsidies and a range of health-tech and technology VCs, strategic investors, and financial institutions.

"Our partnership with SC Health positions us to accelerate our time-to-market for our compelling health and wellness solutions," reckons Rickman. "Our proven sensor technology, world-class partners and a relentless focus on execution will enable Rockley to deliver life-changing benefits to an enormous number of people… bringing laboratory diagnostics to the wrist will transform patient monitoring, healthcare delivery, and overall consumer health and wellbeing," he believes.

"We are healthcare investors, and we very quickly understood the transformational nature of Rockley's technology and the way it will revolutionize consumers' ability to track, monitor and better understand their day-to-day health and wellness," says SC Health's CEO A.J. Coloma. "Based on Rockley's large addressable market, world-class team and the myriad applications that their silicon photonics platform enables, we view Rockley as one of the most compelling opportunities in the entire healthcare space."

The transaction is expected to deliver up to $323m of gross proceeds to the combined company, including the contribution of up to $173m of cash held in SC Health's trust account. The combination is further supported by a $150m PIPE (private investment in public equity) at $10 per share, with participation from top-tier institutional investors including Senvest Management LLC and UBS O'Connor and participation from Medtronic. Proceeds of the transaction will support the Rockley's continued growth through ongoing product development in close collaboration with its initial customers.

Existing Rockley shareholders will roll 100% of their equity into the combined company. The firm's founder Rickman will remain Rockley's CEO & chairman.

The transaction, which has been unanimously approved by SC Health's board of directors and the independent directors of Rockley's board, is expected to close in second-quarter 2021, subject to approval by SC Health's shareholders and other customary closing conditions (including any applicable regulatory approvals).

www.rockleyphotonics.com
www.schealthcorp.com

NeoPhotonics' non-Huawei revenue grows 18% in Q4

Full-year revenue grows 4% to $371.2m, despite further US restrictions on exports to Huawei

NeoPhotonics Corp of San Jose, CA, USA – a vertically integrated designer and manufacturer of silicon photonics and hybrid photonic integrated circuit (PIC)-based lasers, modules and subsystems for high-speed communications – has reported full-year revenue of $371.2m for 2020, up 4% on 2019's $356.8m, despite the additional restrictions imposed on 17 August by the US Department of Commerce's Bureau of Industry and Security (BIS) on exports to China-based Huawei Technologies.

Huawei comprised 40% of 2020's revenue, Ciena 17% and Acacia Communications 10%. However, excluding Huawei, there were three 10%-or-more customers, with Ciena comprising 29% of non-Huawei revenue, Acacia Communications 17% and Nokia 11%.

With no contribution from Huawei, fourth-quarter 2020 revenue was just $68.2m, down by about a third on $102–103m in both Q3/2020 and a year ago, but above the mid-point of the expected range of $64–70m due to strong execution and good revenue growth from Western customers. Excluding Huawei, Q4 revenue was up 18% on Q3's $58m non-Huawei revenue, due largely to 400G-and-above product revenue growing by 35% sequentially (and 153% year-on-year) to 46% of total revenue. Full-year 400G-and-above product revenue grew 92% year-on-year. "In Q1/2020 these products grew 46% year-over-year and their growth accelerated to deliver 153% year-on-year growth by Q4," notes chairman, president & CEO Timothy Jenks.

In Q4/2020 there were four 10%-or-more customers (up from three in Q3, including the now absent Huawei at 44%). These ranged from 10% up to just 22% of revenue each (evidencing increased diversification), amounting to 67% of the total.

On a non-GAAP basis, gross margin was 24.7%, falling from 33.6% in Q3 (just below the firm's long-term target of 35%), as a small increase in product margins was more than offset by higher excess capacity charges (as expected, given the lower volumes). However, this was still in the upper half of the 22–26% guidance range. Also, the last time that NeoPhotonics' revenue was down at $68m, gross margin was just 15%. Full-year gross margin has still grown from 2019's 27.3% to 31.3% for 2020.

"Virtually all of the leading network equipment producers around the world use NeoPhotonics products in their flagship high-speed systems," claims Jenks. "Over the last three years we have developed advanced manufacturing methods for these highest-speed 400G-and-above products, scaled their production, all while steadily increasing our manufacturing utilization, reducing our depreciation costs and expanding our margins. In spite of the impact of US–China trade tensions, we see our actions benefiting our business for the longer term."

Operating expenses have been cut from Q3/2020's $24.5m to a better-than-expected $23.7m in Q4, due to faster execution of spending reductions (scheduled to be about $2m per quarter from Q3/2021, as part of the firm's restructuring, announced in October, involving a 4% staffing cut).

Compared with operating income of $9.9m (operating margin of 9.7% of revenue) in Q3/2020, in Q4/2020 NeoPhotonics reported an operating loss of $6.9m (–10.1% margin), due to the US Department of Commerce's restrictions on exports to Huawei.

Likewise, compared with net income of $6.2m ($0.11 per share) in Q3, in Q4 NeoPhotonics reported a net loss of $7.2m ($0.14 per share, better than the midpoint of expectations of $0.18) due to faster implementation of the restructuring announced in Q3. Despite the Q4 loss, full-year net income still grew from just $0.4m ($0.01 per diluted share) in 2019 to $16.7m ($0.31 per diluted share) for 2020.

Cash generated from operations fell from $15m in Q3/2020 to $5.4m in Q4 (nevertheless, full-year operating cash generation rose from $34.7m in 2019 to $54.9m in 2020). Capital expenditure (CapEx) was just under $5m. Free cash flow was hence about $1m in Q4/2020 (although full-year free cash flow rose from $25m to $41m).

Cash and cash equivalents, short-term investments and restricted cash rose to $123.3m (the firm's highest ever).

Pandemic-driven increased bandwidth deployments a lasting trend

"2020 was a strong and dynamic year for NeoPhotonics, with accelerating market adoption and deployment of our industry-leading ultra-pure-light tunable lasers, high-bandwidth receiver and modulator solutions for the highest-speed-over-distance interconnects," says Jenks. "From a long-term network investment standpoint, we believe 2020 marked an upward inflection in high-speed network growth. While the pandemic drove needs to increase bandwidth deployments, this is a lasting trend. As the pandemic subsides, we expect that companies will move increasingly to hybrid workforce models in the future, with continuing dependence on working from home. This will increase the need for bandwidth at the edge of the network, and the need for high-speed interconnects throughout the network, thereby continuing to benefit our business."

"Our strategy is to grow the business by focusing on the highest-

speed-over-distance solutions at 400G-and-above for telecom equipment providers. Within this, the newest and highest-data-rate communication systems are operating at 600G and 800G per wavelength, and they are now being offered by several of our customers who directly or indirectly use our high-speed components," says Jenks.

"For the last three years, we have been steadily introducing new lasers, modulators and receivers for the highest-speed applications at 600Gb/s and 800Gb/s in chassis-based systems, as well as several new high-speed coherent module products, for 400ZR and 400ZR+ applications. As a result, demand for NeoPhotonics' highest-speed products is very strong, with accelerating market adoption and deployments, and related market share gains at 400Gb/s and beyond, especially for links requiring the highest speed over distance. These high-speed deployments are among the fastest areas of growth in the industry, driven by cloud and data-center demand, and they have been driving our growth and profitability," Jenks continues.

400G-and-above revenue to continuing doubling year-on-year

"In the first quarter [of 2021], we expect the growth of our 400G-and-faster revenues to continue to more than double versus the previous year's first quarter," says Jenks. "With the number of 400G-and-above ports being shipped approximately doubling each year and our market share increasing at these highest speeds, we are seeing our customer diversification continuing to increase."

For Q1/2021, NeoPhotonics expects declines in revenue to $57–62m and gross margin to 18–22%, as normal for the seasonally lowest quarter due to the Chinese New Year shutdowns and the implementation of annual pricing reductions (to be followed by sequential growth in following quarters, "as volume increases and on the implementation of cost reductions through the year," notes senior VP & chief financial officer Beth Eby). Operating expenses should be cut further to $22–23m (so the midpoint of $22.5m is hitting the targeted restructuring savings of $2m per quarter earlier than forecast). Net loss per share is expected to be $0.20–0.10 (the midpoint of which would be an improvement on Q4/2020's $0.14).

"While we have had continued strength in the market for our highest-speed products, in recent months we have seen some softness with customers serving the North American cloud market following substantial bandwidth deployments that were pulled into 2020 in response to the pandemic," says Jenks.

"Current customer indications are that some demand has moved to later in 2021 due to travel restrictions limiting deployment of new systems. This leads us to estimate full-year revenue growth, excluding Huawei, of 25–35%. To reiterate, we believe overall demand in the mid- and long-term for 400G-and-above components and modules remains unchanged," stresses Eby.

Return to operating profit expected in Q3

"As a result of our efforts to develop products which comply with the most recent BIS restrictions for Huawei, we expect a modest level of shipments to Huawei in forward quarters. With these changes, we still expect to return to operating profit in Q3," says Eby. "We are well on our way to a more diversified customer business model, even before we ramp the 400ZR modules in the back half of 2021."

"Products for chassis-based systems operating at 600G and 800G are ramping, and we continue to make progress in gaining design wins and qualifications for 400ZR and 400ZR+ coherent modules with hyper-scale data-center operators. We have shipped dozens of units for qualification and we have installed our first production lines for these modules that are now being readied to ramp volumes," says Jenks.

"For 2021, we are focused on driving growth in our 400G-and-above product lines, moving into the hyper-scale market with added customers for our 400ZR & 400ZR+ modules and a return to profitability. Our strong cash position and the restructuring allows us to invest for that growth while positioning us for even higher levels of growth and profit in 2022," he adds.

"With our current rollout of 400ZR and 400ZR+ coherent modules for cloud data-center interconnects (DCI), we look forward to accelerating growth," says Jenks. "With components for chassis-based high-speed systems and 400ZR and 400ZR+ modules as the growth drivers for our business, we believe rapid growth in our highest-speed products will continue in 2021 and 2022."

Move to higher speeds to drive next wave of growth

"The acceleration of our components for 400G-and-above chassis-based systems, which drove much of the growth in 2020, is a strong beginning. As the market continues to move to higher and higher speeds, including 600G and 800G, we are increasingly well positioned to ride this next wave of growth," reckons senior VP, general manager & chief product officer Dr Wupen Yuen.

"We have announced and are now sampling our newest 96Gigabaud component suite for superb 800G DCI and 400G long-haul transmission, enabled by our ultra-low-noise tunable lasers and ultra-wide-bandwidth modulators and receivers. We expect these products will reach general availability in Q4/2021, adding to the revenue stream of our leading 64Gigabaud component suite," says Yuen.

"Layered on top of these chassis-based opportunities is the 400ZR & 400ZR+ coherent module market. We believe we have been a leader in launching 400ZR and 400ZR+ modules. These products effectively double our addressable market, while serving a particularly fast-growing segment, given the importance of hyper-scale metro DCI applications. We believe cloud providers, especially hyper-scale data-center customers, will be the ►

early adopters of this technology. These will be new volume customers for us, beyond our customer base of network equipment manufacturers," he adds.

"Our new 400ZR and 400ZR+ coherent module products are game changers. They package state-of-the-art data rates and system-level interfaces in very small and low-power form factors, enabling them to be plugged directly into routers and switches, bypassing traditional DWDM equipment. This capability enables operators to realize major savings in network equipment, as well as lower total power consumption and better environmental sustainability, thereby driving adoption rates and expanding use cases, including in new areas such as interconnects for distributed edge networks and for 5G cell sites," Yuen claims.

"We have sampled our 400ZR QSFP-DD and OSFP modules to multiple hyper-scale customers and are in the test and qualification process. We are one of the very few who are capable of meeting the challenging 400ZR optical specification," Yuen claims. "We continue to expect completion of qualifications in the first half of 2021, with deployments starting in the second half."

"An important addition is that we have now demonstrated 400ZR+ performance in a QSFP-DD form factor by leveraging the industry-leading optical performance of our tunable laser and silicon photonics components. We believe that 400ZR+ in QSFP-DD form factor will be widely adopted in cloud-based metro networks for 5G. This is important, as the 400ZR+ market segment substantially expands that of standard 400ZR. We expect that our 400ZR+ modules at metro and longer distances will provide a third major growth revenue stream that will begin to ramp in 2022," he adds.

"Built on our high-performance 64Gigabaud components, our CFP2-DCO 400G modules are now shipping in a high-performance C++ version, offering a wider optical spectrum and, therefore, higher fiber capacity. This product has demonstrated the best transmission performance for 200G and 400G available in a CFP2-DCO form factor," claims Yuen. "Combining its unique ability to operate in 75GHz channel spacings with the wider C++ spectral band, our CFP2-DCO supports fiber capacity that leads the industry at 32Tb/s for regional and metro applications and 16Tb/s for long haul. This wide spectrum performance equals or exceeds line-card-based 64Gigabaud solutions while reducing power consumption approximately 40%."

"Each of these new high-speed systems, including 400ZR and 400ZR+ applications, operate over DWDM line systems, including open-line systems. These require specific high performance multiplexing and de-multiplexing products that have unique channel spacings and filter shapes, including channel monitoring capability. For these applications, our athermal multiplexing products (AWGs) specifically designed for 400ZR and 400ZR+ applications have completed qualification and will be deployed in open-line systems in conjunction with the deployment of 400ZR networks."

"We are at the early stages of several key long-term macro trends. We see rapidly growing global bandwidth demand as a result of cloud services, the new requirements of remote working, artificial intelligence (AI) and machine learning, 3D sensing and light detection & ranging (LiDAR) applications, plus 5G wireless rollouts," summarizes Yuen. "We believe our advanced technologies for speed-over-distance meet these growing needs at the heart of the industry."

Extended-case-temperature QSFP-DD 400G ZR modules

System cooling requirements reduced and electrical power saved in data centers

NeoPhotonics has announced availability of its extended-case-temperature QSFP-DD 400G ZR modules.

The 400G ZR modules utilize NeoPhotonics' coherent optical components including its silicon photonics coherent optical sub-assembly (COSA) and low-power-consumption, ultra-narrow-linewidth Nano-ITLA (integrated tunable laser assembly). Each of these components can be operated over a wide module case temperature range up to 80°C. This enables the 400G ZR modules to be deployed in extended-temperature data-center environments while reducing cooling requirements and fan power.

"The ability of 400G ZR vendors to offer thermally optimized designs capable of supporting higher case temperatures will significantly help reduce system cooling requirements," comments Dr Hacene Chaouch, distinguished engineer at Arista Networks. "This is an important consideration for implementing power-efficient data-center interconnect architectures," he adds.

"We are pleased to support customers with high-performance 400G ZR modules that operate across a wide thermal envelope, without sacrificing optical performance," says chairman & CEO Tim Jenks. "By utilizing our leading high-speed coherent components technology and optimizing the entire optics suite through in-house design, we are able to favorably benefit data centers' need to reduce power consumption and improve environmental sustainability."

www.neophotonics.com

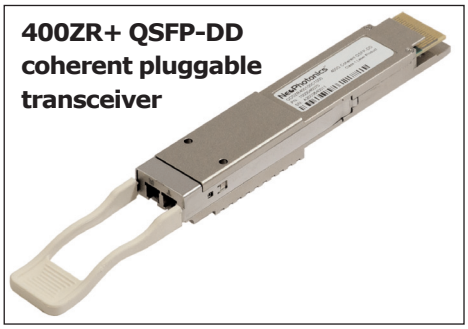
NeoPhotonics' 400ZR+ QSFP-DD transceiver demos 400G transmission over 800km in 75GHz-spaced DWDM

Small-form-factor coherent pluggable modules extended to metro and regional networks

NeoPhotonics Corp of San Jose, CA, USA — a vertically integrated designer and manufacturer of silicon photonics and hybrid photonic integrated circuit (PIC)-based lasers, modules and subsystems for high-speed communications — says that it has demonstrated that its 400ZR+ QSFP-DD coherent pluggable transceiver can effectively transmit at a 400Gbps data rate over a distance of 800km in a 75GHz-spaced DWDM system with more than 3.5dB of optical signal-to-noise ratio (OSNR) margin in the optical signal.

The 400ZR+ coherent pluggable transceiver module is based on NeoPhotonics' high-performance coherent optics and its ultra-pure color tunable laser, and achieves a reach of 800km while staying within the power consumption envelop of the QSFP-DD module's power specification. The firm believes that these 400ZR+ QSFP-DD modules will find wide application in Cloud-based metro 5G networks, and will extend use cases for IP-over-DWDM into metro-core and regional networks.

The 800km transmission demonstration was carried out on NeoPhotonics' Transmission System Testbed and utilized 75GHz-spaced channels. The QSFP-DD uses NeoPhotonics' silicon photonics-based coherent optical sub-assembly (COSA) and its ultra-narrow-linewidth Nano-ITLA tunable laser. The firm says that the longer reach



400ZR+ QSFP-DD coherent pluggable transceiver

was enabled by the superior performance of these optical components along with a commercial digital signal processor (DSP) using proprietary forward error correction (FEC). The COSA exhibits low insertion loss and low impairments, making efficient use of the optical signal. The Nano-ITLA tunable laser exhibits ultra-low phase noise and low power consumption. Additionally, these components allow NeoPhotonics' 400ZR+ QSFP-DD transceiver module to operate at a case temperature of up to 80°C (ten degrees higher than conventional telecom modules), reducing air flow requirements and resulting in lower fan speeds and reduced power for cooling in data centers.

NeoPhotonics' QSFP-DD modules are in the final stages of qualification and have passed 2000 hours of high-temperature operating life (HTOL) and other critical tests per Telcordia requirements. The firm expects these modules to be at general availability (GA) in second-quarter 2021.

NeoPhotonics' 400ZR+ QSFP-DD transceivers are designed to operate in 75GHz-spaced DWDM systems using 64-channel arrayed waveguide grating MUX and DMUX filters, such as those made by the firm. In this case, a fully loaded fiber operating in the C-band would provide total capacity of 25.6 Terabits per second (Tbps). To further maximize the data capacity of optical fibers, NeoPhotonics has developed an enhanced version of its ultra-low-noise laser in a C++ LASER module, which has a tuning range of 6THz, enabling a total fiber capacity of 32Tbps using 400Gbps transceivers and 75GHz channel spacing.

"We are excited to extend the operation of our QSFP-DD coherent transceiver into metro and regional applications in this 400ZR+ configuration," says chairman & CEO Tim Jenks. "Advances in our ultra-pure-light tunable laser, our silicon photonics integrated COSA and electronic DSPs have inexorably decreased the size, power and cost of coherent transmission such that a coherent transceiver capable of up to long-haul distances can fit in the same form factor as a current-generation high-density client-side pluggable module, such as a QSFP-DD," he adds. "This has been a sea change for data-center interconnect (DCI) networks, and we believe it will also bring fundamental changes to metro and regional networks," Jenks concludes.

www.neophotonics.com

First Solar's board gains former Deloitte financial expert

Hollister to serve on audit and compensation committees

First Solar Inc of Tempe, AZ, USA — which makes thin-film photovoltaic modules based on cadmium telluride (CdTe) as well as providing engineering, procurement & construction (EPC) services — has appointed Kathryn A. 'Katy' Hollister, a financial expert with nearly four decades of leadership experience at Deloitte Tax LLP and its affiliates, to its board of directors. Hollister will serve on First Solar's audit and compensation committees.

Hollister has designed and driven strategic initiatives and led operations across Deloitte's most important businesses. Most recently, she was chief strategy officer for Deloitte's Global Tax and Legal practice of 45,000 professionals, where she led the integration of dozens of global practices (involving a technology transformation in a complex environment of multi-jurisdictional regulatory, talent, and brand management). Hollister also served two terms on Deloitte's US and global boards of directors.

First Solar's new board member Katy Hollister.

Hollister brings "a passion for organizations with bold, transformative missions, particularly those focused on important issues, such as the environment and climate change," comments First Solar's CEO Mark Widmar.

"First Solar has an exceptional track record in responsibly produced cleantech and sustainability," comments Hollister. "This is a company focused on balanced growth and competitiveness, while also being conscious of its impact on people and the planet," she adds.

Hollister has been an active community leader, serving multiple academic and charitable organizations. She serves on the boards of trustees of Duke University (where she is the vice-chair of the audit committee) and the University of Cincinnati Foundation. She is also on the boards of MENTOR and the Cincinnati Museum Center. She has served on many other Cincinnati-based charitable board roles, including the YWCA and Habitat for Humanity.

Hollister has a BA from Duke University and a JD from the University of Cincinnati College of Law. She is a licensed lawyer and certified public accountant.

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First Solar wins 2.4GW order from Intersect Power

Series 6 PV modules to power seven US utility-scale projects

First Solar Inc of Tempe, AZ, USA is to supply up to 2.4GW$_{DC}$ of its Series 6 cadmium telluride (CdTe) thin-film photovoltaic (PV) solar modules to Intersect Power LLC in one of the largest aggregate orders for the modules to date.

Modules supplied under the seven purchase orders will be deployed to seven projects developed by Intersect Power, with deliveries scheduled for 2022 and 2023. As part of the deal, the clean infrastructure company has placed firm orders for about 2GW$_{DC}$ of modules, with options to add almost 400MW$_{DC}$, subject to the projects' final designs.

Founded in 2016 and said to be one of the fastest-growing developers of clean energy in the USA, Intersect Power has a pipeline of 3.2GW$_{DC}$ of late-stage solar and storage projects that will be in operation by 2023. It had previously placed a 1.7GW$_{DC}$ order for Series 6 modules in 2019.

"As the Intersect Power team builds out our next 2.4GW portfolio and moves towards asset ownership and operation, we continue to prioritize quality and long-term performance," says Intersect Power's CEO Sheldon Kimber. "Not only is First Solar able to scale quickly with us to meet our vision, but the Series 6 offers the highest quality and long-term value for our portfolio," he adds. "We continue to enjoy a strong values-aligned relationship with First Solar, and prize the reliability and risk mitigation that comes from working together, as we rapidly scale our business."

Designed and developed at First Solar's R&D centers in California and Ohio, the Series 6 PV module is claimed to set industry benchmarks for quality, durability, reliability, design and environmental performance. With a carbon footprint that is 2.5 times lower and a water footprint that is up to 24 times lower than crystalline silicon PV panels manufactured using conventional, energy-intensive production methods, Series 6 is said to deliver a superior environmental profile and the lowest-carbon solar available.

"Intersect Power isn't simply choosing solar technology with a benchmark-setting degradation rate, lifetime energy yield, and robust quality standards," says First Solar's chief commercial officer Georges Antoun. "A company that shares our vision for a sustainable energy future is choosing responsible solar technology that embodies sustainability, while meaningfully supporting the fight against climate change."

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GaInAsSb 1.55µm telecom device

Researchers have claimed the first demonstration for a new material combination "with so much promise".

ETH Zurich in Switzerland has demonstrated the first use of gallium indium arsenide antimonide (GaInAsSb) as an absorber material for 1.55µm telecom wavelengths [Akshay M. Arabhavi, Journal of Lightwave Technology, vol 39, issue 7 (1 April 2021), p2171]. The material was deployed in uni-traveling carrier photodiodes (UTC-PDs), which demonstrated enhanced response to modulated signals with a transit-limited bandwidth of 274GHz, compared with 107GHz for uniform GaAsSb absorbers. GaAsSb performance can be improved by grading the material to give 184GHz bandwidth, but clearly this still falls short of 274GHz.

Previously, it had been thought that the use of quaternary GaInAsSb absorber would not yield much benefit since the alloy components have similar bandgaps. The researchers attribute the GaInAsSb enhancement to improved electron transport in the fabricated devices. The UTC structure depends only on fast electron transport, an advantage over PIN diodes, which are limited by the slower hole drift movement through sections of the conventional structure.

Research leader Colombo Bolognesi comments that the ETH device "provides a nearly 3x improvement in ultimate speed over GaAsSb absorbers (also demonstrated by my group in 2005), and comparisons to similar InGaAs-based devices suggest that the quaternary GaInAsSb alloy is between 30 to 40% superior to InGaAs (the industry workhorse) despite being doped 6.5x higher than the InGaAs devices used for comparison." He adds: "It is not everyday that a new material unexpectedly shows up with so much promise. We'll keep at it and see where it goes."

The semiconductor material (Table 1) for the UTC-PDs was grown by metal-organic vapor phase epitaxy on 2-inch semi-insulating (100) indium phosphide (InP) substrate. The structure was 'type II', where the heterojunction conduction and valence band steps go in the same direction.

The photodiodes (Figure 1) were formed by depositing a palladium/nickel/platinum/gold ohmic electrode as the ohmic p-contact, followed by wet etch of the absorber/collector mesa structure, titanium/platinum/gold metallization for the n-contact, and isolation mesa wet etch. Co-planar waveguide probe pads were added after a Teflon-based etch-back planarization process. An anti-reflection coating consisted of silicon nitride.

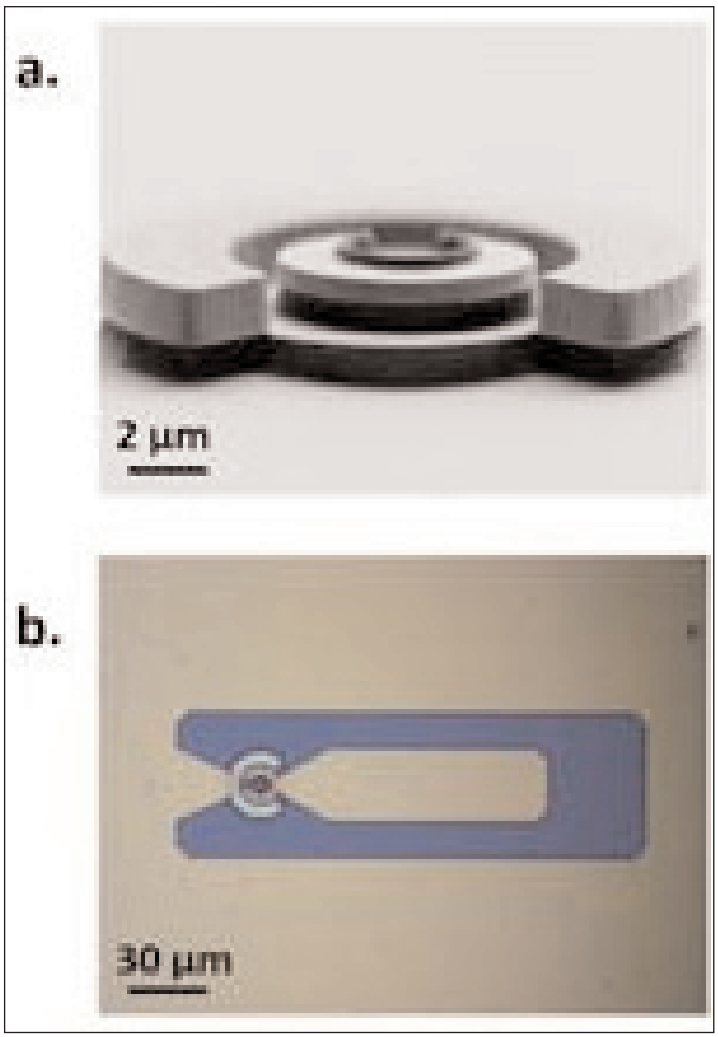


Figure 1. (a) Scanning electron micrograph of UTC-PD following isolation mesa formation; (b) top-view microscope image of completed device with coplanar waveguide probe pads.

The resulting devices demonstrated a dark current of less than 10nA up to reverse biasing of up to 5V. The frequency performance was measured in the range 0.2–60GHz. The input light was a modulated 2mW signal at 1550nm wavelength delivered via lensed optical fiber with a 3µm spot diameter.

The 3dB cut-off frequency (f_{3dB}) point was more than the measured 60GHz when the device areas were less than 80µm^2. Removing the effect of the resistance–capacitance (RC) delay, the researchers extrapolated a transit-time-limited cutoff frequency (f_T)

of 274GHz for an 80μm^2 area device (Figure 2). This value compares with 107GHz and 184GHz for GaAsSb absorber layer devices with uniform and graded compositions.

At present, the performance-limiting factor is RC delay, which can be reduced with the size of the devices. Also, the GaInAsSb quaternary absorber was found to be 34% more responsive to light stimulation relative to the ternary GaAsSb (0.094A/W versus 0.070A/W).

The team comments: "The higher responsivity of GaInAsSb absorbers can be attributed to:
(i) the narrower bandgap in $Ga_{0.81}In_{0.19}As_{0.65}Sb_{0.35}$ compared to GaAsSb;
(ii) reduced carrier recombination in the absorber thanks to a reduced transit time;
(iii) a relatively lower population of electrons in the absorber L-valley (reduced blocking to InP); and
(iv) a longer Auger recombination lifetime of in GaInAsSb relative to GaAsSb".

The indirect L-valley separation from the direct Γ-valley, which responds much more effectively to light, is thought to be larger in GaInAsSb relative to GaAsSb, resulting in lower electron population in the performance-sapping L-valley. In fact, GaAs and GaSb have separations of 0.284eV and 0.026eV, respectively, while the corresponding InAs and InSb separations are much larger: 0.716eV and 0.695eV. In addition, the L-valley has a much lower electron mobility.

The researchers hope to "improve the overall responsivity with resonant cavity structures and/or conversion to a waveguide architecture". They add: "Significant improvements in responsivity are expected since optical electromagnetic simulations for the present UTC-PD demonstrators show that the peak optical field region is not aligned with the absorber layers." ■

https://doi.org/10.1109/JLT.2020.3043537

Author: Mike Cooke

Material	Doping	Thickness
$GaAs_{0.50}Sb_{0.50}$	C:1.2E20	20nm
$Al_{0.17}Ga_{0.83}As_{0.55}Sb_{0.45}$	C:5.0E19	20nm
$GaAs_{0.50}Sb_{0.50}$ $GaAs_{0.50\rightarrow0.62}Sb_{0.50\rightarrow0.38}$ $Ga_{0.81}In_{0.19}As_{0.65}Sb_{0.35}$	C:1.1E18 C:5.2E17→3.5E18 C:1.3E18	100nm
InP	Si:5.9E16	225nm
InP	S:3.1E19	50nm
$Ga_{0.49}In_{0.51}As$	Si:4.0E19	20nm
InP	S:3.1E19	300nm
InP substrate		350μm

Table 1. Epitaxial material.

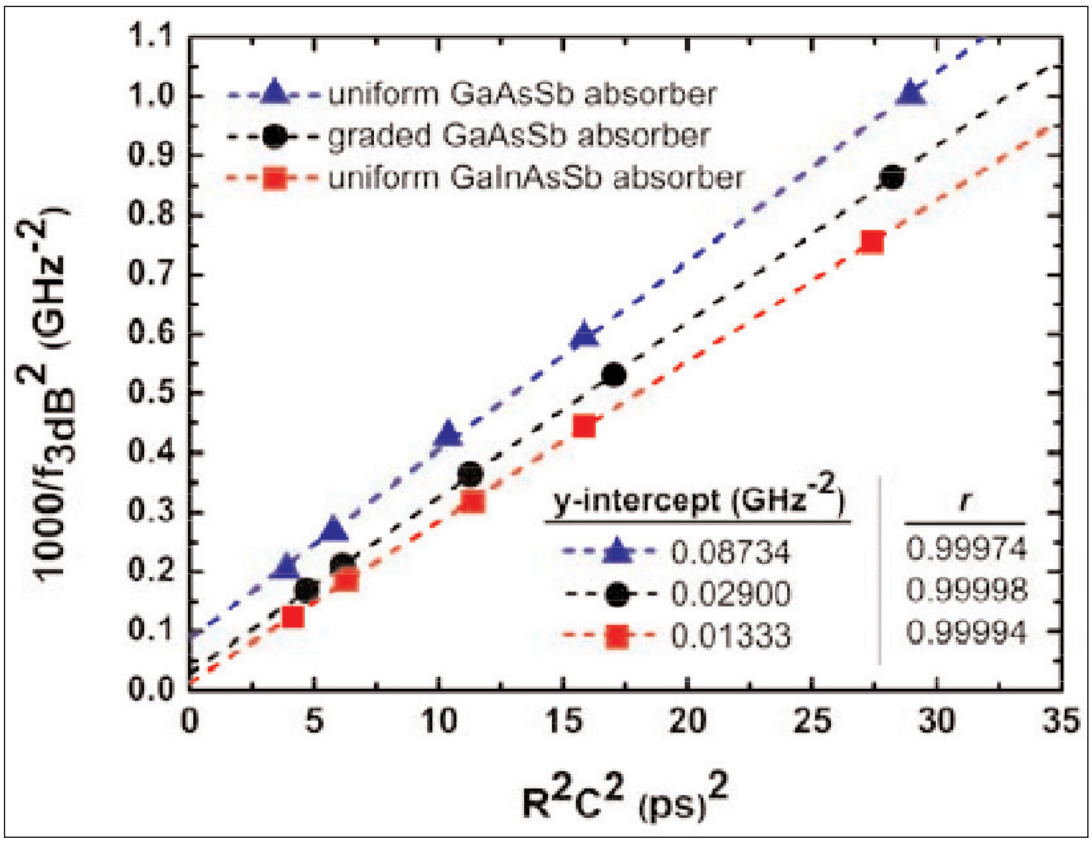


Figure 2. 1000/f_{3dB}^2 versus R^2C^2 for UTC-PDs with three different absorbers. Linear extrapolation to RC = 0 determines transit-limited bandwidth via the y-intercept value. The linear correlation coefficient r also shown.

CMOS-compatible III–V photodetector

Researchers at IBM and ETH in Zürich have fabricated a photodetector on a silicon photonic integrated circuit with 65GHz bandwidth and 100GBd reception.

Researchers in Switzerland and the USA have been working to integrate III–V photodetector structures on silicon photonic integrated circuits (PICs) [Yannick Baumgartner et al, Optics Express, vol29, p509, 2021]. The team from IBM Research Zürich, ETH Zürich and IBM T. J. Watson Research Center have developed a process that is compatible with mainstream complementary metal-oxide-semiconductor (CMOS) electronics manufacturing, a key consideration for mass deployment. This means eliminating gold-based contacts and excessive thermal budgets, for example.

The fabricated devices with a 65GHz bandwidth and data reception of 100gigabaud (GBd) benefited from the tunable direct bandgap and high carrier mobility of the indium aluminium gallium arsenide (InAlGaAs) and indium phosphide (InP) III–V materials. These properties should enable "compact high-speed detectors with lower dark currents and transit times, increased photodetection efficiency and thermal stability, decreased footprint and capacitance" without the need for transimpedance amplifiers, according to the researchers.

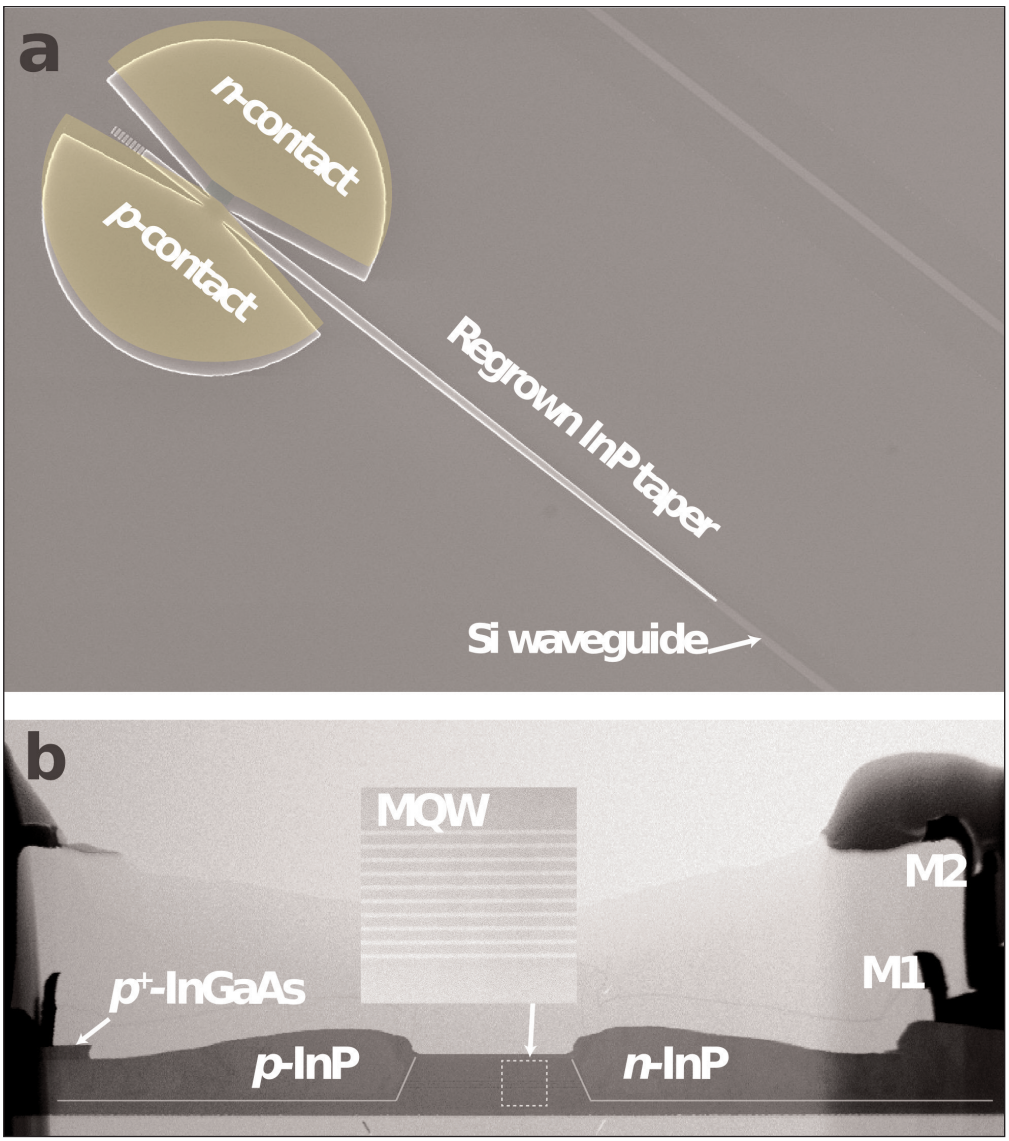


Figure 1. Fabricated III-V-on-Si membrane photodetectors on Si: (a) top-view scanning electron micrograph before metallization; (b) structural scanning transmission electron microscope cross section with inset close-up of InAlGaAs multiple QWs. Scale bar 500nm.

The team hopes that its work will contribute to achieving the low power consumption of femtojoules/bit targeted for 100gigabits/second optical communications by industry.

The active III-V structure consisted of ten InAlGaAs compressive quantum wells grown on InP by 550°C metal-organic chemical vapor deposition (MOCVD). The structure was wafer-bonded to a Si PIC wafer with an aluminium oxide bonding layer at less than 300°C.

The researchers expect the InAlGaAs system to be suitable for devices covering the two main optical communication wavelengths of 1310nm and 1550nm.

The PIC was fabricated in a 220nm silicon-on-insulator (SOI) wafer using hydrogen bromide/oxygen plasma etch in an inductively couple plasma reactive-ion etch (ICP-RIE) tool. The PIC was clad in silicon dioxide and chemical mechanical planarized before the wafer

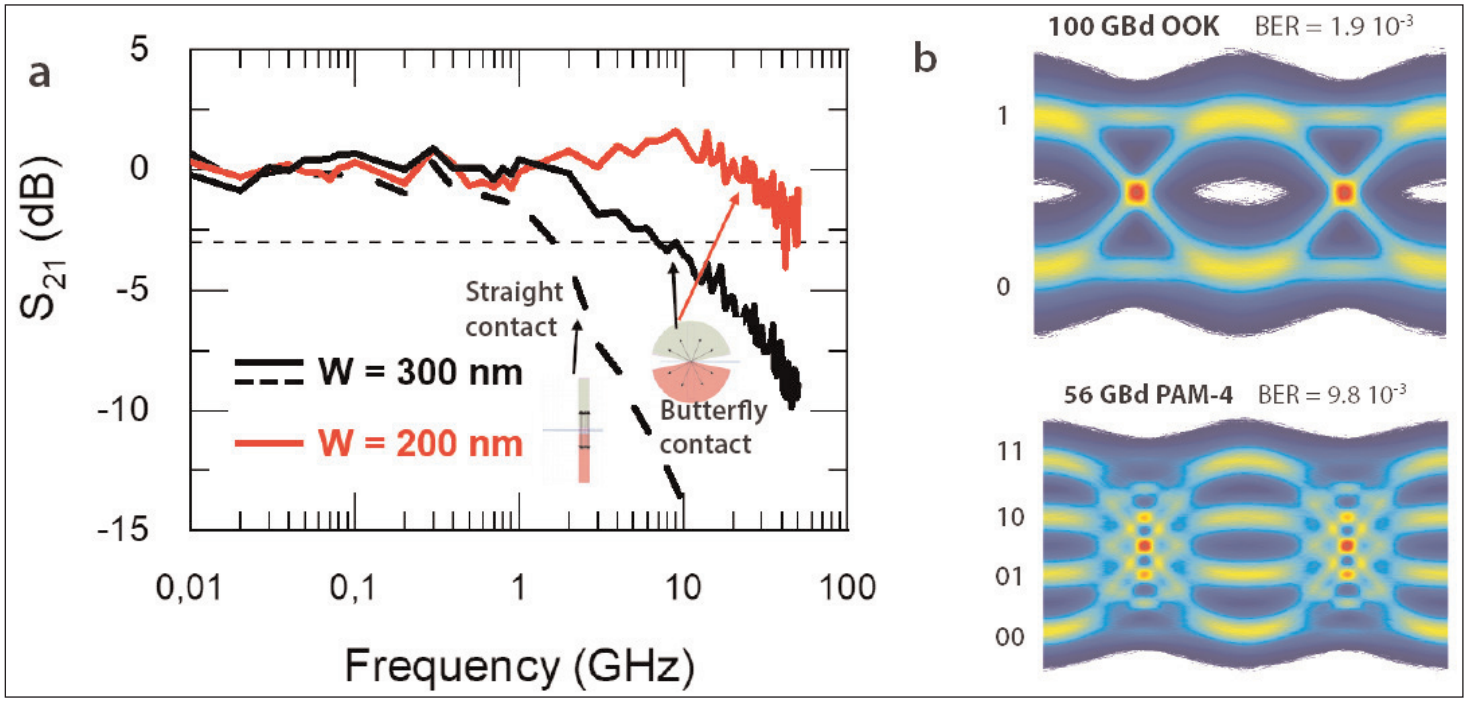


Figure 2. (a) Frequency response with varying stripe width, with (solid line) and without (dashed line) butterfly-shaped contacts. (b) Data reception at 100GBd OOK and 56GBd PAM-4 with corresponding bit-error-rates.

bonding of the III–V material.

The photodetector mesas were formed using chlorine ICP-RIE and wet cleaning with hydrofluoric and sulfuric acid. The n- and p-type side-contact 'butterfly' regions were formed by selective-area regrowth of InP (Figure 1). The researchers comment that the thermal budget from these regrowth steps has been shown previously to be acceptable for bottom field-effect transistor (FET) performance preservation in fully depleted SOI devices with silicon germanium (SiGe) channels. Tin was used as n-type dopant, and zinc for p-type. The p-side included a zinc-doped InGaAs cap to improve the ohmic contact with the metallization.

Electro-optic bandwidth was around 65GHz. The researchers believe that adapting the device geometry could increase the bandwidth to 100GHz. Pad parasitics would need to be reduced

The lateral current collection scheme decoupled the light propagation and carrier collection directions, enabling a strong optical confinement for ultra-compact devices with high efficiency. Simulations suggest that ballistic transport (i.e. minimal scattering) could occur in the wells, since the carriers don't need to overshoot or tunnel through barriers.

The annealed metallization used a two-level CMOS-compatible process with molybdenum and tungsten plugs. The device geometry targeted "optimized absorption in the O-band, low dark currents and the ability to co-integrate light sources and modulators in the same platform".

The optical contact with the underlying PIC also consisted of a regrown InP taper structure. The external quantum efficiency of the device was estimated to be as high as 69%. The capacitance was in the femtofarad range (femto=10^{-15}). The researchers suggest that the benefits of ultra-small capacitances can only be realized with "devices monolithically integrated with CMOS electronics". The dark current was also minimal, at sub-nA levels.

The researchers tested the response of 2μm-long photodetectors with stripe width of 200nm and 300nm. A 300nm-wide device had a 3dB bandwidth (f_{3db}) of 8.5GHz, compared with 1.5GHz for a similar device with straight contact (Figure 2).

The 200nm device was tested under 100GBd on–off key (OOK) signal modulation of 1295nm light. The electro-optic bandwidth was around 65GHz. The researchers believe that adapting the device geometry could increase the bandwidth to 100GHz. The pad parasitics would need to be reduced to achieve this.

The team also performed 100Gbit/s pseudo random bit sequence OOK testing, demonstrating bit-error rates (BERs) of 1.9×10^{-3} with digital interpolation. "The eye opening in this experiment enables the use of multi-level modulation formats, allowing higher capacity per channel," the team comments. They add: "As a practical example, we also show the eye diagram of a 112Gbit/s four-level pulse-amplitude modulation (PAM-4) signal with a calculated BER of 9.8×10^{-3}, which has been recorded by a real-time oscilloscope" (Figure 2b). ■

https://doi.org/10.1364/OE.414013

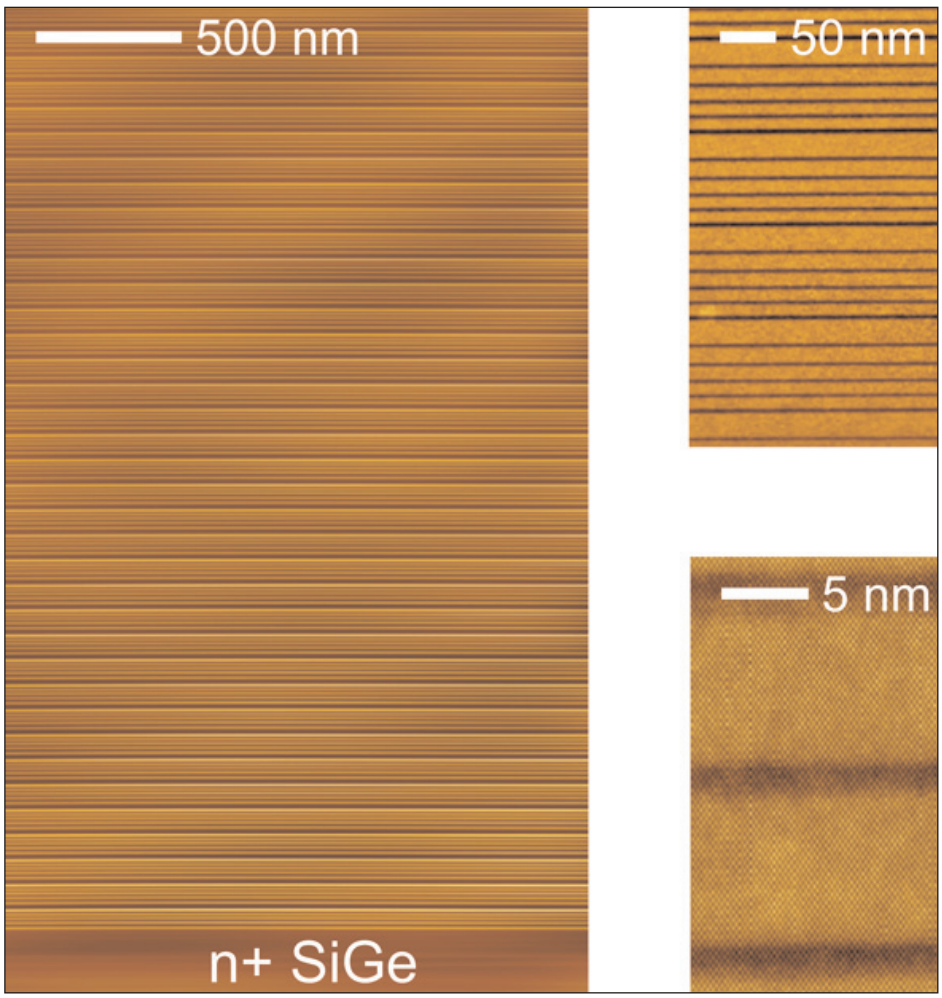
Author: Mike Cooke

Electroluminescence from Ge/SiGe quantum cascade structures

Laser design promises room-temperature operation, targeting silicon photonics.

An international team led by professors Giacomo Scalari and Jérôme Faist at the Institute for Quantum Electronics at Switzerland's ETH Zürich have presented what is claimed to be an important step towards developing a laser on silicon.

They report electroluminescence from a structure based on silicon germanium (SiGe), which is compatible with standard fabrication processes used for silicon devices. Moreover, the emission they observed is in the terahertz frequency band, which sits between those of microwave electronics and infrared optics, and is currently of great interest with a view to a variety of applications (D Stark et al, 'THz intersubband electroluminescence from n-type Ge/SiGe quantum cascade structures', Appl. Phys. Lett. 118 (2021), 101101).

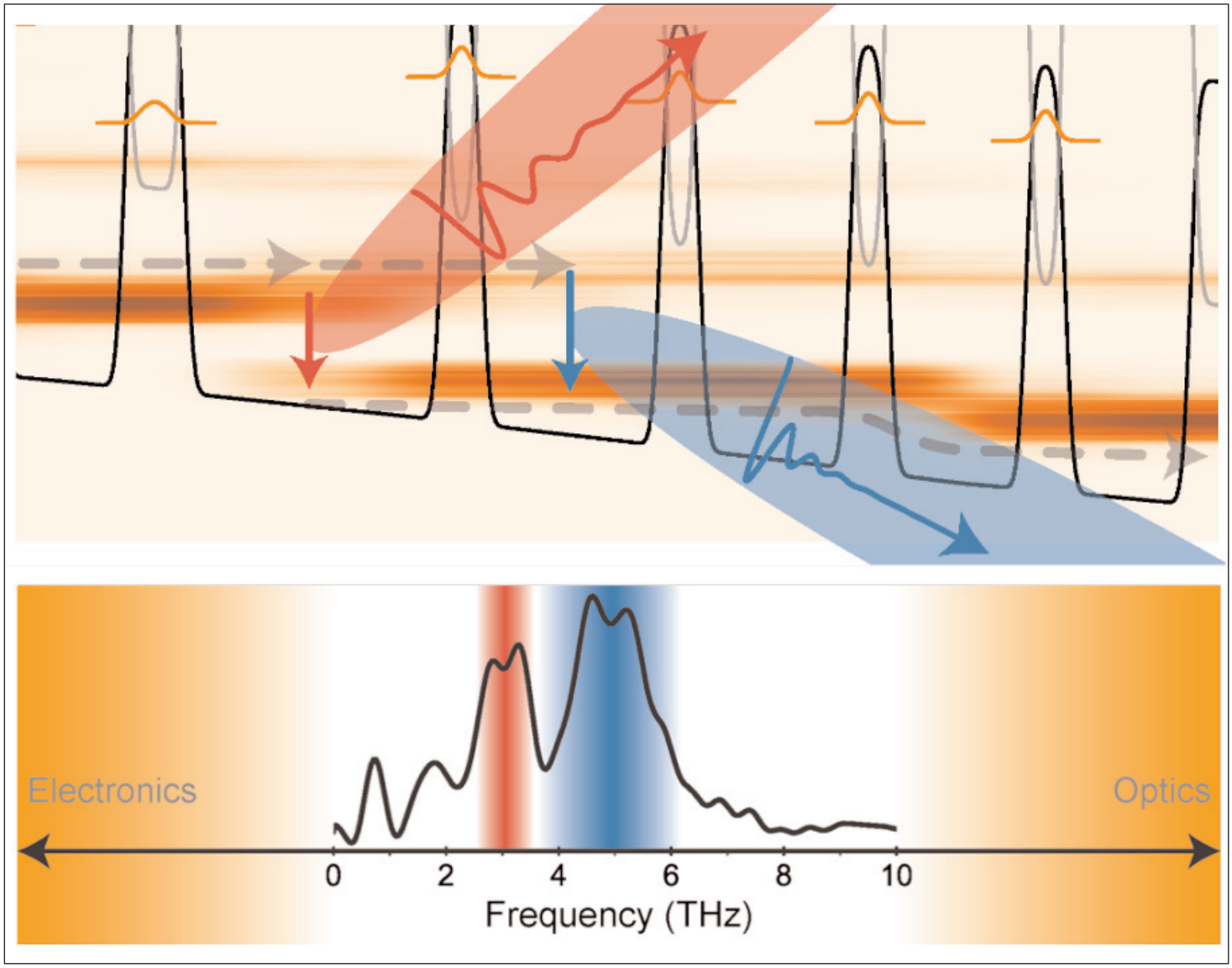


Scanning transmission electron microscopy (STEM) images of one of the Ge/SiGe heterostructures at different magnifications. The SiGe layers appear darker. (Images: Università Roma Tre, De Seta Group)

Light from silicon-based materials

Unlike in gallium arsenide (GaAs), where electrons can recombine with holes across the material's direct energy bandgap and hence produce light, the indirect bandgap of silicon means that another path for electron and hole recombination is required to produce lasing in silicon. ETH Zurich doctoral researcher David Stark and his colleagues are working towards a silicon-based quantum cascade laser (QCL), which achieve light emission not by electron–hole recombination across the bandgap but by letting electrons tunnel through repeated stacks of precisely engineered semiconductor structures, during which process photons are emitted.

QCLs have been demonstrated in a number of materials — for the first time in 1994 by a team including Jérôme Faist (then working at Bell Laboratories in the USA) — but never in silicon-based materials, despite promising predictions. Turning these predictions into reality is the focus of an interdisciplinary project funded by the European Commission, bringing together a team of experts in growing semiconductor materials (at the Università Roma Tre), characterizing them (at the Leibniz-Institut für innovative Mikroelektronik in Frankfurt an der Oder) and fabricating them into devices (at the University of Glasgow). The ETH group of



As electrons tunnel through the Ge/SiGe heterostructure, they emit light, currently at two slightly different frequencies, due to suboptimal injection in the upper state of the radiative transition. (Image: ETH Zurich/David Stark)

Scalari and Faist is responsible for performing the measurements on the devices, but also for the design of the laser, with numerical and theoretical support from partners in the company nextnano in Munich and at the Universities of Pisa and Rome.

From electroluminescence to lasing

With this bundled knowledge and expertise, the team designed and fabricated devices with a unit structure made of SiGe and pure germanium (Ge), less than 100nm in height, which repeats 51 times.

From these heterostructures, fabricated with essentially atomic precision, Stark and co-workers detected electroluminescence, as predicted, with the spectral features of the emerging light agreeing well with calculations.

Further confidence that the devices work as intended came from a comparison with a GaAs-based structure that was fabricated with identical device geometry. Whereas the emission from the Ge/SiGe structure is still significantly lower than for its GaAs-based counterpart, these results clearly signal that the team is on the right track.

The next step will be now to assemble similar Ge/SiGe structures according to a laser design that the team developed. The ultimate goal is to reach room-temperature operation of a silicon-based QCL.

Such an achievement would be significant in several respects, says ETH Zurich. Not only would it realize a laser on a silicon substrate, bringing a boost to silicon photonics, but also the emission of the structure created by Stark et al is in the terahertz region, for which compact light sources are currently widely missing. Silicon-based QCLs, with their potential versatility and reduced fabrication cost, could enable the large-scale use of terahertz radiation in existing and new fields of application, from medical imaging to wireless communication, it is reckoned. ■

https://arxiv.org/abs/2101.05518
www.iqe.phys.ethz.ch

Deep UV tunnel-junction LED efficiency

Researchers claim more than one order of magnitude boost for 255nm-wavelength device.

University of Michigan in the USA has reported boosting the efficiency of tunnel-junction deep ultraviolet (UV) light-emitting diodes (LEDs) by one to two orders of magnitude over previous reports on devices operating around 255nm wavelength [A. Pandey et al, Appl. Phys. Lett., vol117, p241101, 2020].

Deep UV LEDs are of much interest for sterilization applications, particularly in these pandemic-ridden times. Apart from healthcare, sterilization capabilities are of interest in the food preparation industry, with a view to avoiding spoilage. Although 260–280nm wavelengths have been the main ones deployed for these purposes up to now, shorter wavelengths may have some advantages in terms of effectiveness.

Creating efficient LEDs at these wavelengths is a challenge that increases as the wavelength shortens. External quantum efficiencies have reached 20% at 275nm, 10% at 265nm, but only 4.5% at 255nm. Asymmetric doping, with hole density and mobility being so much inferior to those of electrons, is one of the major impediments to efficient LEDs based on aluminium gallium nitride (AlGaN) semiconductors.

The Michigan team is looking to tunnel junctions to reduce the dependence of devices on poorly performing p-type conduction. Tunnel junctions allow an n-type component on the hole injection side to improve current spreading, reducing bunching of current density and consequent efficiency droop effects. Before the Michigan report, tunnel-junction devices at 255nm had only managed efficiencies of less than 0.1%.

The heterostructures (Figure 1) for the devices were grown by a molecular beam epitaxy (MBE) system with a radio-frequency plasma-assisted nitrogen source. The AlN-on-sapphire templates were supplied by Japan-based DOWA Holdings Co Ltd. The bottom n-contact layer was annealed in-situ in several steps with a view to improved structural and optical properties.

The multiple quantum well layers consisted of four AlGaN wells targeted at 255nm-wavelength emission. The thickness of the barrier layers varied, decreasing from 6nm down to 3.5nm. The researchers explain: "Simulations have shown that the reduced barrier thickness closer to the p-doped side of LEDs can help improve device performance by increasing hole injection into the quantum wells, thereby leading to more even charge carrier distribution in the active region."

The electron-blocking layer was graded to take advantage of the charge polarization of the chemical bonds to give an enhancement of the p-type doping and thus hole injection into the light-emitting region.

The final n-AlGaN component of the tunnel junction

Contact/tunnel junction	n-$Al_{0.75}Ga_{0.25}N$	150nm
Interlayer	GaN	5nm
Tunnel junction	p-$Al_{0.75}Ga_{0.25}N$	25nm, heavy doping
Graded electron blocking	p-$Al_{0.90\rightarrow0.75}Ga_{0.10\rightarrow0.25}N$	20nm
Mutiple quantum wells	AlGaN	
Graded transition	$Al_{0.75\rightarrow0.90}Ga_{0.25\rightarrow0.10}N$	25nm
Contact	n-$Al_{0.75}Ga_{0.25}N$	500nm
Template	AlN/sapphire	

Figure 1. Heterostructure.

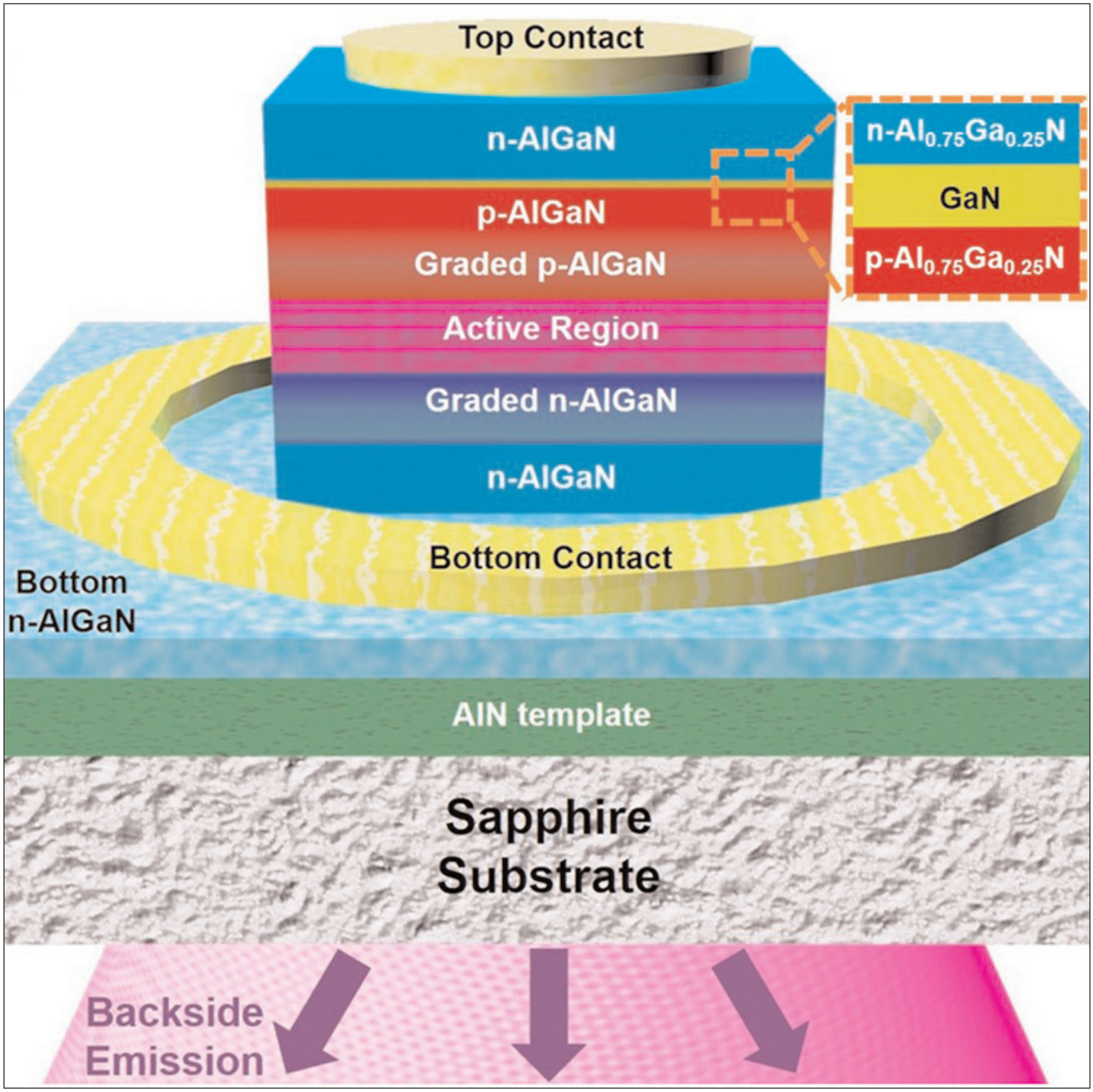


Figure 2. Schematic for tunnel-junction deep UV LED.

included an annealing after 100nm growth. The thin GaN interlayer between the two components of the tunnel junction was designed to reduce the depletion width, enhancing tunneling probability. Again, charge polarization effects at the interfaces between GaN and AlGaN aided this aim.

The MBE used slightly Ga-rich conditions to "enhance dopant incorporation and increase the internal quantum efficiency of AlGaN heterostructures". At the same time, annealing reduced the tendency of Ga-rich growth to introduce "crystalline defects due to the presence of gallium droplets on the sample surface". The annealing consisted of raising the temperature by 50°C and shutting off the flow of material into the growth chamber.

The material was fabricated into LEDs with a 30μmx30μm mesa, silicon dioxide passivation, annealed titanium/aluminium/nickel/gold electrodes, and reflective aluminium/gold contact pads (Figure 2). Light was emitted through the sapphire back-side of the LED.

The researchers report a sharp turn-on voltage and negligible reverse-bias leakage under continuous wave (CW) injection. "It is noticed that the device has much

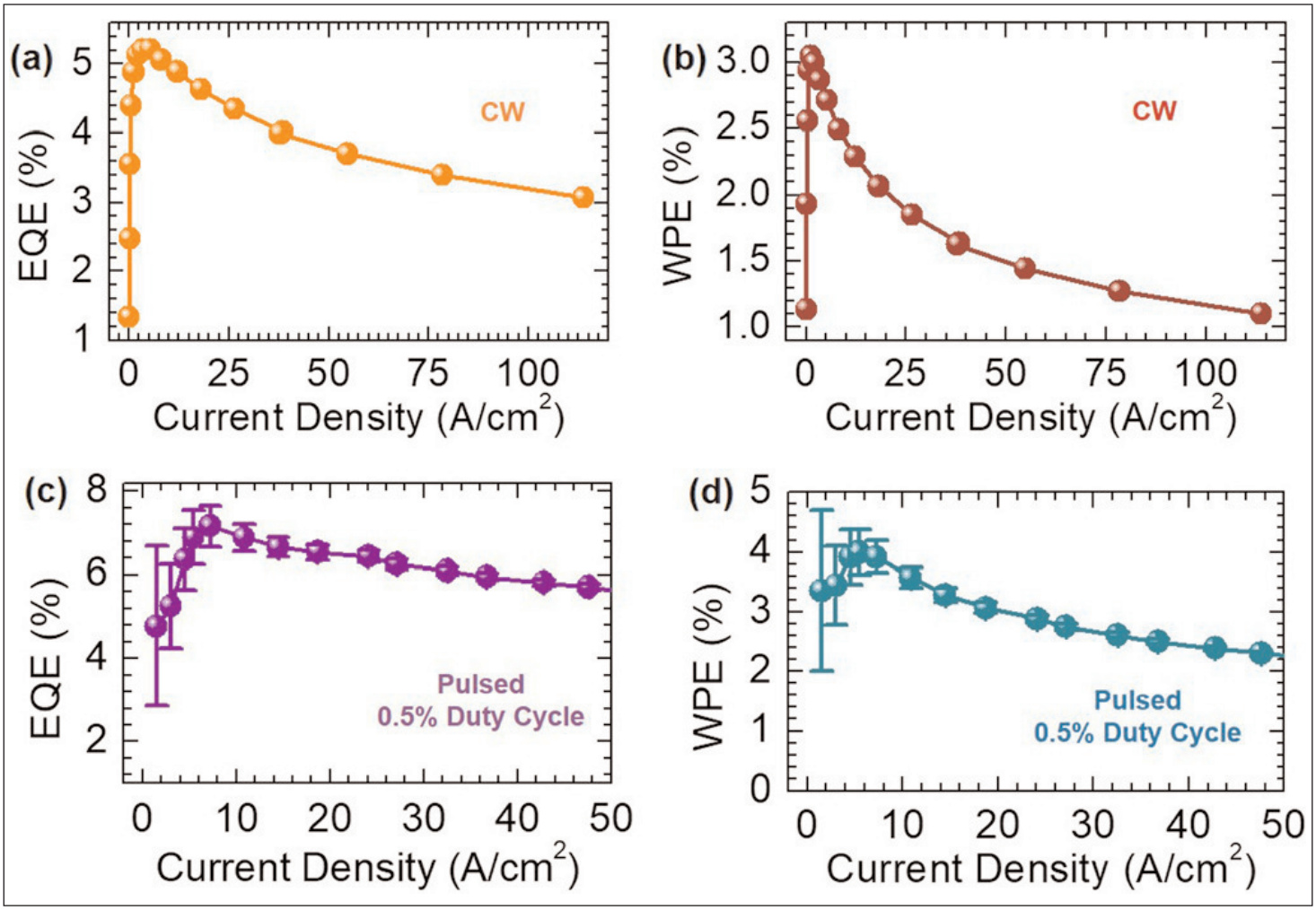


Figure 3. (a) EQE versus current density under CW bias at room temperature. (b) WPE versus current density under CW bias. (c) Pulsed EQE. (d) Pulsed WPE.

improved current rectification, compared to previously reported tunnel- junction devices emitting at similar wavelengths, due to the reduced leakage current in the present devices," they comment.

As the current density increased to 200A/cm^2, the team saw little variation in the peak emission wavelength, unlike in standard LEDs, which suffer from shifting of the energy levels with applied bias - the 'quantum-confined Stark effect'. The constancy of the emission peak position "can be explained by the strong charge carrier confinement in the Ga-rich nanoclusters in AlGaN quantum wells grown under slightly Ga-rich conditions by MBE," the team says.

A significant increase in the full-width at half-maximum (FWHM) of the emission peak on the low-wavelength side "can be explained by luminescence from recombination of carriers within the graded p-doped region of the device". In other words, the electron-blocking layer is not sufficient in its appointed task of stopping electron carrier overflow.

External quantum efficiency and wall-plug efficiency reached 5.3% and 3%, respectively, under CW conditions... nearly one to two orders of magnitude higher than those of previously reported tunnel-junction devices operating at such short wavelengths

The external quantum efficiency (EQE) and wall-plug efficiency (WPE) reached 5.3% and 3%, respectively, under CW conditions (Figure 3). "These values are nearly one to two orders of magnitude higher than those of previously reported tunnel-junction devices operating at such short wavelengths," the researchers report. The team believes better packaging could enhance these efficiencies.

The device suffered severe efficiency droop at high current injection, which was not improved by reducing self-heating effects with pulsed injection, although the peak EQE and WPE were enhanced to 7.2% and 4%, respectively. The researchers point to carrier overflow as the suspected main culprit in the droop. This is evidenced by the pulsed injection test and the spectral behavior, along with other recent studies in the academic literature. ■

https://doi.org/10.1063/5.0036286

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Boosting blue light emission with silica array substrates

Wuhan researchers report 16.5% more light output power using patterned sapphire/silicon dioxide cone array growth substrate.

Wuhan University in China has reported a 16.5% improvement in light output power for indium gallium nitride (InGaN) blue light-emitting diodes grown on patterned sapphire with silica array (PSSA) substrates, compared with a similar device grown on patterned sapphire [Shuyu Lan et al, Optics Express, vol. 28, p38444, 2020]. The team comments: "This work demonstrates a significant step forward in the development of high-performance LEDs for high-resolution display." Other potential applications could come from visible light communications (VLC), automotive front lighting, and general lighting.

The researchers attribute the improvements to better crystal quality and enhanced light extraction through the sapphire substrate in the flip-chip LED devices.

The PSSA was prepared using photoresist thermal-reflow and plasma etch (www.semiconductor-today.com/news_items/2020/jan/wuhan-300120.shtml) to create 2.8μm-diameter silica/silicon dioxide (SiO_2) cones with 3.0μm center-to-center spacing. The cone height was 2μm. Further plasma etch was performed after the cone formation, cutting into the sapphire, giving thin pedestals for the cones.

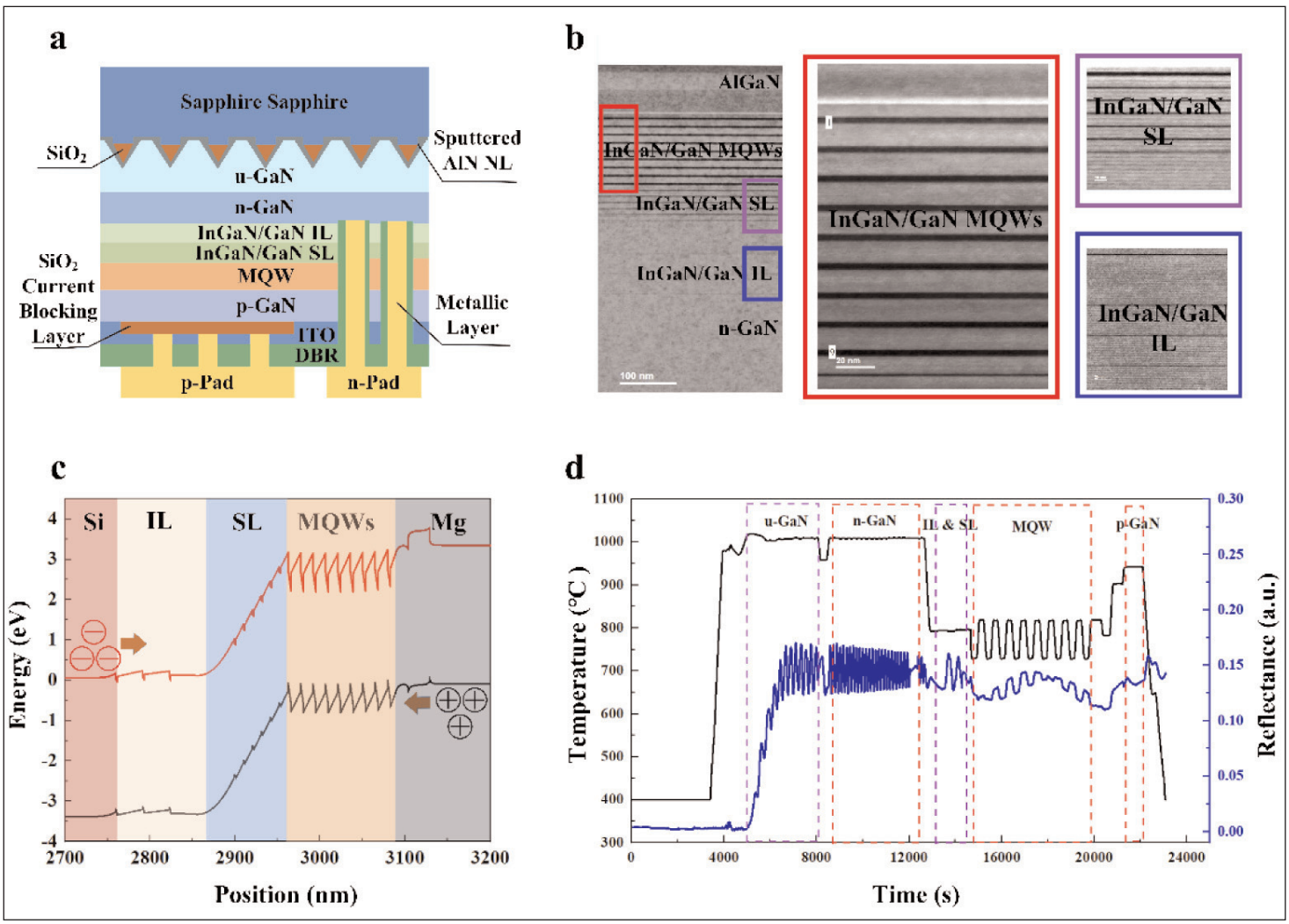

Figure 1. (a) Schematic GaN-based flip-chip LED structure on PSSA. (b) Cross-sectional scanning transmission electron micrograph. (c) Simulated energy-band diagram. (d) In-situ reflectance and temperature transients during epitaxial growth.

These sapphire pedestals are found to bend the threading dislocations (TDs) away from the active regions of the structure. The use of SiO_2 reduces coalescence boundaries in GaN, which leads to less misfit strain, further reducing TD density.

The research team adds: "Since no GaN islands formed on the silica array cone sidewall regions, the LED grown on PSSA effectively decreased the misfit existing in the coalescence boundary of GaN grown on the sidewall regions and c-plane region of the substrate."

III–N growth began with aluminium sputtering at 650°C in a nitrogen, oxygen and argon gas mix, creating a 15nm aluminium nitride (AlN) nucleation layer. The rest of the LED structure (Figure 1) was grown using metal-organic chemical vapor deposition (MOCVD): 3μm GaN buffer, 2.5μm n-GaN contact, 260nm lightly doped n-GaN, 3x 1.5nm/30nm $In_{0.02}Ga_{0.98}N$/GaN interlayer (IL), 6x 1.5nm/9nm $In_{0.05}Ga_{0.95}N$ superlattice (SL), 9x 3nm/12nm $In_{0.16}Ga_{0.84}N$/GaN multiple quantum well (MQW) active region, 15nm p-GaN, 25nm p-$Al_{0.2}Ga_{0.8}N$ electron-blocking layer, and 80nm p-GaN contact.

The researchers explain: "The use of $In_{0.02}Ga_{0.98}N$/GaN IL and $In_{0.05}Ga_{0.95}N$ SL reduced the effective barrier heights for both electrons in the conduction band and holes in the valence band, leading to an increased effective electron capture rate."

X-ray analysis gave a TD density of $1.3x10^8/cm^2$, compared with $3.3x10^8/cm^2$ for a similar structure grown on patterned sapphire substrate (PSS).

The structure was flipped in the processed 380μmx760μm LED, with the light emerging mainly from the sapphire side. The emission wavelength under 60mA current injection was 445nm (blue). By contrast, a PSS device had a longer wavelength of 452nm. The longer wavelength was attributed to the effect of piezoelectic fields arising from extra strain in the PSS-based structure. These fields shift the performance due to the quantum-confined Stark effect (QCSE).

The PSSA substrate also gave benefits in terms of light output power (LOP) and external quantum efficiency (EQE): 225.7mW at 120mA and 77.7% (peak), respectively, compared with 193.8mW and 67.8% for PSS. The improved performance is attributed to both enhanced crystal quality and superior light extraction efficiency.

Light extraction benefited from the presence of SiO_2 with a 1.45 refractive index closer to that of air, 1, compared with sapphire (1.78) or GaN (2.46). The lower refractive index of SiO_2 reduces the amount of total internal reflection, transmitting light to the outside world more readily. ■

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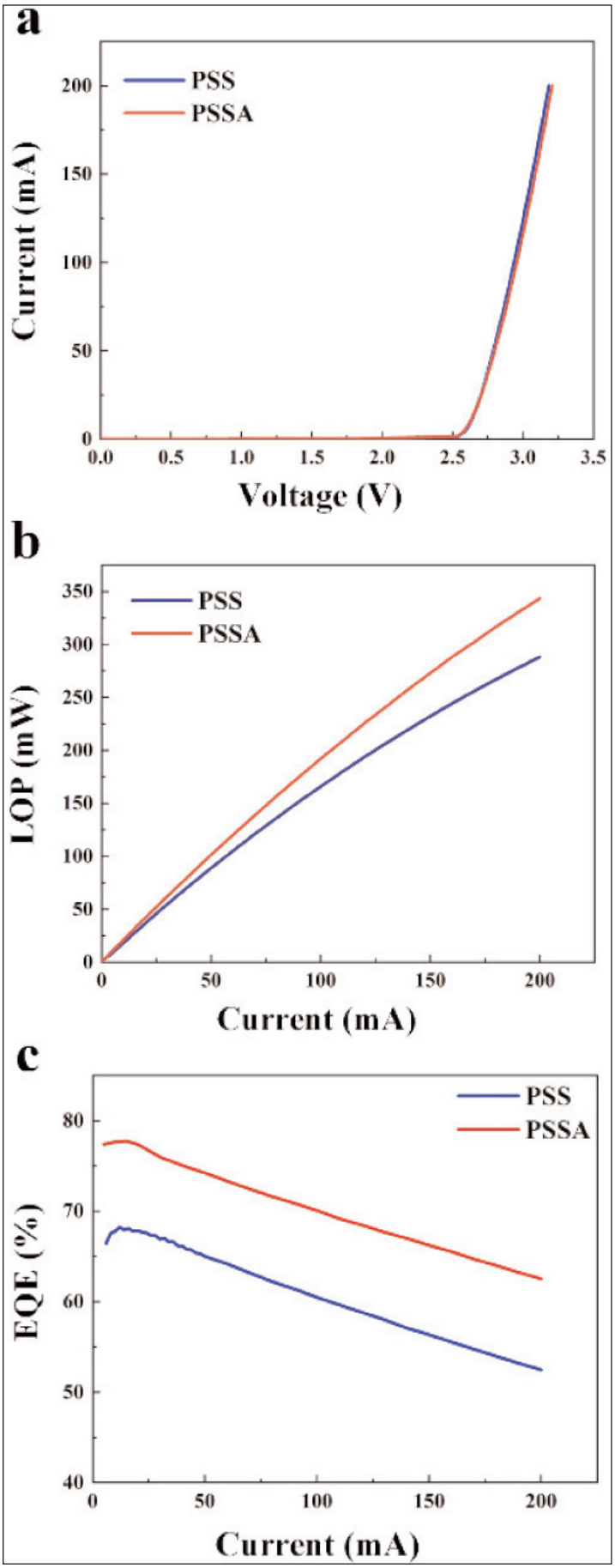


Figure 2. (a) Current–voltage and (b) current–LOP characteristics of LEDs grown on PSS and PSSA. (c) EQEs versus current.

Power semiconductor device market for xEVs growing at 25.7% CAGR to $5.6bn in 2026

The main inverter market is growing at a CAGR of 26.9% to $19.5bn by 2026, reckons Yole Développement.

With the plug-in hybrid electric vehicle (PHEV) and battery electric vehicle (BEV) markets estimated to be increasing at compound annual growth rates (CAGRs) of 37.3% and 44%, respectively, during 2020–2026, the converter market for all electric vehicles (xEV, spanning MHEV, HEV, PHEV, BEV, FCEV) is rising at a CAGR of 27.7%, to more than $28.8bn in 2026, estimates market analyst firm Yole Développement in its report 'Power Electronics for E-Mobility 2021'.

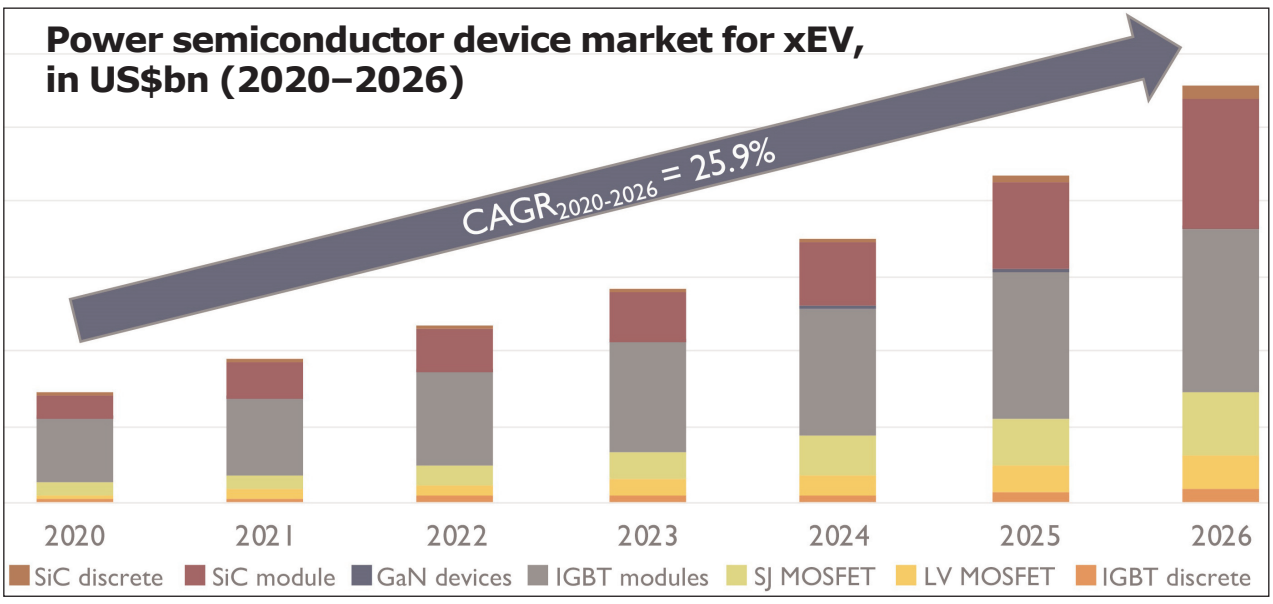
In particular, the main inverter market is expected to grow at a CAGR of 26.9% to $19.5bn by 2026, representing 67% of the total electric vehicle/hybrid electric vehicle (EV/HEV) converter market.

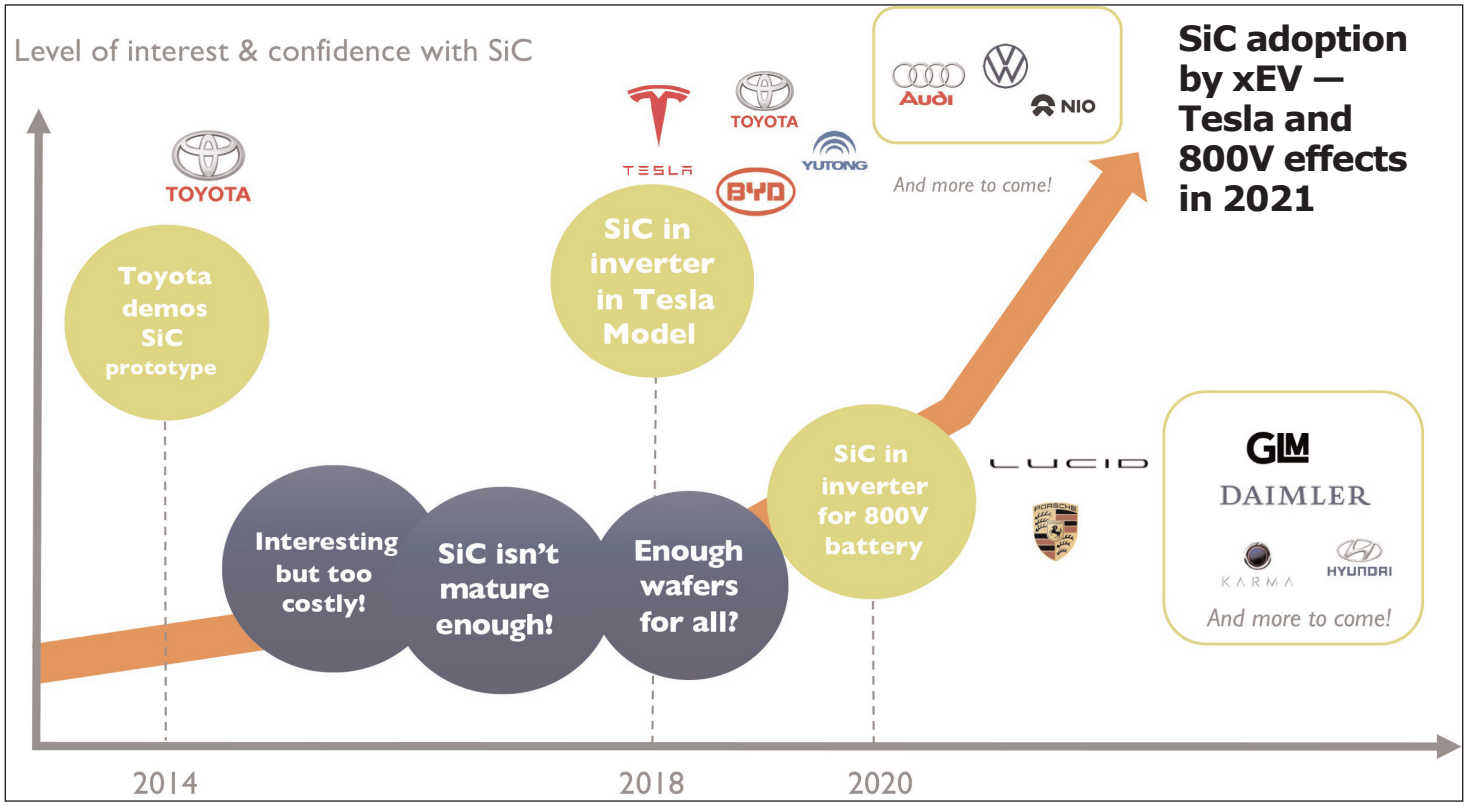
"There are basically three converter types in an electric car: the main inverter, DC/DC and OBC (on-board charger)," notes Ana Villamor, technology & market analyst, Power Electronics. "The main inverter is the largest market among the different converters due to the higher power levels, leading also to the highest content of power semiconductors."

The power semiconductor market for xEVs is expected to triple between 2020 and 2026, growing at a 25.7% CAGR to $5.6bn, driven by a major technology battle between insulated-gate bipolar transistor (IGBT) and silicon carbide (SiC) modules. Indeed, SiC modules are presently still about three times the cost of a 650V IGBT module, but this difference will shrink when larger volumes are produced, with the transition to 8-inch wafers, and with the penetration of 1200V devices for higher battery voltages.

The EV/HEV supply chain continues to be impacted by the increased demand and technology trends. However, the leading semiconductor manufacturers for EVs/HEVs remain the same as for other power applications. They include Infineon Technologies, STMicroelectronics, Hitachi, Mitsubishi Electric, and ON Semiconductor. Other companies, tier-1s, OEMs, power semiconductor manufacturers and pure module newcomers are now offering power modules for EVs/HEVs. A similar situation exists with battery design and manufacturing, where OEMs such as Tesla and GM are further trying to control their supply chains.

"Competition at OEM level has also opened two main fronts: on the one hand, there are the traditional OEMs with established markets and known brands that are transforming their business towards electric vehicles. On the other hand, pure EV OEMs are popping up in the different regions of the world (such as NIO, Rivian, Rimac, Xpeng, and Hozon), some of which are rapidly increasing their volumes year after year (led by Tesla)," says Milan Rosina, Yole's principal analyst, Power Electronics & Batteries.





The new car models being launched often offer better performance/cost ratio, and this has led to a continuous reshaping of the top 10 vehicle sales.

SiC is now walking the EV/HEV red carpet, says Yole. Over the last couple of years (and especially since Tesla introduced SiC in its Model 3 main inverter), there has been much noise around SiC adoption in EV/HEV. But not all converters or all types of electrification are suitable for this expensive material, Yole notes. Without a doubt, the battery electric vehicle (BEV) is the winner due to the requirements of a long driving range and fast charging time (km driven by charge time). Therefore, the increased cost of the converter is repaid, as the efficiency of the converter will improve, allowing battery savings. It is no surprise then that the use of SiC in the main inverter has become a common goal for the leading OEMs, with players such as Daimler and Hyundai soon including it in their main inverters. Who will be next?

Today, there is already a good portfolio of SiC devices, with SiC dies coming from Infineon Technologies, Cree (Wolfspeed), and STMicroelectronics. Many semiconductor players are targeting SiC modules for EV applications, and the SiC module market is expected to reach 32% of the total EV/HEV semiconductor market by 2026, Yole forecasts. ■

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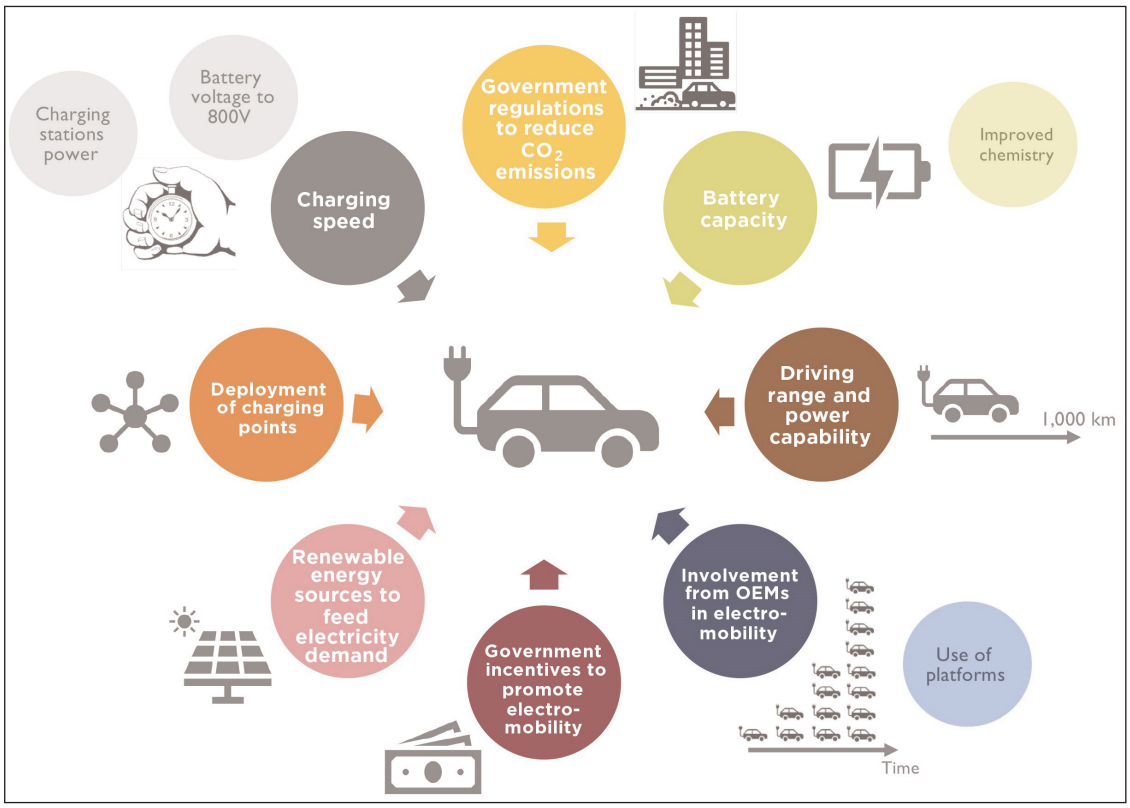

Pushers and enablers for electric mobility.

Extreme-k and Ga_2O_3 power moves

Barium titanate layer massages peak electric field pain in lateral transistors.

Ohio State University in the USA has claimed the highest reported power figure of merit for gallium oxide (β-Ga_2O_3) lateral transistors of 376MW/cm^2 [Nidhin Kurian Kalarickal et al, IEEE Transactions on Electron Devices, vol68, Issue 1 (January 2021), p29]. The researchers used an insulator consisting of barium titanate ($BaTiO_3$), a perovskite oxide that combines an extreme dielectric constant with high breakdown field strength (>8MV/cm).

The dielectric enabled a reduction in peak fields for a given bias, according to simulations. Radio frequency (RF) and power electronics could benefit from higher average electric fields enabling better efficiency, power density, and faster speed.

The team comments: "The integration of extreme permittivity dielectrics based on perovskite oxides into conventional and wide-bandgap semiconductors such as Si, GaAs, GaN and SiC could enable unprece-

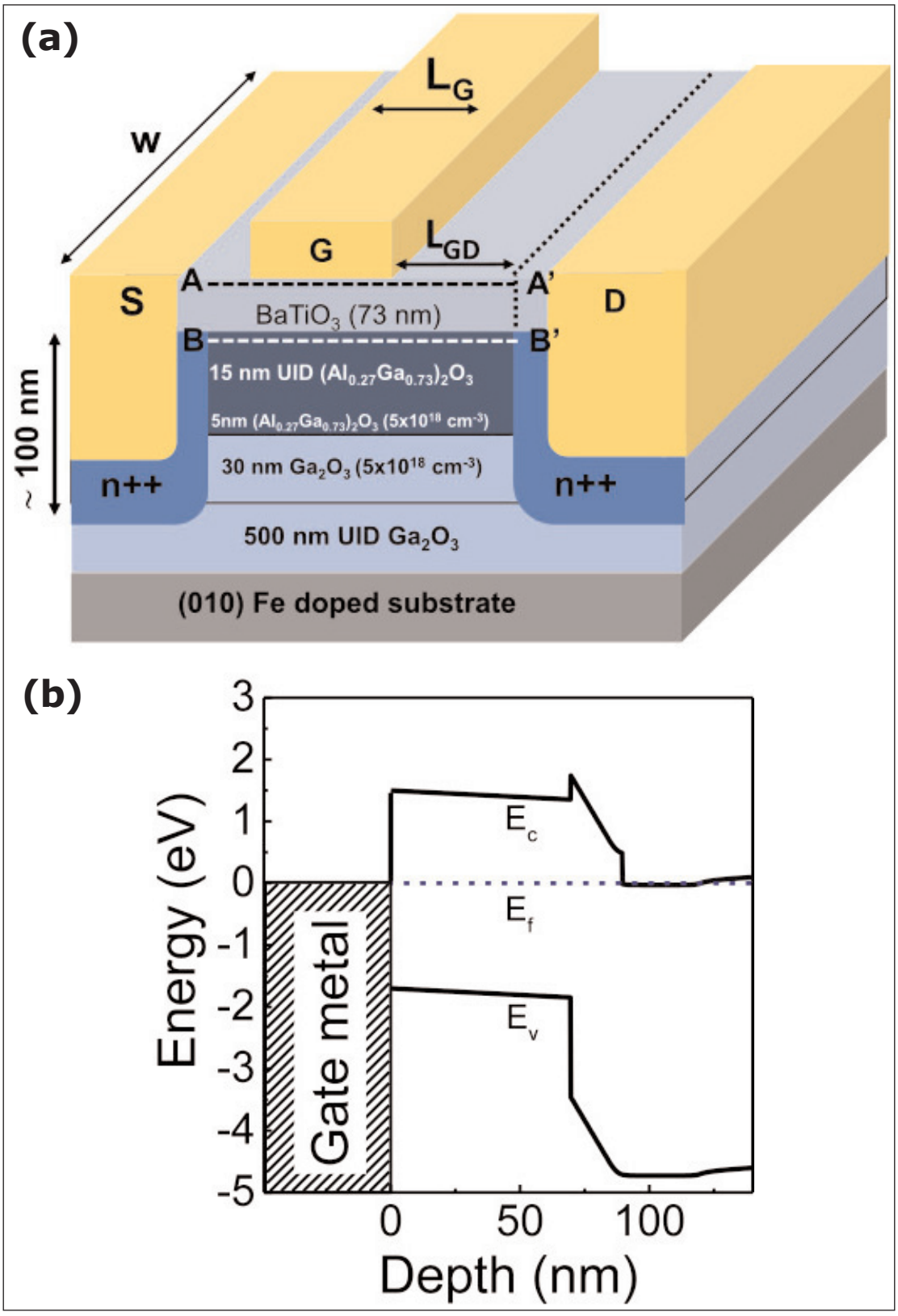

Figure 1. (a) Epitaxial/device diagram of $BaTiO_3$/β-Ga_2O_3 MISFET. (b) Simulated band diagram along vertical cutline through gate.

dented performance improvements in RF and power electronics devices."

The use of the $BaTiO_3$ dielectric also enabled a higher channel charge density of 1.6x1013/cm^2, reducing on-resistance. The β-Ga_2O_3 has a theoretical breakdown field strength of 8MV/cm, which is much greater than the 3MV/cm for gallium nitride (GaN). One drawback of β-Ga_2O_3 is a lower mobility. This can be compensated for somewhat with the higher channel charge.

The researchers fabricated lateral metal–insulator–semiconductor field-effect transistors (MISFETs) on β-Ga_2O_3 with extreme-k $BaTiO_3$ as the insulator (Figure 1). The channel region was formed using 880°C metal-organic chemical vapor deposition (MOCVD) of β-$(Al_xGa_{1-x})_2O_3/Ga_2O_3$ layers on iron-doped β-Ga_2O_3 substrate. The 5x10^{18}/cm^3 intentionally doped aluminium/gallium oxide layers were achieved with silicon from silane (SiH_4).

Source and drain regions were defined using optical lithography followed by silicon ion implantation and activation by 900°C annealing for 30 minutes. The source and drain were then etched down to the β-Ga_2O_3 and annealed metal contacts formed from titanium/gold/nickel.

The $BaTiO_3$ was applied using 670°C RF sputtering from a sintered $BaTiO_3$ source. The $BaTiO_3$ was 73nm thick, a little short of the 75nm target. The sputtering had a negative effect on the channel resistance, which the researchers hope could be ameliorated in the future with an Al_2O_3 interlayer to avoid sputter damage. The source/drain ohmic contacts also suffered from sputter degradation, which could be improved by applying the metals after the $BaTiO_3$ and/or by optimizing the metal stack.

The device was completed with mesa isolation etching and deposition of a nickel/gold/nickel Schottky gate. The gate–drain spacings (L_{gd}) ranged from 0.5μm to 6μm. The gate length was 0.7μm.

Capacitance–voltage measurements suggested a dielectric constant of 235 for the $BaTiO_3$, but the team comments: "This is only a lower bound estimate on the dielectric constant since there is a small depletion of charge in the channel after the deposition of $BaTiO_3$. Nevertheless, the lower bound estimate of 235 is high enough to ensure electric field management."

The lowest on-resistance was 13.6Ω-mm, normalized to the gate width with 0.5μm L_{gd} and 1.5μm L_{sd}. The drain current reached 359mA/mm — "the highest reported in any epitaxially grown β-Ga_2O_3 lateral transistor device under dc conditions, and higher currents have only been obtained in β-Ga_2O_3 nanomembrane transistors transferred onto high-thermal-conductivity substrates like diamond and Si," according to the team.

The three-terminal breakdown voltage (V_{br}) increases with L_{gd}, with the highest value being 918V for 6μm spacing. For 0.5μm Lgd breakdown occurred at 201V. The average field at breakdown reduced from 4MV/cm at 0.5μm Lgd to 1.5MV/cm at 6μm.

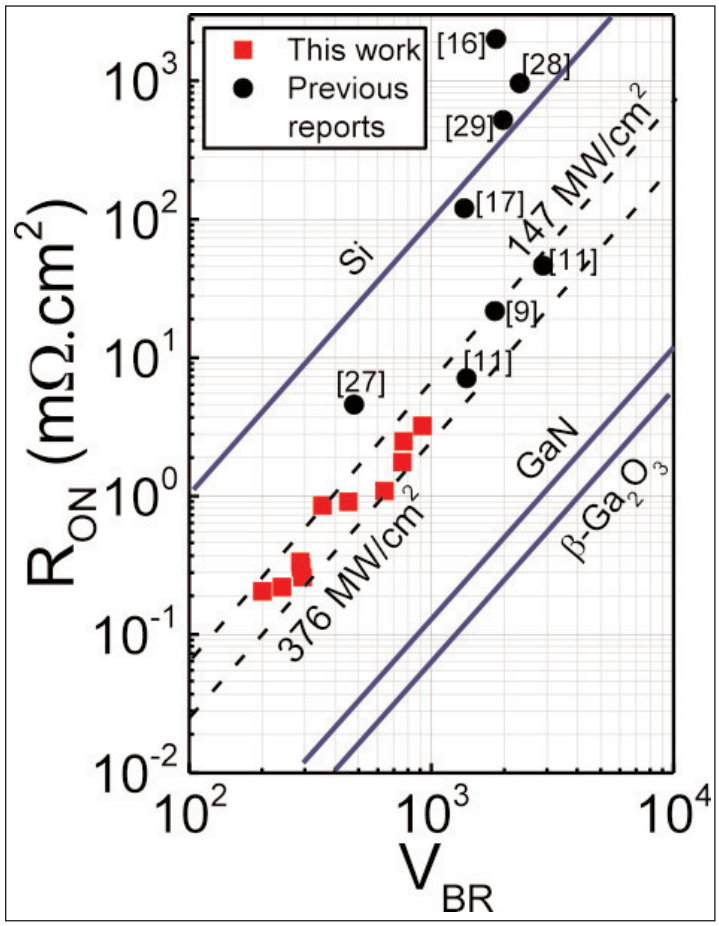

Figure 2. Benchmark plot against previous β-Ga_2O_3 lateral transistor reports.

Reverse-bias current measurements suggested that gate leakage limited the breakdown performance. Simulations showed a spike in electric field at the gate corner, which in the device would increase gate current leakage and result in dielectric breakdown.

The power figure of merit V_{br}^2/R_{spON} balances the trade-off of breakdown and specific on resistance, normalized to the source–drain area (L_{sd} x width). The devices all achieved a value for this figure of merit greater than 147MW/cm^2, reaching 376MW/cm^2 for 4.7μm L_{sd} and 3μm L_{gd}, which had 640V V_{br} and 1.08mΩ-cm^2 R_{spON}. The team claims the 376MW/cm^2 figure as "the highest reported value for any β-Ga_2O_3 transistor to the best of our knowledge" (Figure 2).

The researchers comment: "The extreme-k field management strategy using $BaTiO_3$as the gate dielectric has thus resulted in superior performance even in the absence of additional field termination structures like field plates."

The team hopes that future devices could include such termination to further improve performance. ■

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

11 Process monitoring and control

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

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

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

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

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

12 Inspection equipment

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

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

13 Characterization equipment

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

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

14 Chip test equipment

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

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

15 Assembly/packaging materials

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

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

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

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

16 Assembly/packaging equipment

CST Global Ltd
4 Stanley Boulevard,
Hamilton International Technology Park,
Blantyre, Glasgow G72 0BN, UK
Tel: +44 (0) 1698 722072
www.cstglobal.uk

Kulicke & Soffa Industries
1005 Virginia Drive,
Fort Washington, PA 19034,
USA
Tel: +1 215 784 6000
Fax: +1 215 784 6001
www.kns.com

Palomar Technologies Inc
2728 Loker Avenue West,
Carlsbad, CA 92010,
USA
Tel: +1 760 931 3600
Fax: +1 760 931 5191
www.PalomarTechnologies.com

PI (Physik Instrumente) L.P.
16 Albert St . Auburn ,
MA 01501,
USA
Tel: +1 508-832-3456,
Fax: +1 508-832-0506
www.pi.ws
www.pi-usa.us

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

17 Assembly/packaging foundry

Quik-Pak
10987 Via Frontera,
San Diego, CA 92127,
USA
Tel: +1 858 674 4676
Fax: +1 8586 74 4681
www.quikicpak.com

18 Chip foundry

CST Global Ltd
4 Stanley Boulevard, Hamilton International Technology Park,
Blantyre,
Glasgow, G72 0BN,
UK
Tel: +44 (0) 1698 722072
www.cstglobal.uk

United Monolithic Semiconductors
Route departementale 128,
BP46, Orsay, 91401,
France
Tel: +33 1 69 33 04 72
Fax: +33 169 33 02 92
www.ums-gaas.com

19 Facility equipment

RENA Technologies NA
3838 Western Way NE,
Albany, OR 97321,
USA
Tel: +1 541 917 3626
www.rena-na.com

20 Facility consumables

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

W.L. Gore & Associates
401 Airport Rd, Elkton,
MD 21921-4236,
USA
Tel: +1 410 392 4440
Fax: +1 410 506 8749
www.gore.com

21 Computer hardware & software

Crosslight Software Inc
121-3989 Henning Dr.,
Burnaby, BC, V5C 6P8,
Canada
Tel: +1 604 320 1704
Fax: +1 604 320 1734
www.crosslight.com

Semiconductor Technology Research Inc
10404 Patterson Ave.,
Suite 108, Richmond, VA 23238,
USA
Tel: +1 804 740 8314
Fax: +1 804 740 3814
www.semitech.us

22 Used equipment

Brumley South Inc
422 North Broad Street,
Mooresville, NC 28115, USA
Tel: +1 704 664 9251
Email: sales@brumleysouth.com
www.brumleysouth.com
As an ISO 9001 registered global leader in the remanufacturing of wafer inspection systems, Brumley South Inc specializes in designing, installing and supporting upgrades for ADE, Nanometrics, Dryden and KLA-Tencor Surfscan tools, polysterene latex sphere calibration standards, particle deposition systems, and semiconductor parts and service.

Class One Equipment Inc
5302 Snapfinger Woods Drive,
Decatur, GA 30035, USA
Tel: +1 770 808 8708
Fax: +1 770 808 8308
www.ClassOneEquipment.com

23 Services

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

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

24 Resources

Al Shultz Advertising Marketing for Advanced Technology Companies
1346 The Alameda,
7140 San Jose,
CA 95126, USA
Tel: +1 408 289 9555
www.alshuktz.com

SEMI Global Headquarters
San Jose, CA 95134,
USA
Tel: +1 408 943 6900
www.semi.org

Yole Développement
69006 Lyon, France
Tel: +33 472 83 01 86
www.yole.fr

SEMI Global Headquarters
3081 Zanker Road,
San Jose,
CA 95134, USA
Tel: +1 408 943 6900
www.semi.org

event calendar

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

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

19–20 April 2021
(postponed from 26–29 April 2020)
2nd International Conference on UV LED Technologies & Applications (ICULTA 2021)
— now a virtual, online event
E-mail: contact@iculta.com
www.ICULTA.com

20–22 April 2021
(postponed from 21–23 April 2020)
24th Annual Components for Military & Space Electronics Conference & Exhibition (CMSE 2021)
— now a virtual, online event
E-mail: info@tjgreenllc.com
www.tjgreenllc.com/cmse

9–14 May 2021
2021 Conference on Lasers & Electro-Optics (CLEO)
— now a virtual, online event
E-mail: CLEO@compusystems.com
www.cleoconference.org

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

6–10 June 2021
(postponed from 28 March –1 April 2021)
OFC 2021: Optical Networking and Communication Conference & Exhibition
— now an online, virtual event
E-mail: OFC@csreg.zohodesk.com
www.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.org
www.apec-conf.org

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

advertisers' index

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

~~**22–24 June 2021**~~ **(postponed to 24–26 Aug 2021)**
Strategies in Light 2021
Santa Clara Convention Center, Santa Clara, CA, USA
E-mail: registration@endeavorb2b.com
www.strategiesinlight.com

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

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

1–5 August 2021
SPIE Optics + Photonics 2021 — Conference and Exhibition
San Diego Convention Center, San Diego, CA, USA
E-mail: customerservice@spie.org
www.spie.org/opstm

24–26 August 2021 (postponed from 9–11 February 2021, then 22–24 June 2021)
Strategies in Light 2021
Santa Clara Convention Center, Santa Clara, CA, USA
E-mail: registration@endeavorb2b.com
www.strategiesinlight.com

1–3 September 2021
CIOE 2021 (23rd China International Optoelectronic Exposition)
Shenzhen World Exhibition & Convention Centre, China
E-mail: cioe@cioe.cn
www.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.org
www.icscrm2021.org

13–15 September 2021
ECOC 2021 (47th European Conference on Optical Communication)
Bordeaux Exhibition Centre, Bordeaux, France
E-mail: sales@ecocexhibition.com
www.ecocexhibition.com/ecoc-exhibition-2021

22–24 September 2021
LASER World of PHOTONICS INDIA 2021
Bengaluru, India
E-mail: info@world-of-photonics-india.com
www.world-of-photonics-india.com

10–14 October 2021
27th International Semiconductor Laser Conference (ISLC 2021)
Potsdam, Germany
E-mail: islc@fbh-berlin.de
www.islc2021.org

10–15 October 2021
24th European Microwave Week (EuMW 2021)
ExCel, London, UK
E-mail: eumwreg@itnint.com
www.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.fr
www.ecscrm-2020.com

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

13–15 December 2021
67th IEEE International Electron Devices Meeting (IEDM 2021)
San Francisco, CA USA
E-mail: info@ieee-iedm.org
www.ieee-iedm.org

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

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