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Skyworks and Qorvo cut guidance • Transphorm raises $21m
Eta develops 4” SI GaN • Ecosense acquires Soraa’s assets

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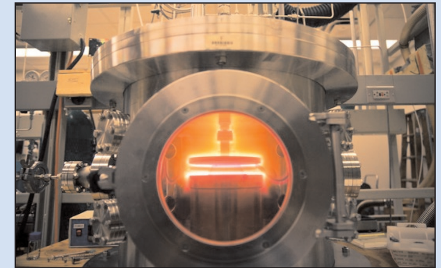
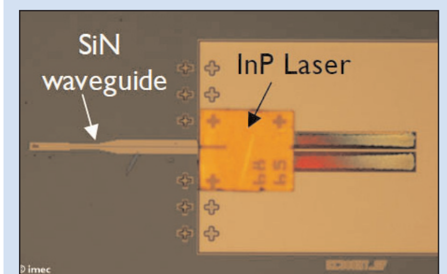


p26 Fraunhofer IAF's GaN transistors have achieved record efficiency of 77.3%, enabling applications in plasma generation for example.

p36 EVG has established the Heterogeneous Integration Competence Center to aid customers developing new products.



p49 InP DFB lasers from CST Global's InP100 platform have been integrated into imec's integrated silicon photonics platform (iSiPP).

Cover: X-FAB Silicon Foundries is now offering SiC foundry services at the scale of silicon, becoming the first pure-play foundry to add internal SiC epitaxy capabilities. X-FAB aims to further expand its SiC capacity at its facility in Lubbock, TX, USA, where it has capacity of 26,000 wafers per month. **p15**

Covid-19 spreads uncertainty

Since the last editorial at the end of February, when cases of Coronavirus globally were just surpassing those within China, the impact has transitioned from limiting or disrupting activities to almost total suspension of non-vital activities as the severity of the affect on public health has magnified.

The Optical Networking and Communication (OFC) event in San Diego went ahead on 8–12 March despite some exhibitors withdrawing and some conference delegates having to participate remotely. However, most events since then, through to at least June, have been either postponed or cancelled, sometimes in favour of a 'virtual' version online (see our Calendar on page 94).

Disruption to industry supply chains is having a severe impact in the short term, and may change many things in the long-term.

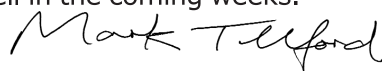
Strategy Analytics reckons that smartphone shipments fell a record 38% year-on-year in February, focused on the impact on both supply and demand in China. In mid-March TrendForce cut its forecast for first-quarter 2020 smartphone production again, from 12% to 13.3% down year-on-year (while also reducing its forecast for 2020 5G smartphone production from 250 million to 200 million units) - see page 7. However, this was on the basis that the Coronavirus outbreak could be contained by the end of Q2/2020, which may be optimistic.

In response to the impact of the Covid-19 outbreak, both RF chip makers Skyworks and Qorvo (in the USA) have reduced their March-quarter revenue guidance by about 6% (see page 8). "The novel coronavirus (Covid-19) has impacted the smartphone supply chain and customer demand more than anticipated," noted Qorvo, adding that "given the uncertainty of the magnitude, duration and geographic reach of the outbreak, the full impact of Covid-19 remains difficult to forecast". Also, epitaxial deposition and process equipment maker Veeco Instruments has withdrawn its Q1/2020 financial guidance (page 30). In contrast, further up the supply chain from end-users and aided by high levels of automation, epiwafer foundry and substrate maker IQE has been able to continue production at its sites in the UK, Taiwan, Singapore and the USA (where it is deemed a 'critical infrastructure provider'), and has maintained its prior guidance for Q1/2020 (page 28). However, IQE is "unable to provide more explicit guidance [for the rest of 2020] at this point in time".

ABI Research forecasts that smartphone production will fall as much as 30% in first-half 2020 (see page 6). "No sooner had 5G smartphones started to gain some traction and break into the market in significant numbers, than the outbreak will now trigger a suppression of its near-term growth, pushing out the development and introduction of affordable 5G phones," it notes. "This move to lower-price tiers was expected to become a key driver for boosting 5G smartphone shipments in 2020, but the desired impact will now be lessened throughout the year," it adds. "In the longer term, expectations are that the outbreak will gradually come under control by end of second-quarter 2020, but it will take some time thereafter for consumer confidence to return and for the device sector to recover," it concludes.

More generally, Covid-19 may change some trends, perhaps boosting home-working/video conferencing (and hence fiber communications) and limiting travel (and hence the automotive sector). In the meantime, Semiconductor Today wishes our readers well in the coming weeks.

Mark Telford, Editor



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

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

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Smartphones production may fall 30% in first-half 2020

Whitepaper identifies short-and long-term impacts of COVID-19

The Coronavirus outbreak is expected to lead to a huge reduction in the production of smartphones, potentially falling by as much as 30% in first-half 2020, reckons market advisory firm ABI Research.

"The ripples from China will be felt globally," says David McQueen, 5G Devices Research Director at ABI. With China located at the epicenter of the COVID-19 outbreak, the resultant impact has been disastrous for the global mobile device market, which has subsequently seen mass disruption to its production lines and a stalling of related supply chains caused by labor shortages and inactive logistics. As China is also the world's manufacturing center for most of these device types, and one of its biggest markets, the sector has been hit hardest by delayed shipments and a weakened development of next-generation products.

"Significantly, in the short term, there will be an adverse effect on 5G devices. No sooner had 5G smartphones started to gain some traction and break into the market in significant numbers, than the outbreak will now trigger a suppression of its near-term growth, pushing out the development and introduction of affordable 5G phones," says McQueen. This move to lower-price tiers was expected to become a key driver for boosting 5G smartphone shipments in 2020, but the desired impact will now be lessened throughout the year due to the outbreak. Shipment volumes for 5G smartphones in 2020 will be much lower than previously expected, slowed by a stagnant supply chain and crippled demand. "Undoubtedly, the market will also be faced with numerous disruptions and delays, most notably the launch of Apple's first 5G iPhones that are due to appear in September," he adds.

No sooner had 5G smartphones started to gain some traction and break into the market in significant numbers, than the outbreak will now trigger a suppression of its near-term growth, pushing out the development and introduction of affordable 5G phones

In the longer term, expectations are that the outbreak will gradually come under control by end of second-quarter 2020, but it will take some time thereafter for consumer confidence to return and for the device sector to recover. "Importantly, with such a large proportion of the world's mobile device market relying on China for manufacturing and component supply, which is contending with disruption on a massive scale, it has become clear that many in the chain were woefully unprepared to react quickly," McQueen notes.

The full extent or lasting effect of COVID-19 on the mobile device ecosystem is not yet clear, but in the short- to medium-term it will heavily impact the smartphone market. "Aside from taking its toll on both demand and the supply chain, it will particularly affect the industry's eagerness to drive 5G to lower price points in 2020, seriously blunting its growth potential," says McQueen.

He recommends that "vendors and suppliers fully understand their exposure to all those along the chain, identifying and evaluating all risks related to issues like capacity management and market demand, enabling them to react accordingly and mitigate the impact of any future market disruptions."

A clearer picture of the current and future ramifications of COVID-19 across technologies and verticals, including 5G devices, smartphones and wearables, is available by downloading the whitepaper 'Taking Stock of COVID-19: The Short- and Long-Term Ramifications on Technology and End Markets' from ABI's website.

https://go.abiresearch.com/lp-taking-stock-of-covid-19

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Q1/2020 smartphone production forecast cut again, from 12% down to 13.3% down year-on-year

Full-year 2020 to drop 3.5% as COVID-19 outbreak disrupts first-half

Due to hindrances such as uneven factory work resumption statuses, a generally low rate of returning labor, and breaks in logistics and transportation, the smartphone supply chain is continuing to feel the effects of the COVID-19 outbreak and has not been recovering as previously expected, notes market analyst firm TrendForce.

The outbreak's impact is projected to last 1–3 months, and the supply chain will not recover to normal levels until the second half of March at the earliest. So, TrendForce is further reducing its projection of first-quarter 2020 smartphone production from the pre-outbreak forecast of 307 million units and its post-outbreak forecast (of 10 February) of 275 million units (down 12% year-on-year) to 270 million units (down 13.3% year-on-year).

In terms of Q1/2020 demand, sluggish Lunar New Year sell-through in the Chinese smartphone market led to excessively high stocks in the sales channels.
On the other hand, the outbreak has spread to more than 70 countries since the second half of February, in turn affecting the global economy and, by extension, smartphone sales in the overseas markets. TrendForce holds a relatively conservative outlook towards the Q2/2020 global smartphone market, with about 318 million units produced, an increase quarter-on-quarter but a 7.4% decrease year-on-year.

TrendForce anticipates that, assuming the outbreak can be contained by the end of Q2/2020, smartphone demand will go into a noticeable upswing in second-half 2020. Furthermore, with the release of 5G and multi-camera phones, 2020 global smartphone production is expected to reach 1.35 billion units, below the pre-outbreak forecast of 1.41 billion but down only 3.5% year-on-year.

Slowdown of China 5G subsidies may defer 5G handset demand

Notably, the government of China (the leading market in terms of 5G development) is allocating most of its current budget to disease prevention and stabilization, potentially reducing 5G telecom funding. Also, since 5G infrastructure is not yet widespread, and new applications of the technology yet remain in their infancy, consumers have taken a wait-and-see approach regarding 5G smartphones, notes TrendForce. On the other hand, as the outbreak considerably affected the global economy, the general public has conserved its disposable income, deferring demand for 5G. TrendForce is thus reducing its 2020 5G smartphone production forecast from 250 million units to 200 million units, with a 15% penetration rate in the overall smartphone market.

Should the outbreak intensify, market demand will become the most important consideration in the long-term analysis of the smartphone industry, says TrendForce. Because of the interconnectedness of the global economy, the progression of the outbreak is damaging not only China's GDP but also the overall global economy, leading to a cutback in consumer purchasing power and shrinking the overall smartphone industry — including 5G — even further, the firm adds.

www.trendforce.com

Smartphone shipments fall a record 38% year-on-year in February, from 99.2 million in 2019 to 61.8 million in 2020

Global smartphone shipments tumbled a record 38% year-on-year in February, from 99.2 million units in February 2019 to 61.8 million in February 2020 (compared with year-on-year contraction of just 3% a year ago), according to the report 'Global Smartphone Monthly Shipments in 2020' by the Strategy Analytics Wireless Smartphone Strategies (WSS) service

"Smartphone demand collapsed in Asia last month, due to the Covid-19 outbreak, and this dragged down shipments across the world," notes Strategy Analytics director Linda Sui. "Some Asian factories were unable to manufacture smartphones, while many consumers were unable or unwilling to visit retail stores and buy new devices," she adds.

"February 2020 saw the biggest fall ever in the history of the worldwide smartphone market," says executive director Neil Mawston. "Supply and demand of smartphones plunged in China, slumped across Asia, and slowed in the rest of the world," he adds.

"Despite tentative signs of recovery in China, we expect global smartphone shipments overall to remain weak throughout March," notes senior analyst Yiwen Wu. "The coronavirus scare has spread to Europe, North America and elsewhere, and hundreds of millions of affluent consumers are in lockdown, unable or unwilling to shop for new devices. The smartphone industry will have to work harder than ever to lift sales in the coming weeks, such as online flash sales or generous discounts on bundling with hot products like smartwatches."

www.strategyanalytics.com

Power GaN device market grows 16% in Q4/2019

Growth driven by adoption for fast chargers in consumer electronics

The gallium nitride (GaN) power industry has been driven by demand from the consumer fast-charger market, with a lot of announcements being made by leading OEMs, including Oppo, Xiaomi and REALme, notes Yole Développement in its 'Compound Semiconductor Quarterly Market Monitor'.

The adoption of GaN by Oppo in fourth-quarter 2019 marks the first milestone for volume production of power GaN devices. Since then numerous smartphone OEMs, such as Samsung, Xiaomi and Realme have integrated power GaN devices in their accessory or inbox fast chargers, the market research firm adds.

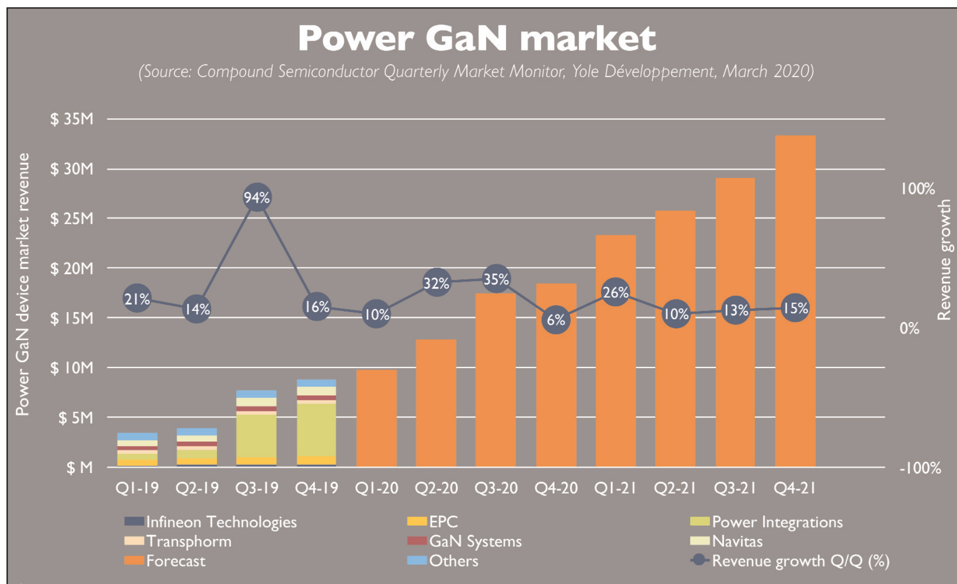
In the light of recent GaN adoption in consumer fast-charger applications, the power GaN device market is estimated to have grown 16% quarter-to-quarter in Q4/2019.

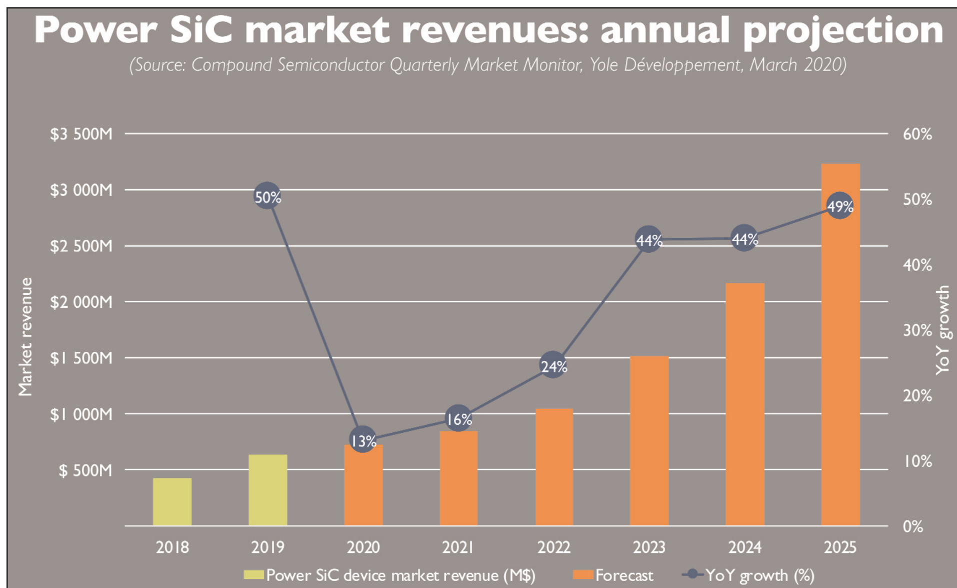
"This is only the beginning of the power GaN market's emergence," says technology & market analyst Ezgi Dogmus. "GaN has taken an important leap in its challenging course and is expected to also enter other major OEMs such as Apple and Huawei fast chargers. In this context, 2020 and 2021 are important years to watch for further market acceptance and the speed of GaN-based high-power changers' proliferation."

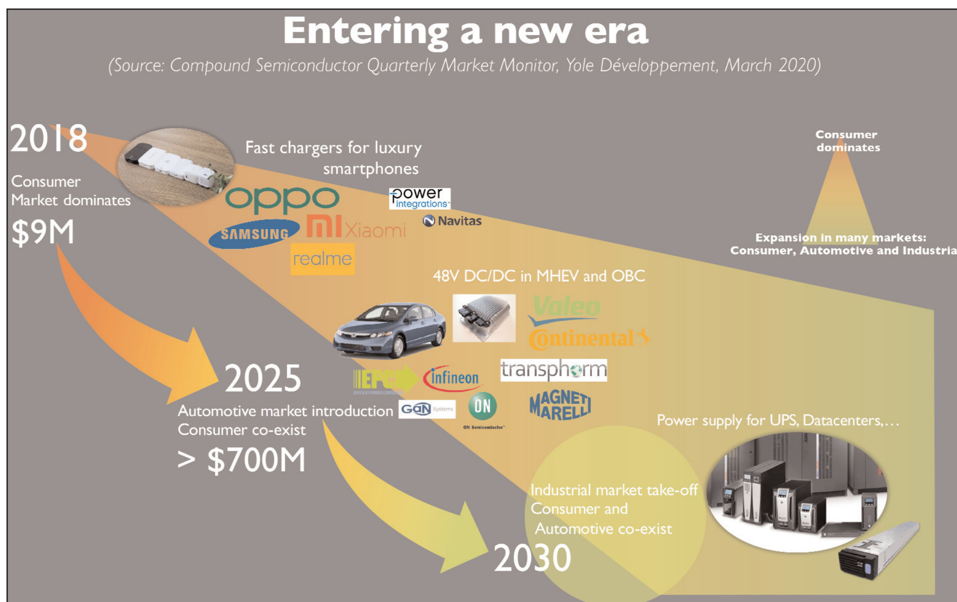
GaN and SiC power business: What's next?

The beginning of 2020 shows that this year will be the year of GaN, reckons Yole. But, in parallel, silicon carbide (SiC) is continuing its emergence. Driven mainly by electric vehicles and hybrid electric vehicles (EVs/HEVs), EV charging infrastructure and industrial power supply applications, Yole expects SiC power discrete and modules to play a key role in the coming years. Power SiC market revenue is expected to grow at over 13% year-to-year to exceed $3bn by 2025.

www.i-micronews.com/products/compound-semiconductor-service-compound-monitor







Skyworks and Qorvo reduce March-quarter guidance by about 6% due to impact of COVID-19

Smartphone supply chain and customer demand hit more than expected

Both Skyworks Solutions Inc of Woburn, MA, USA (which makes analog and mixed-signal semiconductors) and Qorvo Inc of Greensboro, NC, USA (which provides core technologies and RF solutions for mobile, infrastructure and defense applications) have reduced their March-quarter financial guidance in response to the global spread of the severe acute respiratory syndrome coronavirus 2 (SARS-CoV-2).

Reflecting the unanticipated impact that the COVID-19 outbreak is having on the business environment, for its fiscal second-quarter 2020 (ending 27 March) its Skyworks has reduced its guidance for revenue by about 5.6% from $800–820m (provided on 23 January) to $760–770m, and for non-GAAP diluted earnings per share from $1.46 to $1.34.

"Although COVID-19 has caused no significant disruption within Skyworks' manufacturing operations to date, the current demand environment for our products has been negatively impacted by interruptions in global supply chains," says president & CEO Liam K. Griffin. "Despite this, we remain upbeat about our design-win momentum and our ability to deliver strong profitability and cash flow," he adds. "As we navigate these challenges, we continue to focus on the health and safety of all our employees, customers and partners worldwide."

For its fiscal fourth-quarter 2020 (ending 28 March), Qorvo has reduced its guidance for revenue by $50m (6%), from $800–840m (provided on 29 January) to $770m. "The novel coronavirus (COVID-19) has impacted the smartphone supply chain and customer demand more than anticipated," says the firm. However, given the uncertainty of the magnitude, duration and geographic reach of the outbreak, the full impact of COVID-19 remains difficult to forecast, it adds.

www.skyworksinc.com
www.qorvo.com

Qorvo completes acquisition of Decawave

Decawave's CEO to lead Qorvo's new Ultra-Wideband business unit

Qorvo has completed its acquisition of Decawave Ltd of Dublin, Ireland, a pioneer in ultra-wideband (UWB) technology and a provider of UWB solutions for mobile, automotive and Internet of Things (IoT) applications. The Decawave team has become the Ultra-Wideband business unit (UWBU) within Qorvo Mobile Products. The firm's CEO Ciaran Connell will lead the UWBU team as its general manager.

Decawave was founded in 2007 and has deployed more than 8 million chipsets in over 40 different market verticals — from smartphones to drones. Its Impulse Radio UWB technology allows for position accuracy of a few centimeters, and with extremely low latency.

"We are excited about the growth potential offered by UWB and the opportunity to build upon the pioneering work of the Decawave team," comments Eric Creviston, president of Qorvo Mobile Products. "We see tremendous opportunities for Decawave's technology as UWB expands into new markets in mobile, automotive and industrial and consumer IoT," he adds. "We look forward to collaborating with customers to develop UWB solutions that greatly increase the accuracy and security of a host of new location and communication services."

Qorvo wins GTI Award for RF Fusion 5G chipset

Qorvo's RF Fusion 5G chipset has won the 2020 GTI Innovative Breakthrough in Mobile Technology Award. The award recognizes Qorvo's breakthrough innovation in 5G chipsets, which combines compact, high-performance 5G functionality with quick time to market for leading smartphone manufacturers. This is the second time that Qorvo's 5G offerings have been recognized with the GTI Award.

The Global TD-LTE Initiative (GTI) is an open global association of operators and vendors dedicated to promoting the development of TD-LTE and 5G. The GTI Awards program recognizes the most outstanding achievements and success in the industry and encourages the development of innovative products, services and applications.

"This award underscores Qorvo's technology and product leadership in 5G RF front ends," says Eric Creviston, president of Qorvo's Mobile Products Group.

RF Fusion 5G solutions support all 5G bands and utilize E-UTRA New Radio — Dual Connectivity (EN-DC) with full standalone operation, including dual 5G uplink. The range is in full-volume production and offers high reliability and superior performance through use of its GaAs power amplifiers and BAW filters. Qorvo is supporting the launch of multiple new 5G handsets.

Anokiwave announces full commercial release of third-generation 5G mmW IC family

Anokiwave Inc of San Diego, CA, USA — which provides highly integrated silicon core chips and III-V front-end integrated circuits for millimeter-wave (mmW) markets and active antenna-based solutions — has announced commercial high-volume availability of what it claims is the most advanced and complete portfolio of silicon ICs for mmW 5G.

The latest generation brings a complete RF signal chain solution for all mmW bands in play — 24/26GHz, 28GHz and 37/39GHz — to the market while providing extensive functionality that simplifies the active antenna array design. The scalable architecture underpinning the mmW 5G IC family supports everything from mmW 5G macro-cells to small-cells to customer premises equipment with a scalable architecture that supports each use case.

Focusing on the innovation that allows ICs to span the 5G use case spectrum with intelligent array solutions while partner GlobalFoundries provides full turnkey production and mmW test capabilities, Anokiwave has enabled the model of handset technology high-volume manufacturing for all 5G use cases.

"By harnessing the appropriate level of integration, three generations of active-antenna IC learning and cost structures only available on 300mm-diameter silicon processes, we have enabled total ownership for base-stations and small cells that resemble Wi-Fi access points," says chief systems engineer David Corman. "Anokiwave ICs deliver the maximum number of options for performance, cost and functionality for mmW 5G."

"The commercial availability of Anokiwave's mmW IC portfolio is an important step in making 5G connectivity a reality," comments Peter Rabbeni, VP Mobile and Wireless Infrastructure at GlobalFoundries. "Our differentiated RF SOI solutions provide the optimal combination of performance, integration and power efficiency, and our turnkey services enable our clients such as Anokiwave to bring innovative 5G network architecture products to market quickly, enabling a host of new consumer, industrial and automotive applications. Realizing the power of 5G will not happen without the specialty solutions that GF delivers."

The ICs are each packaged in a small WLCSP, fitting within the small lattice spacings at mmW. For ease of adoption, Anokiwave offers evaluation kits that include boards, USB-SPI interface module with drivers and all required cables.

Anokiwave's Gen-2 Ka/Ku-band silicon beam-former ICs for SatComs in large-scale production at GlobalFoundries

Anokiwave has announced high-volume availability of its latest generation of Ku- and K/Ka-band silicon ICs for flat-panel electronically steered antennas. The second generation of SatCom ICs — AWMF-0132/0133 and -0146/0147 quad-channel, dual-polarization beam-former ICs — enable Ku- and K/Ka-band flat-panel phased-array active antennas for SatCom ground terminals and aero equipment for LEO/MEO/GEO and SatCom-on-the-move (SOTM) and are already tested and in use on multiple live satellite links. Anokiwave says it is the only company that has been commercially shipping mmW silicon beam-former ICs in high volume, across SatCom (Ku and Ka), 5G and radar bands.

Combining Anokiwave's innovation that allows the ICs to span the mmW application spectrum with intelligent array solutions with the strength of its partner GlobalFoundries (GF) of Santa Clara, CA, USA in full turnkey production and mmW test capabilities, the two firms are leveraging high-volume production and technical learning of all mmW markets into SatCom products which reduces risk to customers, provides the lowest-cost solution available, and allows very quick time-to-market.

Anokiwave's second-generation SatCom beam-former ICs builds on its prior generation to improve performance, reduce cost, simplify thermal management, and provide a unique digital functionality to simplify overall system design. Anokiwave says that, compared with other firms that are just beginning to promise their early stage ICs, its ICs are fully released and have been shipping in volume to tier-1 and -2 SatCom OEMS. They have been used to build and deploy radios that have been setup with live satellite communication links and offer a level of confidence to ensure first-pass design success.

"The satellite market is growing fast and, to enable low-profile and low-cost flat-panel active antennas, the SatCom market needs beam-former IC solutions that work today, not months or a few quarters from now," says VP of sales Abhishek Kapoor. "The market does not have the appetite to wait and risk multimillion-dollar developments with first-generation IC designs. Anokiwave's Ku- and K/Ka-band SatCom ICs that build upon years of experience and multiple generations of designs have already been delivered to the market for years. Leveraging GlobalFoundries full turnkey production and mmW test capabilities, our new Ku- and K/Ka-band ICs are available today and already used in volume by multiple tier-1 and -2 SatCom OEMs for phased-array-based ground and avionics equipment."

www.anokiwave.com/satcom

Tower's SiGe technology adopted by Renesas for production of SatCom RFICs

The compact and highly efficient Ku- and Ka-band active beamforming and Low Noise Amplifier RFICs will enable next-generation terminals that utilize phased array antennas for LEO, MEO and GEO satellite communications

Specialty foundry Tower Semiconductor Ltd (which has fabrication plants in Migdal Haemek, Israel, and at its US subsidiaries in Newport Beach, CA and San Antonio, TX, and at TowerJazz Japan Ltd) says that its silicon germanium (SiGe) BiCMOS platform has been selected for the development and production of Renesas Electronics' beam-forming and amplifier RFICs for phased-array antenna applications.

Phased-array antennas — or, more specifically, active electronically scanned arrays (AESAs) — have been a staple of the defense industry for over 40 years, but are now rapidly emerging in the commercial marketplace due to the exponentially growing demands for connectivity. These antennas will be critical to the enablement of high-data-rate, low-latency connectivity in the air, at sea and on the ground, taking advantage of the rapid growth in throughput from existing GEO and emerging non-geostationary (NGSO) LEO/MEO satellite networks.

"In migrating to AESAs from mechanical antennas, our customers require reliable, compact and cost-effective ICs with exceptionally low power consumption and noise figure that meet their system EIRP (equivalent isotropically radiated power) and G/T requirements," says Naveen Yanduru, VP of RF Communications, Industrial and Communications Business Division at Renesas. "Thanks to the strong collaboration between Tower Semiconductor and our world-class design team, we are exceeding our customer's expectations by all metrics and progressing rapidly into production."

By leveraging its high-performance SiGe BiCMOS technology, Renesas is able to achieve unprecedented levels of integration, says Tower. For example, the Renesas 8-channel transmit IC has a footprint of only $2mm^2$ per transmit channel and consumes less than 100mW, while delivering 10dBm of output power. Several design parameters had to be pushed to their limits to achieve these results and required a close collaboration between the companies to ensure the accuracy of design models and first-pass success. During early development, the Renesas design team also took advantage of the flexibility and customization of the Tower process offerings to identify the optimal compromise between cost and performance.

"This complements the booming opportunities we see for similar phased-array products in 5G mmWave and automotive radar where SiGe offers dramatically lower power consumption than alternatives while preserving the ability for high levels of integration and low cost," says Marco Racanelli, Tower Semiconductor's senior VP & general manager of Analog IC business unit.

By some estimates, the SatCom market is projected to rise at a compound annual growth rate (CAGR) of 10% to $50bn by 2027. In the same timeframe, the number of satellites is projected to triple from about 8000 to 24,000, driven primarily by growth in NGSO communications satellites providing ubiquitous high-data-rate and low-latency communications. This is expected to fuel a transition from fixed and mechanically steered antennas to electronically steered antennas, creating a significant market for beam-forming ICs.

www.renesas.com/eu/en
www.towersemi.com

Analog Devices withdraws fiscal Q2/2020 guidance

In a business update related to the coronavirus (COVID-19) pandemic, Analog Devices Inc (ADI) of Norwood, MA, USA (which provides mixed-signal ICs for cable access) notes that the economic and social effects caused by COVID-19 are creating supply-chain disruption and uncertainty around future demand. While customer demand in the quarter has been resilient, it has become increasingly difficult to quantify and forecast the business impact of COVID-19, the firm adds. As a result, ADI is withdrawing its outlook for its fiscal second-quarter 2020 (ending 2 May).

"We are stepping up to combat the COVID-19 pandemic by partnering with our customers and world-class healthcare organizations to deploy our innovative healthcare diagnostics solutions," says president & CEO Vincent Roche. "We remain steadfastly committed to supporting our customers, suppliers, and partners to the best of our ability in this unprecedented environment," he adds.

"Throughout ADI's 55-year history, we have encountered several 'Black Swan' events," Roche continues. "We will successfully navigate this one as we have done before given the strength of our talent, technology, and customer and supplier relationships, in addition to our sound financial position. While our team is moving with speed and agility to embrace these short-term challenges, we remain focused on investing in ADI for the long term."

www.analog.com

CSA Catapult to coordinate Materials and Components aspects of UK's DER Industrialisation Centres

Network targets faster design, development and industrialization of power electronics, electric machines and drives, focusing on SiC

The UK's not-for-profit Compound Semiconductor Applications (CSA) Catapult, based in South Wales, says that Newport has been chosen as part of a national network of centers (spanning Newport, Nottingham, Glasgow and Sunderland) to enable faster design, development and industrialization of power electronics, electric machines and drives (PEMD) across seven sectors – including automotive, aerospace and energy.

Backed by £30m of UK Government funding, the 'Driving the Electric Revolution' (DER) Industrialisation Centres and their 35 partners will be a base for state-of-the-art equipment and will bring together the UK's innovators and manufacturers in electrification R&D. The network aims to help to propel the UK's advanced technologies and manufacturing capabilities to the fore on a national scale and to take the UK one step closer to its Net Zero ambitions.

Established by UK Government agency Innovate UK (which provides funding and support for business innovation as part of UK Research and Innovation), CSA Catapult is a not-for-profit organization (headquartered in South Wales) focused on accelerating the adoption of compound semiconductors and on bringing applications to life in four technology areas: power electronics, RF & microwave, advanced packaging and photonics. It works across the UK in a range of industry sectors from automotive to medical, and from digital communications to aerospace.

The new DER Industrialisation Centre based at CSA Catapult's Innovation Centre in Newport will coordinate the national Materials and Components and the South Wales and South West (SW2) aspects of the DER Industrialisation Centres. Partners currently include the Universities of Bath, Swansea, Cardiff, Bristol, Birmingham and Exeter, the CSA Catapult, the Compound Semiconductor Centre and a range of industrial organizations and partnerships.

"DER Centre SW2 will focus on the Materials and Component aspects of the national DER Industrialisation Centre capability and harness it to help grow the UK supply chain in the relevant technologies," says CSA Catapult's CEO Stephen Doran.

Because compound semiconductor technology, specifically silicon carbide (SiC), can cope with more power than silicon, it produces less heat in electronics than the silicon equivalent. SiC technology hence needs less cooling and, therefore, as cooling systems can be large, heavy and costly, this helps to reduce size, weight and expense.

One application where this will be beneficial is with electric vehicles (EVs) because reducing size and weight leads to a longer time without needing to re-charge, reducing 'range anxiety'. Also, reducing expense could boost the use and hence production of electric vehicles, paving the way to the UK Government's route to Net Zero carbon emissions.

"The announcement of the DER Industrialisation Centres' program is exciting news for PEMD in the UK. The centres will bring together UK-wide PEMD capability with industry requirements to accelerate supply chain development," says Garry Wilson, Industrialisation Centre – SW2. "The Materials and Components and SW2 aspects of the national DER Industrialisation Centres' program include world-class capabilities in compound semiconductors and magnetic materials," he adds. "SW2 as a region is a global leader in a range of the critical PEMD technologies which are applicable across all seven of the DER Challenge sectors that will underpin the growth in the UK PEMD supply chain."

www.csa.catapult.org.uk

Raytheon Supplier Excellence Award for Teledyne e2v HiRel

Teledyne e2v HiRel of Milpitas, CA, USA (a business unit of the Teledyne Defense Electronics Group that provides solutions, sub-systems and components to the space, transportation, defense and industrial markets) has been chosen by Raytheon's Integrated Defense Systems as a recipient of its 3-Star award for Supplier Excellence.

Raytheon's Integrated Defense Systems business instituted the annual Supplier Excellence Awards program to recognize suppliers that have provided outstanding service and partnership in exceeding customer requirements. Award candidates are judged on certain criteria, including overall quality and on-time delivery. Teledyne e2v HiRel was one of 34 companies recognized for 3-Star honors.

Teledyne e2v HiRel offers high-performance, high-reliability semiconductor solutions that address the critical functions of the complete signal chain. With a range of products and package solutions, HiRel caters to civil aerospace, industrial, medical, military, scientific and space applications.

www.e2v.com/products/semiconductors/power-solutions

Microchip expands SiC family of 700, 1200 & 1700V Schottky barrier diode-based power modules

Microcontroller, mixed-signal, analog and Flash-IP solution provider Microchip Technology Inc of Chandler, AZ, USA has (via its Microsemi subsidiary) has expanded its portfolio of silicon carbide (SiC) power modules, as demand continues to grow rapidly for SiC-based systems to maximize efficiency and reduce size and weight, allowing engineers to create innovative power solutions. Applications leveraging SiC technology range from electric vehicles and charging stations to smart power grids and industrial and aircraft power systems.

Microchip's SiC family includes commercially qualified Schottky barrier diode (SBD)-based power modules in 700, 1200 and 1700V variants. The new power module family includes various topologies including dual diode, full bridge, phase leg, dual common cathode and 3-phase bridge, in addition to offering different current and package options. The addition of the new SiC SBD modules simplifies designs by integrating multiple SiC diode die with the option to mix and match substrate and baseplate material into a single module — which maximizes switching efficiency, reduces thermal rise and allows for a smaller system footprint.

"SiC technology adoption and expansion is a driving force in today's system innovation and Microchip is at the forefront, collaborating with customers across all segments and global regions," says Leon Gross, VP of Microchip's Discrete Product Group business unit. "Our focus continues to be delivering reliable and innovative solutions. From definition to product release, our SiC technology provides superior reliability and ruggedness, helping power system designers to ensure a long application life with no degradation in performance," he claims.

The flexible portfolio of 700, 1200 and 1700V SiC SBD modules uses Microchip's new generation of SiC die, which maximizes system reliability and ruggedness and enables stable and lasting application life. The devices' high avalanche performance allows system designers to reduce the need for snubber circuits, and the body diode stability allows designs to use the internal body diode without long-term degradation.

The firm's 30kW 3-phase Vienna power factor correction (PFC), SiC discrete and SP3/SP6LI module drive reference designs/boards provide system developers tools to help reduce development cycle times. The recently added AgileSwitch family of digital programmable gate drivers further supports accelerating the process of moving from the design stage to production.

Microchip's 700, 1200 and 1700V SiC SBDs power modules are released and available for order. The complete SiC portfolio is supported by a range of SiC SPICE models, SiC driver board reference designs and a PFC Vienna reference design. Microchip SiC products are available in production volumes along with their associated support offerings. A variety of die and package options are available for the SiC MOSFETs and SiC diodes.

www.microchip.com/design-centers/

SK Siltron closes acquisition of DuPont's SiC wafer unit

Silicon wafer supplier SK Siltron of Gumi, South Korea has completed the acquisition of the silicon carbide wafer (SiC Wafer) unit of Delaware-based DuPont Electronics & Imaging (E&I). The acquisition was decided at a board meeting in September and closed on 29 February.

The $450m acquisition is regarded as a global technology investment to meet demand from consumers and governments for sustainable energy and environmental solutions. SK Siltron will continue to invest in related fields after the acquisition, which is expected to increase SiC wafer production and create additional jobs in the USA. The primary site for the business is in Auburn, MI, about 120 miles north of Detroit.

Demand for power semiconductors is rapidly increasing as automakers are entering the electric vehicle (EV) market and telecom companies are expanding ultra-fast 5G networks. High hardness, heat resistance and withstanding high voltages mean that SiC wafers can yield power semiconductors for EVs and 5G networks where energy efficiency is key.

Through this acquisition, SK Siltron expects to maximize R&D and production capabilities and synergy between its major businesses, while securing new growth engines by entering rapidly expanding areas.

SK Siltron is South Korea's only silicon wafer maker and one of the top five worldwide, with annual sales of 1.542 trillion won, accounting for 17% of global sales of silicon wafers (300mm-diameter equivalent). SK Siltron has overseas subsidiaries and offices in five locations — USA, Japan, China, Europe and Taiwan. Founded in 2001, the US subsidiary sells silicon wafers to eight customers, including Intel and Micron.

SK Siltron is an affiliate of Seoul-based SK Group, South Korea's third-largest conglomerate. SK Group has made North America a global hub, with its investments in the USA in batteries for EVs, biopharmaceuticals, materials, energy, chemicals and ICT, reaching $5bn in investment in the USA over the past three years.

www.sksiltron.com
www.dupont.com/electronic-materials.html

GTAT and ON Semiconductor sign five-year, $50m deal for production and supply of SiC material

ON Semiconductor to use GTAT's 150mm SiC crystal to make wafers

GT Advanced Technologies (GTAT) of Hudson, NH, USA — which produces silicon carbide (SiC) and sapphire material and crystal growth equipment for the solar, power electronics and optoelectronics industries) — has signed a five-year agreement, valued at a potential of $50m, to produce and supply its CrystX silicon carbide (SiC) material to power semiconductor IC supplier ON Semiconductor of Phoenix, AZ, USA, for use in high-growth markets and applications.

"Our agreement today helps address the very steep trajectory for SiC as the preferred semiconductor substrate material for power electronics applications," says GTAT's president &CEO Greg Knight.

Our agreement today helps address the very steep trajectory for SiC as the preferred semiconductor substrate material for power electronics

"Combining ON Semiconductor's 40 years of experience in high-volume wafer production with GTAT's expertise and rapid advancement in SiC crystal growth will create a robust and scalable supply chain for the dynamic high-power wide-bandgap market," says Brent Wilson, senior VP of global supply chain at ON Semiconductor.

High-growth applications such as electric vehicle (EV) traction systems, hybrid and plug-in EVs, solar and energy storage, and EV charging all require and depend on a robust supply of high-quality and cost-competitive SiC material. ON Semiconductor will use GTAT's proprietary 150mm SiC crystal to make its SiC wafers, to further accelerate its role as a vertically integrated supplier within the SiC supply chain and to maintain its supply.

www.gtat.com

ON Semiconductor launches 900V and 1200V SiC MOSFETs for demanding applications

ON Semiconductor of Phoenix, AZ, USA — which supplies power management, analog, sensors, logic, timing, connectivity, discrete, system-on-chip (SoC) and custom devices — has expanded its range of wide bandgap (WBG) devices with the introduction of two additional families of silicon carbide (SiC) MOSFETs for demanding high-growth applications including solar power inverters, on-board charging for electric vehicles (EV), uninterruptible power supplies (UPS), server power supplies and EV charging stations.

ON Semiconductor says that the new 1200V and 900V N-channel SiC MOSFETs deliver faster switching performance and enhanced reliability compared with silicon. A fast intrinsic diode with low reverse recovery charge delivers a significant reduction in power losses, boosts operating frequencies, and increases the power density of the overall solution.

High-frequency operation is further enhanced by the small chip size, which leads to a lower device capacitance and reduced gate charge Q_g (as low as 220nC), reducing switching losses when operating at high frequencies. These enhancements improve efficiency, reduce EMI compared with Si-based MOSFETs, and allow for the use of fewer (and smaller) passive components. The robust SiC MOSFETs offer higher surge ratings, improved avalanche capability and improved short-circuit robustness compared with silicon devices, delivering the higher reliability and longer lifetimes that are essential in demanding modern power applications. A lower forward voltage provides threshold-free on-state characteristics that reduce the static losses that occur when the device is conducting.

1200V devices are rated at up to 103A (I_D maximum), while 900V devices carry ratings as high as 118A. For applications requiring higher currents, ON Semiconductor's MOSFETs can be operated in parallel due to their positive temperature coefficient/temperature independence.

"If design engineers are to meet the challenging efficiency and power density goals that modern renewable energy, automotive, IT and telecom applications demand, then they require high-performance, high-reliability MOSFET devices," says Gary Straker, VP/general manager, Power MOSFET Division, in ON Semiconductor's Power Solutions Group. "ON Semiconductor's WBG SiC MOSFETs extend performance beyond what was possible with silicon devices, delivering lower losses, higher operating temperatures, faster switching, improved EMI and better reliability," he adds. "Further supporting the engineering community, ON Semiconductor provides a wide range of resources and tools that simplify and speed up the design process."

All of ON Semiconductor's SiC MOSFETs are Pb-free and halide-free, and the devices intended for automotive applications are AEC-Q100 qualified and PPAP capable. All devices are offered in industry standard TO-247 or D^2PAK packages.

www.onsemi.com

X-FAB further expands SiC capacity and adds new in-house epitaxy capabilities

In-house control of epi process to speed lead times and boost performance and yield

Analog/mixed-signal, micro-electro-mechanical system (MEMS) and specialty foundry X-FAB Silicon Foundries SE of Tessenderlo, Belgium is now offering silicon carbide (SiC) foundry services at the scale of silicon, becoming the first pure-play foundry to add internal SiC epitaxy capabilities. The firm says that, with its proven ability to run silicon and SiC on the same manufacturing line, customers have access to high-quality and cost-effective foundry. X-FAB aims to further expand its SiC capacity and, with the 26,000 wafers per month capacity at its facility in Lubbock, TX, USA, has the platform to meet growing customers demand, it reckons.

By offering in-house epitaxy, X-FAB is taking control of an additional part of the process chain. This should result in better lead times, so customers' products are faster in getting to market. Through the new epitaxy toolset (which comes with an option for dual epilayer implementations), X-FAB should be able to achieve greater epilayer uniformity, increasing device performance parameters and overall yield. The firm is also undertaking further investments in characterization tools to improve the epilayer quality, and is working with substrate manufacturers to ensure the long-term continuity of supply for essential raw materials.

With X-FAB's site in Lubbock focused on serving the SiC market, the company is prepared for the expected acceleration of SiC device shipments, enabling key applications such as electric vehicles (EVs) and advanced power management systems. It will allow customers to import their SiC projects into a stable and trusted, fully automotive-qualified fab environment that supports output levels that are comparable with those of integrated device manufacturers (IDMs), adds the firm.

"We have already demonstrated our SiC onboarding credentials, with numerous high-volume projects for diodes, metal-oxide-semiconductor field-effect transistors (MOSFETs) and junction field-effect transistors (JFETs) all currently running, and these are paving the way towards mass-market adoption," says Ed Pascasio, chief financial officer at X-FAB Texas. "By making even more capacity available for SiC, we will be able to keep up with demand requirements as this technology matures. Also, with all the required epitaxy expertise now located internally, X-FAB is in a unique position to control every aspect of SiC production," he adds. "Our engineering team has direct influence across the whole process, and this will translate into best-value performance and quality as well as more attractive price points."

www.xfab.com

Infineon adds D²PAK real 2-pin packages to CoolSiC Schottky diode family

Infineon Technologies AG of Munich, Germany has expanded its silicon carbide CoolSiC Schottky diode 1200V portfolio by adding six devices in D²PAK real 2-pin packages.

Using SMD packages, designs can be more compact and more cost effective. Moreover, the new D²PAK real 2-pin package eliminates the middle pin to offer 4.7mm creepage and 4.4mm clearance distance. Compared with a standard D²PAK package this enhances safety margins. The diodes are a suitable fit for applications such as industrial power supplies, and DC charging stations, uninterruptable power supplies (UPS) and solar string inverters.

The new devices use Infineon's CoolSiC Schottky diode 1200V technology G5, which offers what is claimed to be best-in-class forward voltage and high surge current capability. Additionally, it prevents reverse recovery losses and allows for temperature-independent switching behavior. These features can streamline designs with lower cooling requirements and smaller magnetics when used at higher switching frequency.

Available for order now, the CoolSiC Schottky diodes 1200V G5 are rated from 2A to 20A and represent what is claimed to be the broadest portfolio in a D²PAK real 2-pin package.

By using the new SiC diodes in the D²PAK real 2-pin package, designers are able to reach a new level of power density and reliability compared with silicon solutions, says the firm. Combined with other Infineon products, such as CoolSiC MOSFETs 1200V or TRENCHSTOP 1200V IGBT6 and EiceDRIVER gate driver ICs, the new portfolio offers a complete solution for high-efficiency designs.

www.infineon.com/sicdiodes1200v
www.infineon.com/coolsic

Nexperia partners with Ricardo to produce technology demonstrator for GaN-based EV inverter

Nexperia's AEC-Q101-approved GaN FETs to be designed into inverter and trialled through Ricardo

Nexperia BV of Nijmegen, Netherlands (which manufactures discrete and MOSFET components and analog & logic ICs) has announced a partnership with global transportation technology company Ricardo to produce a technology demonstrator for an electric vehicle (EV) inverter based on gallium nitride (GaN) technology.

Nexperia says that GaN is the preferred switch for these applications as GaN FETs lead to systems with greater efficiencies at lower costs with improved thermal performance and simpler switching topologies. In automotive terms this means that the vehicle has a greater range — the major concern for EV purchasers. GaN is on the brink of replacing silicon carbide (SiC) or silicon-based insulated-gate bipolar transistors (IGBTs) as the preferred technology for the traction inverters used in plug-in hybrids or full battery electric cars, adds the firm.

Last year Nexperia launched a range of AEC-Q101-approved GaN devices, providing automotive designers with a wider portfolio of proven, reliable devices, providing the power density required for electrification of the powertrain. Ricardo designs and consults on concepts within the automotive industry, including the manufacture of prototypes and demonstrations, and has collaborations with high-profile brands such as McLaren and Bugatti.

"By designing our GaN devices into an inverter and trialling them through Ricardo, we will be able to better understand how a vehicle can be driven safely and reliably," says Michael LeGoff, general manager GaN, Nexperia. "We are developing a real solution that I think a lot of automotive designers will be interested in having a look at," he adds.

"Semiconductor technology is key to the efficiency of the inverter system and the role that it plays in the performance and efficiency of an electrified vehicle," says Adrian Greaney, director - technology & products, Ricardo. "By delivering significant benefits in terms of the switching speed and efficiency, gallium nitride is a real enabling technology. As well as leading to increased range, it allows us to reduce the package size and weight of the inverter, which provides greater powertrain design flexibility as well as contributing to vehicle mass reduction," he adds. "There are also many associated benefits when we look at the design from a system level."

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

SweGaN grows revenue 300% year-on-year in 2019

SweGaN AB of Linköping, Sweden, which manufactures custom gallium nitride on silicon carbide (GaN-on-SiC) epitaxial wafers (based on unique growth technology) for RF and power electronics devices, has reported revenue growth of 300% year-on-year in 2019.

"2019 was an outstanding year for SweGaN, with a doubling of commercial orders and collaboration in multiple prestigious EU projects," says chief executive officer Olof Kordina.

The company's technology was highlighted in the largest Swedish technical magazine Ny Teknik, which selected SweGaN as one of the most promising and innovative young companies. Also, a featured article 'Transmorphic Epitaxial Growth of AlN Nucleation Layers on SiC Substrates for High-Breakdown Thin GaN Transistors' in the journal Applied Physics Letters, volume 115, issue 22, showed the material's unique very high electrical breakdown voltage, making it suitable for power devices.

"In 2020, we will continue focusing on ground-breaking product development, building our manufacturing capabilities and further energizing our global network of customers and strategic partners," says Kordina.

In addition, SweGaN has further strengthened its board of directors with the introduction of new members Agneta Franksson and Richard Weil at its annual meeting on 12 February:

- Agneta Franksson has an M.Sc. in Electrical Engineering and extensive experience from several CEO positions and over 25 years' experience in R&D and business development and sales. Since 2006, she has run her own management consulting company and has served on several boards of directors during the last 14 years.
- Richard is a co-founder and managing director of Mount Wilson Ventures, an early-stage venture fund that invests in hard-science companies rooted in biology, chemistry, materials science and data science. He is an experienced finance and operating professional with a background in start-up growth, financing and restructuring; banking; and management consulting.

"Agneta and Richard bring a wealth of specialized experience, valuable assets to the board of directors in further guiding SweGaN in its long-term strategy and growth," comments Kordina.

www.swegan.se

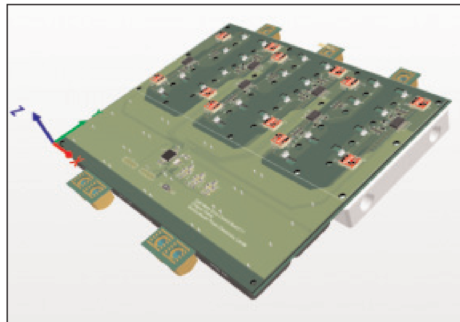
VisIC launches 100kW motor inverter reference design for 800V power-bus based on D3GaN

VisIC Technologies Ltd of Nes Ziona, Israel — a fabless developer of power conversion devices based on gallium nitride (GaN) metal-insulator-semiconductor high-electron-mobility transistors (MISHEMTs) for the automotive, data-center and industrial markets — has cooperated with the University of Texas at Austin to develop a 100kW inverter reference design that can be used as a base for a 800V power-bus motor inverter in electric vehicle (EV), industrial, PV and other applications.

Wide-bandgap (WBG) power technology is fast becoming the technology of choice to replace silicon in EV motor drives to achieve better efficiency. It is commonly viewed that GaN technology will be used primarily in the 400V power-bus due to its lower cost compared with other WBG technologies, and silicon carbide (SiC) is commonly used in the high-voltage 800V power-bus for higher-power applications. VisIC says that the new 100kW inverter reference design proves that GaN technology can also be used in the 800V power-bus applications, producing the most cost-effective solution for both the 400V and 800V EV power-bus.

Based on VisIC's unique D3GaN technology, the 100kW inverter reference design can be adapted to work both under 800V and 900V power-bus. The firm says that the GaN devices have highly thermally efficient SMD packaging, high threshold voltage, fast switching and easy paralleling for what is claimed to be most cost-effective, highly efficient and reliable inverter solution for EVs.

The estimated peak efficiency can reach 99.3% with 40kHz switching frequency, due to the low switching losses of D3GaN devices. The total dimension is 26.9cm x 21.4cm x3.5cm with liquid cooling heatsink. The power density is 50kW/liter including the liquid cooling. The total weight is about 2.5kg.



The developed 100kW 800V GaN-EV inverter.

"Previously GaN has demonstrated its superior performance in achieving high power density for chargers," says Dr Alex Huang, director of The Semiconductor Power Electronics Center at University of Texas at Austin. "Thanks to VisIC GaN's superior packaging concept and low losses, we believe high power density can also be achieved in very high-power application such as traction inverters," he comments.

"We are very happy with the cooperation with University of Texas as they've shown professional power design and innovative system solution," says VisIC's chief technology officer Gregory Bunin. "This breakthrough will also enable the 800V EV power-bus to benefit from the GaN low-cost and high-efficiency technology and provide cost-effective EV cars."

As the IEEE Applied Power Electronics Conference and Exposition (APEC 2020) in New Orleans (15–19 March) was cancelled, the inverter reference design is now planned to be displayed in booth 9-137 at PCIM 2020 (Power Conversion and Intelligent Motion) in Nuremberg, Germany (28–30 July).

www.visic-tech.com
www.spec.ece.utexas.edu
https://pcim.mesago.com/nuernberg/en.html

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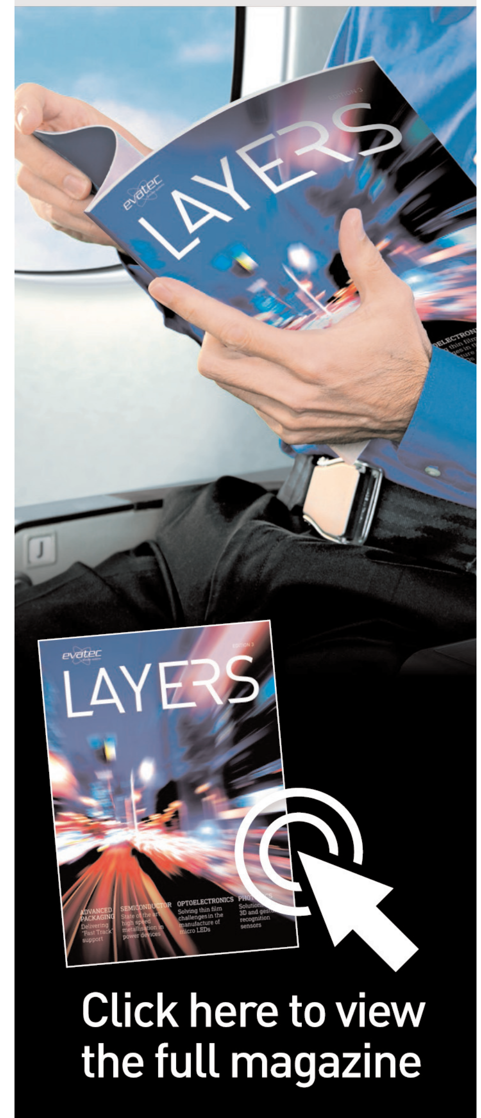
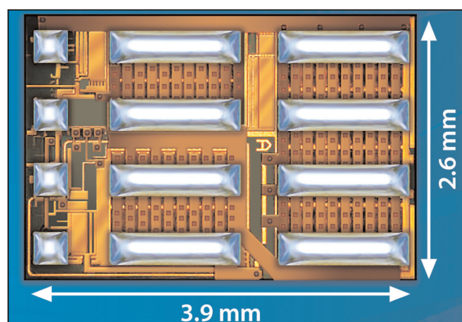


EPC launches first product in new ePower Stage IC family

Efficient Power Conversion Corp (EPC) of El Segundo, CA, USA — which makes enhancement-mode gallium nitride on silicon (eGaN) power field-effect transistors (FETs) for power management applications — has launched an 80V, 12.5A power stage integrated circuit designed for 48V DC–DC conversion used in high-density computing and in motor drives for e-mobility.

The EPC2152 is a single-chip driver plus eGaN FET half-bridge power stage using the firm's proprietary GaN IC technology. Input logic interface, level shifting, bootstrap charging and gate drive buffer circuits along with eGaN output FETs configured as a half-bridge are integrated within a monolithic chip. This results in a chip-scale LGA form-factor device that measures only 3.9mm x 2.6mm x 0.63mm.

When operated in a 48V-to-12V buck converter at 1MHz switching frequency, the EPC2152 ePower Stage achieves a peak efficiency above 96% with a solution that is 33% smaller in size on the printed circuit board (PCB) compared with an equivalent multi-chip discrete implementation, it is reckoned.



The EPC2152 is the first offering in what will be a wide-range family of integrated power stages available in chip-scale package (CSP) as well as multi-chip quad flat modules (QFM). Within a year the family will fill out with products capable of operating at high frequency up to 3–5MHz range as well as high current from 15A to 30A per power stage.

The family of products makes it easy for designers to take advantage of the significant performance improvements made possible with GaN technology, says EPC. Integrated devices in a single chip are easier to design, easier to layout, easier to assemble, save space on the PCB, and increase efficiency, the firm adds.

"Discrete power transistors are entering their final chapter. Integrated GaN-on-silicon offers higher performance in a smaller footprint with significantly reduced engineering required," says CEO & co-founder Alex Lidow. "This new family of integrated power stages is the next significant stage in the evolution of GaN power conversion, from integrating discrete devices to more complex solutions that offer in-circuit performance beyond the capabilities of silicon solutions and enhance the ease of design for power systems engineers."

The EPC90120 development board is a 80V maximum device voltage, 12.5A maximum output current, half-bridge featuring the EPC2152 Integrated ePower Stage. This 2" x 2" (50.8mm x 50.8mm) board is designed for optimal switching performance and contains all critical components for easy evaluation of the EPC2152 Integrated ePower Stage.

www.epc-co.com

Comtech wins $8.8m contract for Ka-band SSPAs

Comtech Telecommunications Corp of Melville, NY, USA says that, during its fiscal second-quarter 2020, its subsidiary Comtech Xicom Technology Inc of Santa Clara, CA — a part of Comtech's Commercial Solutions segment that makes tube-based and solid-state power amplifiers (SSPAs) for satellite communication (SATCOM) uplink applications — received a contract worth over $8.8m for Ka-band solid-state amplifiers to be used in an in-flight connectivity satcom application.

"We have incorporated the latest GaN solid-state technology for use in a new cabin external application," says chairman & CEO Fred Kornberg. "We have shipped over 2000 airborne amplifiers to date, and we continue to expand our presence in this growing market."

Comtech Xicom's product range spans power levels from 8W to 3kW, with frequency coverage in sub-bands within the 2–52GHz spectrum. Amplifiers are available for fixed and ground-based, shipboard and airborne mobile use.

www.xicomtech.com

GaN Systems named in 2020 Global Cleantech 100 list

GaN Systems Inc of Ottawa, Ontario, Canada (a fabless developer of gallium nitride-based power switching semiconductors for power conversion and control applications) has been named by Cleantech Group in its 2020 Global Cleantech 100 list of companies.

As the 11th edition of the annual guide to the leading companies and themes in sustainable innovation, the 2020 Global Cleantech 100 features the private, independent and for-profit companies best positioned to contribute to a more digitized, de-carbonized and resource-efficient industrial future.

The list combines Cleantech Group's research data with qualitative judgements from nominations and insight from a global 80-member expert panel of leading investors and executives from corporations and industrials active in technology and innovation scouting.

www.gansystems.com

www.i3connect.com/gct100/the-list

JEDEC publishes 'Guideline for Switching Reliability Evaluation Procedures for Gallium Nitride Power Conversion Devices

The JEDEC Solid State Technology Association (which develops standards for the microelectronics industry) has announced the publication of JEP180: Guideline for Switching Reliability Evaluation Procedures for Gallium Nitride Power Conversion Devices. Developed by JEDEC's JC-70 Committee for Wide Bandgap Power Electronic Conversion Semiconductors, JEP180 is available for free download from the JEDEC website.

To enable the adoption of GaN power transistors, both reliable operation in power conversion applications and switching lifetime need to be demonstrated, says JEDEC. Existing tests for silicon power transistors do not necessarily validate operation under actual-use conditions of power conversion equipment and may not be applicable for GaN power transistors.

To address this need, JEP180 is intended for use by manufacturers of GaN power transistors and power conversion equipment. For the first time since the introduction of GaN power transistors, JEP180 will enable manufacturers to evaluate the switching reliability of GaN power transistors and to assure their robustness at the technology level and in power conversion applications. The document provides guidelines for Switching Accelerated Life and Dynamic High-Temperature Operating-Life tests that are applicable to GaN planar enhancement-mode, depletion-mode, cascode power transistors, and integrated power solutions.

JEP180 was developed over a period of more than two years by experts from leading GaN power device manufacturers.

"This new guideline provides engineers a robust evaluation of switching behavior, which will further accelerate industry-wide adoption of GaN, especially in automotive and industrial markets where efficiency, power density and reliability matter the most," says Dr Stephanie Watts Butler, GaN technology innovation architect at Texas Instruments and the chair of JC-70.

"This latest guideline covers switching reliability and helps assure successful usage of GaN devices in a wide range of applications by addressing one of the key topics identified by our committee members," says Tim McDonald, senior advisor to Infineon's CoolGaN program and the chair of the JC-70.1 subcommittee. "We continue in our work to build a full coverage of guidelines and standards for use of both GaN and SiC devices."

Formed in October 2017 with 23 member companies, JC-70 now has over 60 member companies, underscoring industry interest in the development of universal standards to help advance the adoption of wide-bandgap (WBG) power technologies. Global multi-national corporations and technology startups from the USA, Europe, Middle East and Asia are working together to bring to the industry a set of standards for reliability, testing and parametrics of WBG power semiconductors. Committee members include industry leaders in power GaN and SiC semiconductors, as well as prospective users of wide-bandgap power devices, and test & measurement equipment suppliers. Technical experts from universities and national labs also provide input.

JEDEC says that interested companies worldwide are welcome to join it to participate in this standardization effort. JC-70 plans to hold four committee meetings in 2020.

www.jedec.org/standards-documents/docs/jep180

AlN piezoelectric films – The road to even better stress uniformity

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Marelli partners with Transphorm

Automotive supplier Marelli has announced a strategic partnership with Transphorm Inc of Goleta, CA, USA, which designs and makes JEDEC- and AEC-Q101-qualified 650V and 900V GaN FETs for high-voltage power conversion applications. The partnership will enable Marelli to gain access and insights into technologies for the development of electric vehicles (EVs), in particular power converters, on-board chargers and inverters.

Transphorm has direct experience with GaN in the automotive sector, especially Japan. So, Marelli reckons access to their technologies will be of strategic benefit, as it looks at ways to grow through innovation within its Electric Powertrain business. Direct investment in such power electronics will mean a substantial step in the evolution of electric powertrains, with higher efficiency and lower system costs, eventually resulting in benefits for customers and final consumers, Marelli reckons.

Marelli and Transphorm believe the partnership will enable knowledge and information exchange for new automotive/EV power conversion solutions including on-board chargers (OBCs), DC–DC converters and powertrain inverters. Working alongside Transphorm engineers, Marelli engineers will use their experience in manufacturing to advise and guide on product development relevant to its ongoing investment in the development of e-powertrain solutions for electric vehicles and also for motorsport applications. For such joint development and co-working of engineers, Transphorm will exclusively cooperate with Marelli for two years, to enable the development of new technologies for electric vehicles.

"Electric vehicle power conversion is fundamentally important to the future of electric vehicles and investment in technologies like this are critical to ensure the very highest performance of electric vehicles at a lower cost," says Joachim Fetzer, CEO, Electric Powertrain, Marelli. "This partnership allows us to work with the Transphorm team to shape and improve products that will ultimately ensure improved performance, efficiency of power electronics and ultimately lower the cost of electric vehicles," he adds.

"Automotive and EVs represent one of the largest opportunities for GaN in power conversion, and our partnership with a global leader like Marelli is a strong testament to the quality, reliability, manufacturing and overall product performance of our GaN solutions," says Transphorm's co-founder & chief operating officer Primit Parikh. "The long-term innovative system-level vision of the Marelli Electric Powertrain team will be extremely valuable in furthering GaN in the electric vehicle."

www.marelli-corporation.com

Transphorm's GaN FETs used in HZZH's 98%-efficient power module

Transphorm says that Hangzhou Zhongheng Electric Co Ltd (HZZH) has developed an ultra-efficient, GaN-based power module. The 3kW ZHR483KS uses Transphorm's GaN devices to reach 98% efficiency, making it the telecoms industry's most efficient GaN-powered module to date, it is reckoned. Original design manufacturers (ODMs) can swap the ZHR483KS — which offers standardized output connector configurations — with existing same-wattage power modules to achieve a high-reliability, higher-performing solution at a lower overall system cost.

Currently in production, the ZHR483KS is HZZH's first GaN-based power solution and is the flagship product for a new product line. The module's input voltage ranges from 85V to 264V, while its output voltage ranges from 42V to 58V. Transphorm's TPH3205WS GaN devices are used in an interleaved bridgeless totem-pole PFC to achieve 98% efficiency at half load. The GaN devices lower the power module's switching and driving losses, leading to the ZHR483KS outperforming preceding modules that used superjunction silicon MOSFETs.

"We sought a power transistor that would enable us to develop a more efficient yet cost-effective solution for our customers," says HZZH's chief technology officer Dr Guo. "We considered silicon carbide devices but could not achieve the desired advantages at low voltages. We then vetted several GaN manufacturers' devices, and ultimately selected Transphorm's GaN FETs due to their reliability, device cost, and simple implementation."

Transphorm's GaN FETs are two-chip normally-off devices available in standard TO-XXX packages and PQFN modules that can be driven with common off-the-shelf drivers. The existing Gen III family offers what is claimed to be the GaN semiconductor industry's highest threshold voltage at 4V and highest gate robustness at ±20V. These features enable customers to easily design in highly reliable GaN solutions to gain the technology's high-power density benefits.

"Transphorm develops each generation of its GaN platform with four key factors in mind: reliability, drivability, designability, and reproducibility," says Kenny Yim, VP of Asia sales. "We're proud that HZZH selected us as its GaN partner as it affirms that those four factors are what our customers need to disrupt their markets. They result in our GaN being designed into a wide range of multi-kilowatt power systems that are setting industry records. We anticipate HZZH will continue to innovate as our collaboration continues on future products."

www.hzzhpower.com

Transphorm raises $21m and completes reverse merger

New financing to support and accelerate product development, manufacturing and sales of GaN power products

Transphorm Inc of Goleta, near Santa Barbara, CA, USA — which designs and manufactures JEDEC- and AEC-Q101-qualified 650V gallium nitride (GaN) field-effect transistors (FETs) for high-voltage power conversion applications — has raised $21.5m in a private placement equity financing. Prior to the financing, Transphorm Technology Inc completed a reverse merger with Peninsula Acquisition Corp (a public Delaware corporation) whereby Transphorm became a wholly owned subsidiary of Peninsula. Following the merger, Peninsula changed its name to Transphorm Inc and will continue the historical business of Transphorm. Previous members of Transphorm's board David Kerko, Eiji Yatagawa, Brittany Bagley, Mario Rivas and Dr Umesh Mishra will remain as directors.

Transphorm has developed, and is in the market with, multiple families of products that are the building blocks for an array of power converter and inverter systems. The firm's GaN products switch faster than traditional silicon-based solutions and provide higher efficiency with increased system power density while enabling system size reduction.

Transphorm says that it has begun to see meaningful customer adoption of its GaN products in power adapters/fast chargers, power supplies for data centers, communication infrastructure and broad industrial applications, and that it continues to see heightened interest from automotive electric vehicle (EV) suppliers for chargers, converters and inverters. This is in-line with the ongoing overall adoption of GaN solutions in power conversion applications which, according to the firm's analysis, amounts to an accessible total available market (TAM) for GaN of about $3.1bn in 2024. Factoring in GaN market adoption rates, market research firm Yole Développement predicts robust growth and that GaN power device revenues may approach $400m by 2023.

The new equity financing will "support and accelerate our product development, manufacturing, and sales for our GaN power solutions," says CEO Mario Rivas. "The success of this financing demonstrates confidence and support in Transphorm's team, technology and products by both our current partners as well as our new investors," he believes.

"Our core capabilities in GaN epitaxy, design, process and circuit applications have positioned us well to innovate and address the power conversion systems needs of our customers," reckons co-founder & chief operating officer Dr Primit Parikh. "We have created an integrated device model [including design, fabrication, device and application support] and developed highly reliable, high-performance GaN device technology, as well as amassed one of the largest intellectual property portfolios in the GaN power industry," he adds.

The financing was led by existing investors including an affiliate of Kohlberg Kravis Roberts & Co L.P. (KKR), a new strategic investor Marelli and new prominent institutional investors. B. Riley FBR Inc (member FINRA/SIPC) was the lead placement agent and Craig-Hallum Capital Group LLC was the co-placement agent. Montrose Capital Partners was the sponsor for the transaction.

www.transphormusa.com

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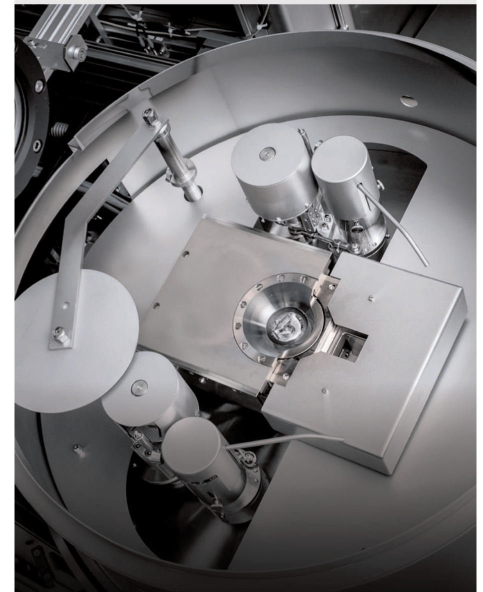

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ST to acquire majority stake in Exagan

Acquisition to accelerate ST's GaN expertise, roadmap and business for high-frequency, high-power automotive, industrial and consumer applications

STMicroelectronics of Geneva, Switzerland has signed an agreement to acquire a majority stake in gallium nitride on silicon (GaN-on-Si) technology start-up Exagan of Grenoble, France (founded in 2014 with support from CEA-Leti and Soitec). Exagan's expertise in epitaxy, product development and application know-how will broaden and accelerate ST's power GaN roadmap and business for automotive, industrial and consumer applications. Exagan will continue to execute its product roadmap and will be supported by ST in the deployment of its products.

Closing of the acquisition remains subject to customary regulatory approvals from French authorities. The signed agreement also provides for the acquisition by ST of the remaining minority stake in Exagan 24 months after the closing of the acquisition of the majority stake. The transaction is funded with available cash.

"ST has built strong momentum in silicon carbide and is now expanding in another very promising compound material, gallium nitride, to drive adoption of the power products based on GaN by customers across the automotive, industrial and consumer markets," says ST's president & CEO Jean-Marc Chery.

In power electronics, GaN-based devices provide high-frequency operation, with increased efficiency and higher power density compared with silicon-based transistors, leading to power savings and total system downsizing. GaN products can address a wide variety of applications such as power factor correction (PFC) and DC/DC converters in servers, telecom and industrial applications, on-board chargers for electric vehicle (EV) and DC–DC converters for automotive applications, as well personal electronics applications like power adaptors.

"The acquisition of a majority stake in Exagan is another step forward in strengthening our global technology leadership in power semiconductors and our long-term GaN roadmap, ecosystem and business," says Chery. "It comes in addition to ongoing developments with CEA-Leti in Tours, France, and the recently-announced collaboration with TSMC."

www.st.com
www.exagan.com

Power Integrations expands range of InnoSwitch3 ICs incorporating robust 750V GaN transistors

Power Integrations of San Jose, CA, USA, which provides high-voltage integrated circuits for energy-efficient power conversion, has expanded its InnoSwitch3 families of offline CV/CC flyback switcher ICs. The new INN3x78C devices incorporate a smaller 'size 8' 750V PowiGaN transistor, enabling compact, efficient power supplies delivering 27–55W without heatsinks. The ICs are housed in the same high-creepage, safety-compliant InSOP-24D package as larger members of the GaN-based InnoSwitch3 families, which target up to 120W.

With efficiency of up to 94% across line and load, PowiGaN technology is also extremely robust, making them highly resistant against line surges and swells commonly seen in regions with unstable mains voltage, says the firm.

InnoSwitch3 IC incorporating PowiGaN.

This enables OEMs to specify a single power supply design to be used worldwide. Applications include USB PD (power delivery) and high-current chargers/adapters for mobile devices, as well as set-top boxes, displays, networking and gaming products and appliances — especially those aiming to comply with the planned European Energy Labeling Regulation.

"We have experienced increased demand for our efficient AC–DC converter ICs with the highly robust 750V GaN transistor," notes Chris Lee, director of product marketing. "Simultaneous electrical strength and efficiency are difficult to achieve due to the relationship between silicon MOSFET breakdown voltage and COSS-related switching loss," he adds. "Our electrically strong PowiGaN transistors have very low COSS, so achieving over 94% efficiency and low field return rate from tropical markets is very straightforward."

The new InnoSwitch3 ICs are available now with InnoSwitch3-CP and InnoSwitch3-EP priced at $2.95 in 10,000 quantities, and InnoSwitch3-Pro priced at $3.25 in 10,000 quantities.

www.power.com/innoswitch3

Eta develops 4” semi-insulating GaN wafers

Eta Research of Lingang Free Trade Zone, Shanghai, China, which was founded in 2015 to develop free-standing gallium nitride (GaN) wafers, has developed semi-insulating 4” GaN wafers. The firm claims to be first to commercially develop semi-insulating free-standing GaN wafers at this size.

Eta uses the hydride vapor phase epitaxy (HVPE) method to produce GaN wafers. To compensate the unintentional n-type dopants, a deep-level co-doping strategy was used to achieve high resistivity. Whereas iron doping has been the most prevalent choice for semi-insulating GaN, Eta uses carbon doping. Secondary-ion mass spectroscopy (SIMS) data shows the carbon concentration to be in the range of 5E17–3E18/cm^3. The unintentional n-type dopants of oxygen and silicon are below 1E17/cm^3. The resistivity has been measured by Hall measurement and I-V curve, which result in room-temperature resistivity greater than 1E9Ω-cm.

The crystal and wafer quality specifications of the semi-insulating GaN wafers remains the same as the company’s n-type GaN wafers. XRD rocking curves of both the (002) and (102) are <100 arcsec and typically 50–60 arcsec. The dislocation density has been measured by cathodo-luminescence (CL) to be 1E6/cm^2. The lattice radius of curvature is greater than 10m. Total thickness variation (TTV) and bow can be controlled within 30μm for 100mm wafers. The surface has an epi-ready polish with roughness <0.3nm for a 10μm x 10μm atomic force microscope (AFM) measurement and <1.0nm for 239μm x 318μm optical interferometry measurement.

The market for semi-insulating GaN wafers is for RF HEMT devices. The RF device market is experiencing high growth due to the implementation of 5G and other wireless communication applications. GaN is a useful semiconductor material for high power and high frequency RF devices, but the industry is almost exclusively producing GaN HEMTs on silicon carbide (SiC) substrates. GaN-on-GaN RF devices will have lower dislocation density device layers and no buffer layer is required, so the firm expects that higher power and better performance will result from RF devices made on GaN substrates.

The wafers are currently available for sale and the company is building new HVPE reactors with carbon doping capability. In addition, we are able to provide MOCVD epi layers on GaN wafers

“Due to the very limited supply, size and quality of semi-insulating GaN wafers, there has only been a limited body of research work conducted on GaN RF devices grown homoepitaxially,” says CEO Troy Baker. “We plan to work with customers to prove the value proposition of GaN wafers for RF devices. We are very optimistic about the performance gains that could be made using semi-insulating GaN wafers,” he adds. “The wafers are currently available for sale and the company is building new HVPE reactors with carbon doping capability. In addition, we are able to provide MOCVD [metal-organic chemical vapor deposition] epi layers on GaN wafers.”

Each wafer will be shipped with a detailed wafer inspection form. Standard products are 2” and 4” wafers, and customized sizes are available as well.

www.etaresearch.com

AKHAN issued European patent

AKHAN Semiconductor Inc of Gurnee, IL, USA — which was founded in 2013 and specializes in the fabrication and application of lab-grown, electronics-grade diamond as functional semiconductors — has been issued a patent by the European Patent Office (EPO) covering its next-generation n-type diamond semiconductor system and diamond-based multi-layer anti-reflective coating systems (key components in military & aerospace sensor and detector applications), amongst other applications.

Patent no. 2737112 is another addition to AKHAN’s Miraj Diamond intellectual property portfolio, and the firm’s first European-issued patent.

Integration of high-quality diamond into semiconductor electronics applications and multi-layer materials can yield next-generation electronic performance and optical components with ultra-hardness, scratch-resistance, high thermal conductivity, hydrophobicity, chemical and biological inertness, and with high transmittance at a variety of critical angles, says AKHAN.

“Over the past few months, AKHAN has been issued a number of patents from around the world, and this latest from the European Union is further proof that we’re world leaders in producing diamond technology for semiconductor application,” reckons founder & CEO Adam Khan. “Diamond is proven to be the ideal material for semiconductors and crucial to making next-generation electronics faster, more powerful and lightweight,” he adds. “Now that we’ve been issued the European patent, we look forward to building further relationships with various partners from across the continent who can benefit from this generational technology.”

www.akhansemi.com

Odyssey names former MACOM executive Alex Behfar as executive chairman & acting CEO

Odyssey Semiconductor Inc, which is developing high-voltage power switching components and systems based on proprietary gallium nitride (GaN) processing technology, has appointed Alex Behfar (a member of the board of directors since June 2019) as executive chairman & acting CEO.

The appointment comes as Odyssey's GaN foundry in Ithaca, NY, USA is in the final stage of being transformed into a facility for GaN transistor fabrication and development. The foundry is nearly fully operational.

Former chairman & CEO Dr Richard Brown has been named chief technical officer, and will oversee efforts to accelerate the development of a prototype of the firm's technology to produce GaN-based high-voltage switching power conversion devices and systems that may quickly supplant silicon carbide (SiC) as the dominant premium power-switching device material, it is believed.

Behfar has over 30 years of experience in the semiconductor industry. He currently serves as a mentor for Cornell University's Praxis Center for Venture Development and is president of technical and business consulting firm Ulexus Consulting. From January 2016 to January 2019, Behfar served as MACOM's senior VP & chief scientist, Photonics. From December 2014 to January 2016, he was MACOM's senior VP & general manager, Photonic Solutions. In 2000, Behfar founded BinOptics Corp, a supplier of indium phosphide (InP) lasers for data centers, mobile backhaul, silicon photonics and access networks, and served as its chairman & CEO from inception through to its $230m acquisition by MACOM in December 2014. Prior to BinOptics, he worked at IBM for more than 10 years in various capacities, including Laser Enterprise, where he designed the first commercially viable high-power 830nm and 980nm gallium arsenide (GaAs)-based lasers. Laser Enterprise was later sold by IBM to Uniphase and is now part of II-VI Inc. He also served as IBM's worldwide cross-functional Intellectual Assets Program Manager for optoelectronics and telecommunications.

Behfar has been awarded over 50 US patents. He holds an M.S. and a Ph.D. in Electrical Engineering from Cornell University and a B.Sc. in Electrical and Electronic Engineering from King's College, University of London.

Brown has 18 years of experience in the design and fabrication of semiconductor devices, specializing in GaN and related materials. Prior to Odyssey, he was a visiting scientist at Cornell University, where he worked on developing GaN-based transistors for radio-frequency communications applications. He was also a founding member and device scientist at Avogy Inc, a firm funded by Khosla Ventures. Brown holds a B.S., M.S. and Ph.D. in Electrical and Computer Engineering from Cornell University.

GaN-based systems outperform silicon and SiC-based systems due to the superior material properties of GaN. To date, GaN devices have proven difficult to process using standard semiconductor processing methods. Odyssey says that it has developed a novel processing modification that will allow GaN to be processed in a manner that, for the first time, will make production of high-voltage GaN power switching devices viable.

The premium power switching device market — which is described as applications where silicon-based systems perform insufficiently — is projected to reach over $3.5bn by 2025 and is currently dominated by silicon carbide. This growth is driven largely by the rapid adoption of electric vehicles (EV) and hybrid electric vehicles (HEV) and the growing number of installations of renewables such as solar and wind power as well as increased demand for more efficient industrial motor drives.

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Compound Semiconductor Centre participating in £36.7m round of challenge projects to push UK to net-zero-carbon growth by 2050

Projects focusing on getting GaN-based power electronic materials through supply chain more quickly and efficiently, and developing in-line characterization of electrical steels using magnetic sensors

The Compound Semiconductor Centre Ltd (CSC) — a joint venture founded in 2015 between Cardiff University and epiwafer foundry and substrate maker IQE plc of Cardiff, Wales, UK — is to participate in a £36.7m round of challenge projects awarded to push the UK to net-zero-carbon growth by 2050.

About £30m will be used to create four Driving the Electric Revolution (DER) centers of excellence in Newport, Nottingham, Strathclyde and Sunderland, bringing together climate change pioneers to research and develop green electric machines including planes, ships and cars.

A further £6.7m will be awarded to 14 projects that aims to help increase the efficiency and breadth of UK supply chains for the advanced components required for the electrification of transport.

The CSC projects focus on:

- Progressing the next generation of power electronic materials based on gallium nitride (GaN), ensuring that advanced semiconductor materials can reach the final buyer in a supply chain more quickly and efficiently, with partners Newport Wafer Fab Ltd and the Centre for Device Thermography and Reliability (CDTR) at Bristol University.
- The development of a novel method for in-line characterization of electrical steels using novel compound semiconductor-based magnetic sensors, with partners Advanced Hall Sensors Ltd, Cogent Power and Microsemi Semiconductors Ltd.

"Compound semiconductor materials are essential building blocks for the next generation of electrification technologies, and we are aiming to develop novel materials and device technologies to address a rapidly emerging GaN power device market," says CSC's Power Materials Programme Manager Rob Harper.

"The UK is leading the way in developing cleaner technologies to help us reach our target of zero emissions by 2050 and these new centers will play an important part in that," believes the UK Government's Business Secretary Alok Sharma. "The £30m industrialization centers will provide a home for virtual product development, digital manufacturing and advanced assembly techniques that could drive world-leading improvements in the testing and manufacturing of electric machines."

www.compoundsemiconductorcentre.com

Compound Semiconductor Applications Catapult becomes Competence Centre for ECPE Network

CSA Catapult's Innovation Centre to be used as research facility for over 200 network organizations and several joint programs

The European Centre for Power Electronics (ECPE) has welcomed the Compound Semiconductor Applications (CSA) Catapult as a new Competence Centre for its network.

The ECPE Network was founded in 2003 and acts as a research network to promote education, innovation, research and technology transfer and collaborations in power electronics in Europe.

Established by UK Government agency Innovate UK (which provides funding and support for business innovation as part of UK Research and Innovation), CSA Catapult is a not-for-profit organization (headquartered in South Wales) focused on accelerating the adoption of compound semiconductors and on bringing applications to life in four technology areas: power electronics, RF & microwave, advanced packaging and photonics. It works across the UK in a range of industry sectors from automotive to medical, and from digital communications to aerospace.

As a Competence Centre, CSA Catapult's Innovation Centre will be used as a research facility for over 200 network organizations and several joint programs. The ECPE will collaborate with CSA Catapult on shared resources, as well as training and talent acquisition.

"The CSA Catapult and ECPE share the same values in striving to support collaboration across our industries' diverse supply chains," comments CSA Catapult's chief commercial officer Amar Abid-Ali. "Compound semiconductors are at the heart of next-generation electronics technologies. We are delighted to partner and share our expertise and resources with other ECPE members to support research and development across Europe."

www.ecpe.org

www.csa.catapult.org.uk

Fraunhofer IAF boosts GaN transistor efficiency to record 77.3% at 1–2GHz after doubling operating voltage to 100V

Long-term goal is operation through 10GHz

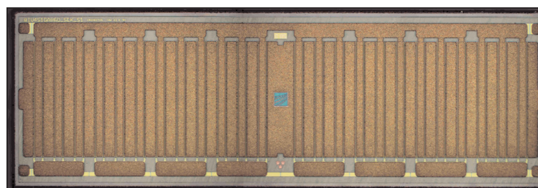
The Fraunhofer Institute for Applied Solid State Physics (IAF) in Freiburg, Germany has significantly increased the output power of its gallium nitride (GaN)-based high-frequency transistors for the frequency range from 1–2GHz, doubling the operating voltage of the devices from 50V to 100V and achieving record power-added efficiency (PAE) of 77.3%. The technology allows the development of high-efficiency amplifiers with even higher power, as required for applications in plasma generation, industrial heating, communications and radar technologies, adds IAF.

For use in high-power applications in the GHz range, the power density of transistors determines the size of amplifier modules and thus largely the system complexity — both of which are decisive for the manufacturing costs and the required use of resources.

There are several ways to increase transistor power density. Fraunhofer IAF chose the path of increasing the operating voltage: By scaling the transistor design vertically and laterally, the researchers succeeded, for the first time in Europe, in realizing high-frequency transistors suitable for applications at an operating voltage of 100V. The GaN-based devices are characterized by significantly increased power density at frequencies in the GHz range.

Laboratory measurements show record efficiency

Performance in the 1–2GHz frequency range has already been demonstrated in the laboratory. Measurements showed a power density of more than 17W/mm and a power-added efficiency of 77.3% at a frequency of 1.0GHz (the highest PAE achieved for 100V operation in this frequency range ever reported). Tests have even shown that this technology delivers a power density in excess of



A 100V GaN power transistor with an output power of 600W at a frequency of 1.0GHz. © Fraunhofer IAF

20W/mm at 125V. The results were presented for the first time in December at the International Electron Devices Meeting (IEDM 2019) in San Francisco (S. Krause, P. Brückner, M. Dammann and R. Quay, 'High-Power-Density AlGaN/GaN Technology for 100-V Operation at L-Band Frequencies', 2019 IEDM, p17.4.1–17.4.4).

Twice the voltage for much higher power

"Increasing the operating voltage from 50V to 100V enables higher power densities. This means that a system can deliver more power on the same area than what is possible with commercially available 50V or 65V technologies," says Sebastian Krause, one of the main developers of the technology.

On the one hand, this enables systems of the same size with higher output power. On the other hand, it is possible to create more compact and lighter systems delivering the same power, since less chip area is required to achieve the desired power level. "By doubling the operating voltage to 100V, the transistor exhibits a four times higher output impedance for a given power," says Krause. This allows the implementation of smaller and therefore less lossy matching networks, which in turn results in higher energy efficiency of the overall system.

Usage in industrial high-power systems

"The long-term goal of our development is operation through 10GHz," says Krause. This would make the Freiburg-based Fraunhofer Institute the first source for such 100V GaN-based devices. This is of particular interest for high-performance applications such as particle accelerators, industrial microwave heaters, mobile-phone amplifiers, pulse- and continuous-wave radar and amplifiers for plasma generators. These systems require high output power levels while maintaining a preferably small footprint — exactly what the 100V technology can deliver, says IAF.

Particle accelerators play an important role in research, medical technology and industry. Plasma generators in the high-frequency range are used, for example, for coating processes in the production of semiconductor-based chips, data-storage media or solar cells.

Power semiconductors replace vacuum components

Another large industrial field of application is power generators for microwave heating. "In this field, industry usually works at higher frequencies, but vacuum components, e.g. magnetrons or klystrons, are predominantly used to date," says Krause. "Here, we are working on providing a semiconductor-based alternative," he adds. "Semiconductors are much more compact and more lightweight, which enables arrangements such as phased arrays."

For many years, tube-based components (e.g. traveling-wave tubes) have dominated electronic systems with high output power. However, development is moving towards power semiconductors. Fraunhofer IAF believes that the GaN-based 100V technology can provide an efficient alternative for increasing the power of microwave generators.

https://ieeexplore.ieee.org/document/8993632
www.iaf.fraunhofer.de

Keysight adds radiated EMI pre-compliance to PathWave Advanced Design System

Keysight Technologies Inc of Santa Rosa, CA, USA (which supplies electronic design automation software for microwave, RF, high-frequency, high-speed digital, RF system, electronic system level, circuit, 3D electromagnetic, physical design and device-modeling applications) has announced a new add-on to PathWave Advanced Design System (ADS) that enables designers to perform pre-compliance testing on virtual prototypes of switched-mode power supply (SMPS) designs. The new capability saves the time and cost of iterative build and test of physical prototypes.

Demand for SMPS is driven by the need for greater efficiency, increased power density and lower cost. Due to their high performance and efficiency, fast, low-loss switches made from silicon carbide (SiC) and gallium nitride (GaN) will power future applications. However, there are unwanted side effects from the high current slew rate, such as difficulty meeting the radiated electromagnetic interference (EMI) spec. Pre-compliance analysis of a 'virtual prototype' is suitable for managing this challenge, but until now it required expertise with a complicated, general-purpose electromagnetic (EM) field solver.

To address this growing need, Keysight has added a radiated EMI capability to its Power Electronics Professional (PEPro) software, available as an add-on to PathWave ADS. This new capability includes automatic setup (eliminating the need for an expert) as well as pre-built testbenches, frequency-domain far-field analyses that mimic real-world tests, and comparison with government-mandated masks.

"High current slew rate in the switched loop brings many benefits but also requires greater discipline in circuit design and layout," notes Dr Rakesh Lal, principal scientist at Transphorm Inc of Goleta, near Santa Barbara, CA, USA — which designs and manufactures JEDEC- and AEC-Q101-qualified 650V gallium nitride (GaN) field-effect transistors (FETs). "The high-frequency switching harmonics give unwanted radiation into the VHF frequency band, so we look to Keysight for their experience in modeling these effects. PEPro encapsulates their decades of experience and makes it accessible to power electronics designers to optimize wide-bandgap circuits and layouts for highest performance and reliability," he adds.

"The interactions between PE, SI, PI and EMI are well known," says Steve Sandler, managing director of Picotest, a company that specializes in high-fidelity testing and measurement tools, primarily for power-related applications. "Being able to simulate all four together in a single environment adds tremendous visibility to the design process," he adds.

"I talk with dozens of SMPS engineers every year and the one thing they are all struggling with is EMI compliance in the high di/dt area," notes Colin Warwick, product manager for power electronics EDA tools at Keysight. "They really see the value of the pre-compliance 'virtual prototyping' capability of this new version of PEPro."

Keysight's power electronics design solutions enable power device production across the entire workflow from simulation, design, and verification to manufacturing, deployment, and optimization. The firm offers a complete electromagnetic circuit co-simulation environment with its PathWave Advanced Design System.

www.keysight.com/find/eesof-power-electronics
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IQE pre-announces 2019 financial performance in line with November trading update

First-quarter 2020 trading in line with prior expectations

Following advice to auditor KPMG from the Financial Reporting Council (FRC) in the midst of the COVID-19 Coronavirus outbreak, epiwafer foundry and substrate maker IQE plc of Cardiff, Wales, UK has delayed reporting its full-year 2019 financial results (which were due for publication on 24 March) for at least two weeks. Instead, IQE has provided a trading update (representing a pre-announcement based on unaudited financial accounts) for 2019 and for first-quarter 2020.

Revenue is £140m, down 10% on 2018's £156.3m but in line with November's revised guidance of £136–142m (which was reduced from June's guidance of £140–160m). By segment, Photonics grew by 4% and Wireless fell by 23%. The year-on-year reduction in revenue was primarily due to two customers, one in Wireless and one in Photonics.

Compared with a profit of £16m in 2018, 2019 yielded an adjusted operating loss was £4.7m, in line with the November trading update guidance, reflecting negative operating leverage and an increase in depreciation and amortisation from targeted investments.

Capital expenditure (CapEx) rose from £30.4m in 2018 to £31.9m in 2019 (as expected, towards the bottom end of the initial guidance of £30–40m), as IQE completed the infrastructure phase of the capacity expansions at its Newport, Taiwan and Massachusetts sites.

Adjusted operating cashflow was £16.5m (down from 2018's £17m), representing 100% adjusted EBITDA to adjusted operating cash conversion.

Net debt (excluding lease liabilities of £16m) as at end-December 2019 was near the lower end of the November trading update's £15–20m guidance range (against increased debt facilities of £57m announced in June), reflecting strong working capital management.

Operational highlights in 2019 are listed as follows:

Infrastructure phase of the capacity expansion program completed:

- The Mega Foundry in Newport, South Wales entered production for 3D sensing products in May following full and comprehensive end-to-end supply-chain qualification with IQE's lead vertical-cavity surface-emitting laser (VCSEL) customer.
- Capacity in Taiwan has been increased by 40%, enabling growth in revenues within expanding Asian markets. Five tools are now qualified for wireless products for a major Taiwanese foundry, with four currently in production.
- Consolidation and investment in gallium nitride (GaN) capacity in Massachusetts has been completed, to capitalize on upcoming 5G infrastructure deployments.

Newport Mega-Foundry 3D sensing production and qualification progress:

- The foundry was in mass production for the existing major supply chain on four tools at year-end, with stable demand forecast through first-half 2020. Currently five tools are in production for this customer.
- Commencement of production in second-half 2019 is expected with a second major customer serving Android supply chains.
- Device and module qualification was announced in second-half 2019 with a third major customer related to Android supply chains, and other Android qualifications are ongoing.

Next-generation product development:

- IQE made continued strong progress in the development of filters (based on the firm's patented cREO crystalline rare-earth oxide technology) and switches for 5G.
- IQE introduced 10G and 25G full-service distributed feedback (DFB) laser for high-speed datacoms using nano-imprint lithography (NIL), and 10G and 25G avalanche photodiodes (APDs), both for high-speed datacoms serving the 5G infrastructure and data-center markets.
- Continued Photonics roadmap progress was made, including best-in-class results for long-wavelength VCSELs for future smartphone and LiDAR deployment plus lasers and sensors for environmental and health monitoring.

Evolution of board and executive management to support growth ambitions and scalability of operations:

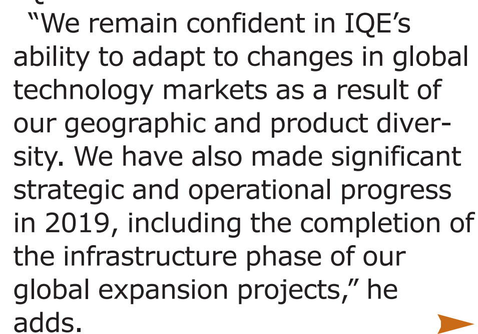
- Phil Smith CBE was appointed as chairman;
- Carol Chesney FCA was appointed as non-executive director and chair of the Audit Committee;
- Tim Pullen ACA was appointed as chief financial officer (CFO);
- The executive management board was established and is fully operational.

Increase to credit facilities to support navigation of challenging market conditions:

- £30m asset financing facility put in place, increasing total available facilities to ~£57m (£25m drawn down at 31st December 2019).

"In 2019 IQE faced extremely challenging market conditions and our financial performance reflects the considerable disruption in global semiconductor markets and supply chains, caused by the geo-political environment," says IQE's CEO Dr Drew Nelson.

"We remain confident in IQE's ability to adapt to changes in global technology markets as a result of our geographic and product diversity. We have also made significant strategic and operational progress in 2019, including the completion of the infrastructure phase of our global expansion projects," he adds.



"The spread of Coronavirus has introduced significant near-term uncertainty into global economies and markets. However, to date we have not experienced any significant disruption to our current production or order intake relating to coronavirus, but we have implemented appropriate business continuity measures and we are well placed to withstand the near-term market uncertainty," Nelson continues. "We continue to monitor this fast-moving situation very closely".

First-quarter 2020 trading update

IQE says that it has been trading in line with expectations in first-quarter 2020. "Forecasts from customers are relatively strong, with high levels of production in March in particular for Wireless products and 3D sensing VCSELs," the firm notes. The revenue trajectory for March is currently, on a weekly run rate, significantly higher than average monthly revenue for 2019.

2020 outlook

Concerns over the spread of Coronavirus (COVID-19) are currently creating significant near-term uncertainty across global markets, notes IQE. The firm's production has so far not been affected by any disruption, with all sites continuing to operate as normal.

"There is a still-evolving risk to future production at IQE or at others within our supply chains. However, as a critical technology supplier, IQE is less likely to be affected by 'lockdown' scenarios than other businesses," believes IQE. "This is evidenced by our classification as a 'critical infrastructure provider' in both the States of Pennsylvania and Massachusetts, where the Department of Homeland Security deems IQE to have a 'special responsibility to maintain (our) normal work schedule'," the firm adds.

"The effects of Coronavirus on global economic output in 2020 and on semiconductor demand are as yet uncertain. Given the significant current levels of uncertainty, we are unable to provide more explicit guidance at this point in time," IQE cautions.

IQE has access to material debt facilities, should they be required in the event of a significant downturn. "IQE has a long-standing and trusted relationship with our bankers HSBC, who remain supportive," the firm notes. "We are in close ongoing dialogue regarding the evolving effects of Coronavirus on supply chains and markets. In the event of a significant slowdown, we will work proactively with HSBC to ensure the ongoing liquidity of the group," it adds.

2020 investment guidance

With the infrastructure phase of the capital investment program completed in 2019, the property, plant & equipment (PPE) cash capex guidance for 2020 is set at less than £10m. IQE says that it will continue to invest in R&D programs to underpin future growth opportunities, with intangibles capitalization in 2020 expected to be less than £10m. Capital spend can be reduced further if conditions require additional cash preservation measures.

www.iqep.com

IQE continuing production at all sites despite COVID-19

Epiwafer foundry and substrate maker IQE plc of Cardiff, Wales, UK says that production is continuing at all of its global sites, despite the impact of the COVID-19 coronavirus. "Given the diversified nature of our global operations, there are differing operating conditions across our various sites," notes the firm.

A consistent factor is that IQE's manufacturing business has a 'low people intensity' compared to other industries, so the company can operate effectively and safely with reduced numbers of staff on site.

USA

A number of States in the USA have issued 'stay at home orders' to their residents, but IQE is not affected because it has been granted special exemption to carry on with production at all four of its sites. As a 'critical infrastructure provider' the company is operating under direction from the US Department for Homeland Security, which deems IQE to have "a special responsibility to maintain (our) normal work schedule". Nevertheless, all members of staff are working from home as a default, unless they are essential to production.

UK

As in the USA, all members of UK staff who can work from home are doing so and, in observance of the Government's directions regarding essential trips for work, exercise, food and care, the firm's sites are operating at minimal staffing levels and only where essential for production.

Asia Pacific

Taiwan and Singapore are currently less impacted by the virus, so operations there are unaffected.

Supply chain and order book

IQE says it has not encountered any disruption to supply chains, and its approach of dual- or multi-sourcing helps to reduce exposure to disruption at any single supplier.

Order demand for the firm's products has been unaffected, and production output in March is above average levels for the previous 12 months.

"There remains an increased risk to near-term demand and therefore revenues due to the impact of Coronavirus on the global economy," says IQE. "However, the total impact of these conditions and risks on IQE's markets remains unquantifiable at this point in time," the firm adds. "Our business continuity sub-committee continues to monitor risk indicators and external guidance and is responding swiftly to this rapidly evolving situation."

www.iqep.com

Veeco withdraws Q1 guidance following California's 'shelter-in-place' COVID-19 restrictions on San Jose operations till 7 April

Epitaxial deposition and process equipment maker Veeco Instruments Inc of Plainview, NY, USA says that, as the worldwide COVID-19 (coronavirus) outbreak continues to spread, it has taken precautions to protect employees and visitors while minimizing the risk of disruption to its business, where possible.

On 16 March, several California counties issued a 'shelter-in-place' directive related to the COVID-19 virus which has rendered Veeco's San Jose facility and possibly the facilities of certain customers unable to operate until 7 April. Veeco says that these government directives may impact its ability to meet its first-quarter 2020 guidance.

As a result, given the additional uncertainty and disruptions to Veeco and possibly to certain customers, the firm is withdrawing its first-quarter guidance, previously provided on 13 February, which was based on best known information at the time.

Veeco notes that it continues to monitor what it describes as a dynamic situation and expects to provide a further update during its Q1/2020 earnings conference call.

www.veeco.com

Riber's Picault to resign as member of executive board

Riber S.A. of Bezons, France — which makes molecular beam epitaxy (MBE) systems as well as evaporation sources and effusion cells — says that Michel Picault will resign from the firm's executive board at the end of this year, on 31 December, after over 35 years with the firm.

Riber's supervisory board thanks Picault for his major contribution to the company's development.

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Aixtron meets 2019 guidance for order intake, sales, gross margin and EBIT margin, aided by strong Q4

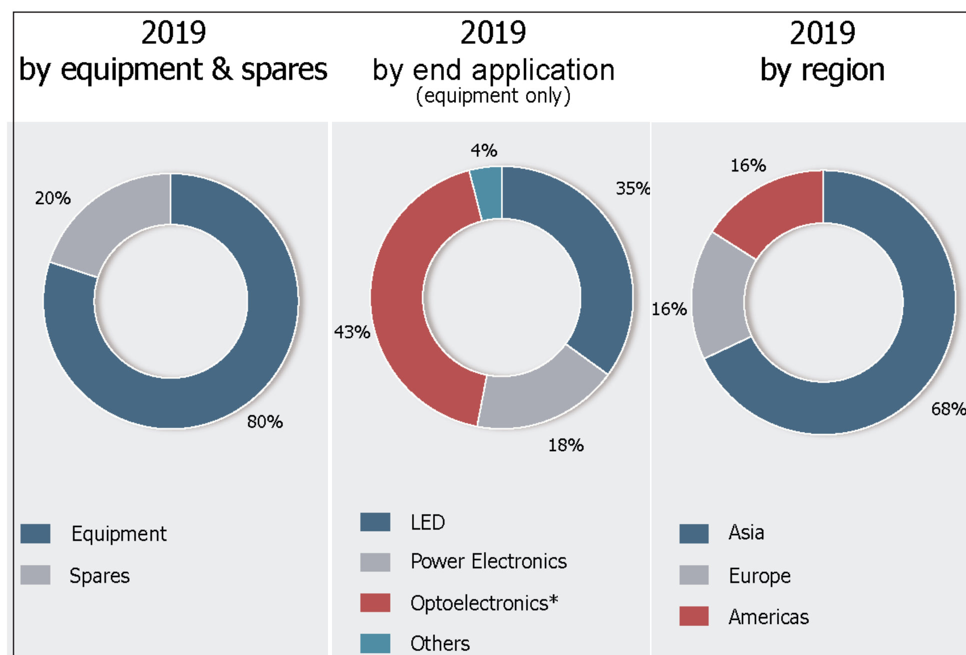
Drop in MOCVD system sales for lasers/VCSELs mitigated by growth for specialty LEDs and power electronics

For fourth-quarter 2019, deposition equipment maker Aixtron SE of Herzogenrath, near Aachen, Germany has reported revenue of €75.1m, down 15% on €87.9m a year ago but up 43% on €52.6m in Q3/2019. "We have seen a continuing improvement of the business after the challenging second quarter last year caused by the geopolitical environment," says president Dr Bernd Schulte.

Full-year revenue was €260m, at the bottom end of original guidance range of €260-290m but down just 3% on €268.8m in 2018. In particular, sales of spare parts & services grew by 11% from €47.1m to €52.4m (rising from 18% to 20% of total revenue), while equipment revenue shrank by 14.5% from €221.8m to €207.3m (falling from 82% to 80% of total revenue).

Of equipment revenue, the proportion from metal-organic chemical vapor deposition (MOCVD) systems for manufacturing optoelectronic components (i.e. lasers and solar, excluding LEDs) declined as expected (falling back from 66% to 43% of total revenue) after the particularly strong laser business in 2018 did not repeat in 2019. However, systems for producing LEDs — including red-orange-yellow (ROY) and specialty LEDs — nearly doubled (rebounding from just 16% to 35% of total revenue). Revenue from systems for manufacturing power electronics doubled (growing from 8% to 18%).

Asian revenue has rebounded from 54% of total revenue in 2018 to 68% in 2019 (rising by 23% from €144.7m to €177.4m, including China rising by 65% from €72.6m to €119.7m while Korea fell from €11.9m to €4.6m and Taiwan from €43.2m to €33m). Meanwhile, the Americas fell back from 20% to 16% (shrinking by 23% from €54.4m to €41.9m) and Europe fell back from 26% to 16% (down by 42% from €69.7m to €40.3m).



"Our strategy to serve multiple end applications with one product platform has proven to be very effective in 2019," says Schulte. "We were able to largely compensate for the somewhat weaker sales in the laser/VCSEL [vertical-cavity surface-emitting laser] segment, primarily through sales in power electronics and specialty LEDs, and thus achieve an operating result similar to that of the previous year."

Cost of sales was roughly level with 2018's €151.2m, at €150.9m in 2019, but rose from 56% to 58% of revenue due to lower-margin ROY LED systems shipped in first-half 2019.

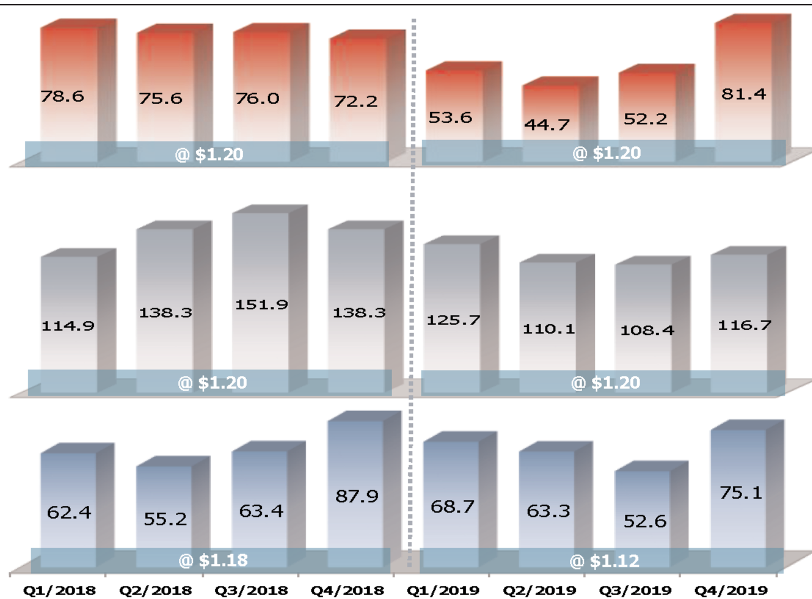
Full-year gross margin has fallen from 2018's 44% to 42% for 2019, due mainly to the different sales mix (with more sales into the display market in first-half 2019) partly offset by a favorable dollar exchange rate. However, this is above the original guidance range of 35–40%. Also, Q4 gross margin was 45%, level with a year ago and recovering further from Q1's low of 39% and 42% in Q3.

Full-year operating expenses were cut from 2018's €76.2m (28% of revenue) to €69.7m (27% of revenue) for 2019. In particular, selling, general & administrative (SG&A) expense fell from €27.7m to €26.4m (remaining 10% of revenue), due mainly to lower project-related advice costs and lower variable pay. This was despite staffing rising from 628 to 688 people (as the positive business development leading to new hires). Research & development (R&D) expenses have been increased by 5% from €52.2m (19% of revenue) to €55m (21% of revenue), as product development for MOCVD systems (including power electronics and micro- and mini-LEDs) increased significantly in 2019 over 2018. In particular, this came mainly from activities related to the finalization and launch of the new tool for silicon carbide (SiC) power electronics.

Net other income rose from €3.8m to €11.6m, due mainly to an

increase in R&D grants received from €4.7m to €7.9m as a result of a higher number of publicly funded R&D projects.

Full-year operating result (EBIT) has fallen from 2018's €41.5m to €39m in 2019 (though remaining 15% of revenue, and above the originally forecasted EBIT margin of 8–13%). Although down from €20.8m (24% of revenue) a year ago, quarterly operating result almost tripled from €5.5m (10% of revenue) in Q3/2019 to €14.4m (19% of revenue) in Q4/2019.



Aixtron's 24-month business development

USD order intake and backlog were recorded at the prevailing budget rate (2018: $1.20/€; 2019: $1.20/€)
USD revenues were converted at the actual period average FX rate (2018: $1.18/€; 2019: $1.12/€)

Full-year operating cash flow improved from €11.9m in 2018 to €42.8m in 2019, because 2018 cash flows included both €12m of open payments related to the sale of the ALD/CVD business in 2017 as well as increases in inventories and receivables. Capital expenditure (CapEx) and interest received amounted to –€6.8m. So, full-year free cash flow in 2019 was €36m (up from 2018's €4.4m), due mainly to a stable level of working capital in 2019 compared with increases in the previous year. "Free cash flow was higher than guided [€15–25m], due to the substantially higher cash inflows towards the very end of the year," says Schulte. Free cash flow was €37.8m in Q4, up from just €2.6m in Q3, and –€4.9m in first-half 2019.

Inventories rose from €73.5m to €79m, including around €5m of prototype systems. Very good cash collections from customers in December cut trade receivables from €40.1m (36 days sales outstanding) at end-2018 to €29.2m (30 days sales outstanding) at end-2019. Advanced payments received from customers of €51m was similar to the end of 2018, but increased by €7m in Q4, reflecting the good order intake. Advanced payments comprise 44% of the order backlog.

Because of the lower receivables and increased customer advanced payments, the cash balance rose to €298.3m at the end of 2019, up from €260.6m at the end of Q3 and €263.7m at the end of 2018.

"2019 was a challenging year in which Aixtron successfully maintained its leading market position in MOCVD equipment and applications," says Schulte. "Despite a market environment characterized by political and economic uncertainties, we met our full-year guidance."

In 2019, Aixtron invested significantly in the development of new or enhanced products for all major applications. The launch of the new fully automated, high-throughput silicon carbide (SiC) production tool in September was followed by first customer qualifications and orders for the AIX G5 WW C system.

"As part of this comprehensive product initiative, we have been working intensively on the enhanced next-generation MOCVD equipment for optoelectronics and power electronics," says Aixtron. "In doing so, we focus on high-performance tools for the production of high-quality devices based on gallium arsenide (GaAs) and gallium nitride (GaN).

In the organic light-emitting diode (OLED) area, Aixtron's South Korea-based subsidiary APEVA continued in 2019 to work on the qualification of a Gen2 system (370mm x 470mm) together with a large Asian display manufacturer. APEVA expects a decision on the further development of this project this year.

Total order intake (including spares & services) for 2019 was €231.9m, down 23% on 2018's €302.5m, due to "customers' hesitant approach to increase their capital expenditures against the backdrop of ongoing trade disputes and the uncertainty associated with this environment". However, this was above the most recent guidance of €220m, as the expected lower level of orders for MOCVD systems for the production of 3D sensing VCSELs was partially offset by demand for power semiconductors and telecoms production systems as well as by strategic investments of customers in mini- and micro-LEDs production feasibility projects. Most recently, orders in Q4/2019 were €81.4m, up 56% on €52.2m in Q3 and up 13% on €72.2m a year ago.

Equipment order backlog was €116.7m at the end of 2019, down 16% on €138.3m at the end of 2018 but up by 8% from €108.4m at the end of Q3/2019.

"In light of the many challenges we faced, we are very pleased with the past year," says Schulte. "We have met our full-year guidance [for order intake, sales, gross margin and EBIT margin] and further strengthened our global market leadership position in MOCVD equipment," he adds.

For full-year 2020, Aixtron expects stable to growing revenue compared with 2019. In terms of order intake, customer demand is expected across all technology areas. Due to this diversity, the development of orders in second-half 2020 is difficult to predict. "We are optimistic about the long-term positive outlook, both for demand for MOCVD systems for the production of 3D sensing lasers or lasers for optical data transmission as well as for LED-based display applications," says Aixtron. "In particular, we expect the demand for systems for the production of power electronics made of the wide-bandgap materials SiC and GaN to increase again in 2020 compared to 2019," the firm adds. So, based on its existing corporate structure, the assessment of the order situation and the budget exchange rate of $1.20/€, Aixtron expects order intake for full-year 2020 to grow to €260–300m.

Based on the equipment order backlog of €117m on 1 January joined by an estimated €98–138m of order intake shippable during 2020 plus an estimated €45m of spares & services revenue, for 2020 Aixtron expects revenue of €260–300m. Gross margin should be about 40% and EBIT margin should be 10–15% of revenue.

As part of this comprehensive product initiative, we have been working intensively on the enhanced next-generation MOCVD equipment for optoelectronics and power electronics

Expectations for 2020 include in full the results of the APEVA Group, including all necessary investments to further advance the development of OLED activities and are based on the assumption that the coronavirus COVID-19 outbreak will not have a significant impact on the development of Aixtron's business.

"Last year we paid particular attention to the development of new or enhanced products within our product portfolio. The successful start with our new production system for silicon carbide applications in 2019 was very promising," says president Dr Felix Grawert. "We expect the same from the enhancement of our next-generation products for optoelectronics and power electronics, which we will be bringing to market in the course of this and next year. In addition, we expect a decision on the further development of our OLED qualification project with a major Asian display manufacturer in 2020," he adds.

www.aixtron.com

China-based KONKA enters micro-LED pilot production with Aixtron AIX G5+ C and AIX 2800G4-TM MOCVD systems

Deposition equipment maker Aixtron SE of Herzogenrath, near Aachen, Germany says that China-based KONKA Group Co Ltd has ordered multiple AIX G5+ C and AIX 2800G4-TM metal-organic chemical vapor deposition (MOCVD) systems to build its own volume production of gallium nitride (GaN)-based and arsenide-phosphide (AsP)-based mini- and micro-LEDs. KONKA, which recently announced its plans to enter the North American consumer electronics market in 2020, established its micro-LED initiative as a joint venture with Chongqing Liangshan Industrial Investment Co. Most recently, the Chinese electronics manufacturer has launched its Smart Wall micro-LED TV.

Micro-LED technology is on the verge of superseding existing display technologies for next-generation consumer products. Since displays made of micro-LEDs consist of micron-sized LED arrays forming individual sub-pixel elements, they offer the lowest power consumption while simultaneously exhibiting superior pixel density, contrast ratio and brightness. Compared with existing LCD and OLED technologies, micro-LEDs open new opportunities for the design of consumer mobile products as well as premium TV displays.

"Aixtron's market-leading fully automated MOCVD tools AIX G5+ C and AIX 2800G4-TM perfectly meet our tightened wavelength uniformity requirements for micro-LED manufacturing," comments Dr Allen Tsai, general manager & CEO at Chongqing KONKA Opto-electronics Technology Research Institute Co Ltd. "The advanced Planetary technology stands out due to excellent wavelength uniformity, high yield and efficient high-volume manufacturing at lowest cost per wafer. Besides our commercial market entry for micro-LED applications, Chongqing KONKA and Micro Crystal Transfer Group will develop new technologies and applications based on GaN materials," he adds.

"Following the recent qualification of our AIX G5+ C tool for micro-LED production means another step forward in the commercialization of our system technology for micro-LED manufacturing," says Aixtron president Dr Bernd Schulte. "We are looking forward to the further cooperation with KONKA," he adds. "Aixtron will continue to support the joint effort between Chongqing KONKA and Micro Crystal Transfer Group for their development of new technologies and applications based on GaN materials."

www.konka.com

LayTec unveils InspiRe in-situ monitoring tool used for monitoring perovskite formation

The efficiency of perovskite photovoltaics has recently risen greatly. In a tandem configuration at Germany's Helmholtz-Centre Berlin (HZB), even the best silicon solar cell was surpassed (29.1%) using wet-chemical low-cost methods. Despite this progress, many challenges remain for this technology.

In-situ metrology system maker LayTec AG of Berlin, Germany says its new InspiRe (Figure 1) system applies high-speed in-situ reflectance measurements for monitoring perovskite thin-film formations during spin-coating and subsequent annealing.

In collaboration with professor Norbert Nickel's group at HZB, LayTec designed the InspiRe in-situ metrology system, which was applied to monitor both spin-coating and annealing (Figure 2). Gathering data at a time resolution on the millisecond scale allows resolving of the kinetics and phase formations during film formation.

While spin-coating, the absorption behavior and the thinning of precursor solution is monitored. The absorption edge (i.e. bandgap) of the deposited perovskite film is derived directly during annealing. Spectral changes during annealing indicate 'over-annealing' after the desired bandgap has been achieved.

This methodology, for the fist time, allows the systematic study of film formation during two crucial process steps for identifying optimization routes and for implementing a rigid quality control scheme for upscaling and industrialization.

www.laytec.de/inspire

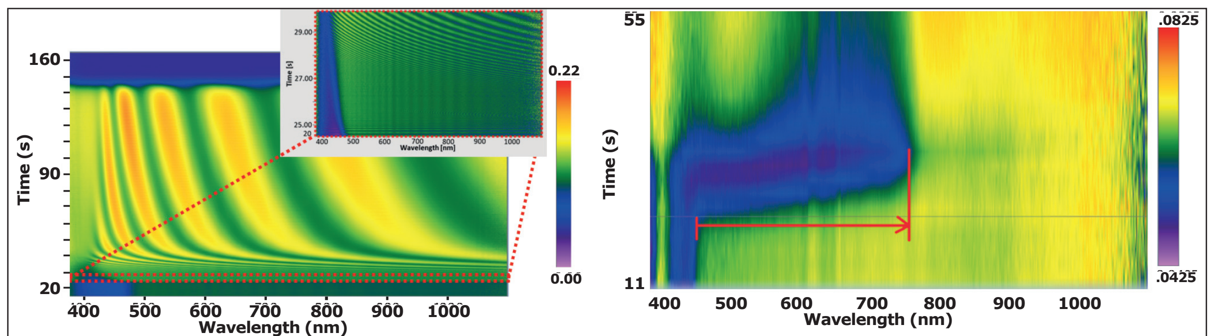


Figure 2: (a) Spin-coating: exemplary color plot obtained during perovskite deposition. The inset zooms into the first 5s after starting the rotation.(b) Annealing: example of a color plot obtained during perovskite annealing. The red arrow marks the shift of the absorption edge.

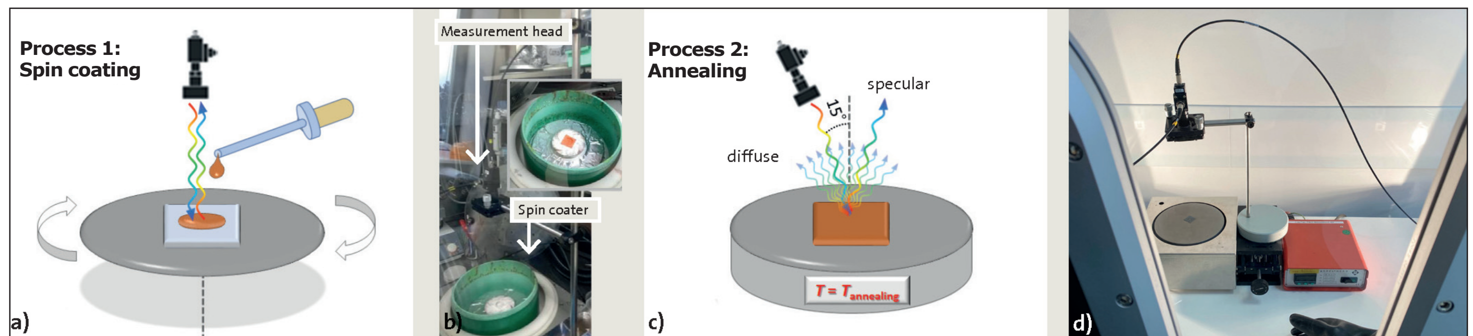


Figure 1: Spin-coating (a, b) and annealing (c, d) of perovskite thin films.

Astrum LT chooses EpiX wafer mapper for VCSEL manufacturing

LayTec's EpiX wafer mapping station has been chosen by Astrum LT UAB of Vilnius, Lithuania for vertical-cavity surface-emitting laser (VCSEL) production at its new Astrum LT s.r.o. facility in Kralupy nad Vltavou near Prague, Czech Republic.

Astrum LT s.r.o. was set up to offer high-power gallium arsenide (GaAs)-based devices — including edge-emitting lasers (EELs) and VCSELs — for medical, industrial, automotive, spectroscopy and consumer electronic applications.

The stand-alone metrology tool will help Astrum LT to determine post-growth wafer uniformity and to better understand the growth process in its metal-organic chemical vapor deposition reactor.

LayTec's EpiX mapping stations combine spectroscopic white-light reflectance and photoluminescence detection with an XY-mapping stage and provide a comprehensive 2D analysis of optical wafer properties by non-contact measurement. In combination with the in-situ results of LayTec's EpiCurve TT VCSEL installed on its MOCVD system, Astrum LT will be able to correlate live run data — like growth-temperature distributed Bragg reflector (DBR) mirror or cavity position — with the room-temperature results from the EpiX mapping station.

www.astrum-lasers.com

EVG sets up Heterogeneous Integration Competence Center

Center to help customers accelerate new product development fueled by heterogeneous integration and advanced packaging

EV Group of St Florian, Austria — a supplier of wafer bonding and lithography equipment for semiconductor, micro-electro-mechanical systems (MEMS) and nanotechnology and semiconductor applications — has established the Heterogeneous Integration Competence Center, which is designed to assist customers in leveraging the firm's process solutions and expertise to enable new and enhanced products and applications driven by advances in system integration and packaging. These include solutions and applications for high-performance computing and data centers, the Internet of Things (IoT), autonomous vehicles, medical and wearable devices, photonics and advanced sensors.

The Heterogeneous Integration (HI) Competence Center combines EVG's wafer bonding, thin-wafer handling and lithography products and expertise, as well as pilot-line production facilities and services at its cleanroom facilities at EVG's headquarters in Austria, supported by the firm's worldwide network of process technology teams. Through the HI Competence Center, EVG will help customers to accelerate technology development, minimize risk and develop differentiating technologies and products through heterogeneous integration and advanced packaging, while guaranteeing IP protection standards required for working on pre-release products.

"Heterogeneous integration fuels new packaging architectures and demands new manufacturing technologies to support greater system and design flexibility, as well as increased performance and lower system design costs," says Markus Wimplinger, corporate technology development & IP director. "EVG's new HI Competence Center provides an open-access innovation incubator for our customers and partners across the microelectronics supply chain to collaborate while pooling our solutions and process technology resources to shorten development cycles and time to market for innovative devices and applications enabled by heterogeneous integration," he adds.

The Heterogeneous Integration Competence Center combines EVG's wafer bonding, thin-wafer handling and lithography products and expertise, as well as pilot-line production facilities and services at its cleanroom facilities.

EVG has an extensive background in heterogeneous integration, providing solutions for this key technology trend for more than 20 years. Among these are: permanent wafer bonding (including direct fusion and hybrid bonding for 3D packaging and metal bonding) and die-to-wafer bonding with and without collective carriers for integration of III-V compound semiconductors and silicon as well as high-density 3D packaging; temporary bonding and debonding (including mechanical, slide-off/lift-off and UV laser assisted); thin-wafer handling; and innovative lithography technologies, including mask aligners, coaters and developers, and maskless exposure/digital lithography.

Advanced packaging milestones

In the field of permanent bonding, EVG pioneered the patented SmartView wafer-to-wafer alignment system more than 20 years ago, and has refined this technology over the years to support technology advances such as backside-illuminated CMOS image sensors (BSI-CIS) and, more recently, the first demonstration of sub-100nm wafer-to-wafer alignment overlay for hybrid bonding — enabling devices such as 3D BSI-CIS and memory-on-logic stacking. EVG developed the first temporary bonding systems for ultra-thin wafers as early as 2001, which are essential for 3D/stacked die packaging, as well as revolutionized low-temperature laser debonding for ultra-thin and stacked fan-out packages.

In lithography, EVG delivered the first UV molding solutions for high-volume production of wafer-level optics more than a decade ago, and has since led the proliferation of nanoimprint lithography (NIL) to high-volume manufacturing (HVM). The firm continues to break speed and accuracy barriers in mask alignment lithography for advanced packaging and, more recently, unveiled the first highly scalable maskless exposure technology, which addresses emerging requirements in HVM back-end lithography.

www.evgroup.com/products/process-services

Plasma-Therm adds systems engineering expertise with acquisition of UK-based JLS Designs

Table-top etch and deposition added to portfolio

Plasma-Therm LLC of St Petersburg, FL, USA (which makes plasma etch, deposition and advanced packaging equipment for specialty semiconductor and nanotechnology markets) has acquired JLS Designs Ltd of Somerton, Somerset, UK, a supplier of compact plasma systems and custom-designed engineering solutions.

"This transaction immediately increases our capabilities, both to support existing customers in the United Kingdom and to attract new customers throughout Europe," says Jim Garstka, Plasma-Therm's VP of sales & business development. "This is a strategic acquisition to increase our presence in the UK and Europe, and to enhance the award-winning customer service that Plasma-Therm provides around the world," he adds. "We are excited also to be adding specialized engineering capabilities, for which JLS Designs team is known, and to bring the myriad process technologies they have developed to the Plasma-Therm portfolio."

"The PlasmaPOD is a unique product addition to Plasma-Therm's portfolio, offering high-performance capabilities for etch and deposition in a table-top package," says John Sambell, formerly of JLS Designs and now Plasma-Therm business line manager. "We look forward to reaching new customers through an integrated, global sales network."

www.jlsdesigns.co.uk
www.plasmatherm.com

ClassOne's Solstice S4 chosen by FBH for electroplating and wafer surface processing

ClassOne Technology of Kalispell, MT, USA (which manufactures electroplating and wet-chemical process systems for ≤200mm wafers) has sold a Solstice S4 system to the Ferdinand-Braun-Institut, Leibniz-Institut für Höchstfrequenztechnik (FBH) in Berlin, Germany. As a research institute in the fabrication of III–V compound semiconductors, FBH develops microwave and optoelectronic devices for communications, energy, health, mobility and other industries.

"We were looking for the right tool to optimize our metal lift-off processes, and we did a rigorous comparison of competitive equipment," says Olaf Krüger, head of FBH's Process Technology Department. "The Solstice S4 came out the winner, with superior performance in comparison demos. And one strong differentiator was ClassOne's unique face-down wafer processing design," he comments.

"It's an elegant design that does the job better and also eliminates fundamental problems common in other tools," claims Roland Seitz, director of ClassOne's European Operations. "For example, it prevents re-adhesion issues.

ClassOne's Solstice S4 system.

After metal fragments and cross-linked photoresist have been dislodged, gravity simply pulls them away from the wafer surface and down the chamber drain — leaving the wafer surface clean."

After metal fragments and cross-linked photoresist have been dislodged, gravity simply pulls them away from the wafer surface and down the chamber drain

Seitz says that the Solstice S4's compact footprint and its configuration and multi-processing flexibility were additional factors in the purchase decision — as well as FBH's experience with ClassOne's other equipment and customer support, since FBH is a repeat customer. With the addition of the S4, FBH's Berlin facility will now be employing virtually the entire portfolio of ClassOne tools, including the Solstice S8 as well as SAT, SST, and SRD systems.

The Solstice platform includes three complementary configurations: the 8-chambered Solstice S8 with up to 75wph (wafer per hour) throughput, the 4-chambered automated Solstice S4, and the 2-chambered Solstice LT for process development. In addition to electroplating, the Solstice's special Plating-Plus capabilities enable it to handle numerous other functions, including wafer cleaning, high-pressure metal lift-off, resist strip, and UBM (under-bump metal) etch. This multi-processing flexibility often reduces the number of different tools that a user needs to purchase, the firm adds.

www.fbh-berlin.com
www.classone.com/products

k-Space issues application note 'Continuous Reflectivity Measurements for Growth Rate and Emissivity-Corrected Pyrometry in MBE Systems'

k-Space Associates Inc of Dexter, MI, USA — which makes in-situ, ex-situ and in-line thin-film metrology instrumentation for both research and manufacturing of microelectronic, optoelectronic and photovoltaic devices — has released a new technical note on continuous reflectivity measurements for growth rate and emissivity-corrected pyrometry (ECP) in molecular beam epitaxy (MBE) systems. Real-time growth rate and wafer temperature measurement during MBE growth are important to the final product quality and yield, notes the firm.

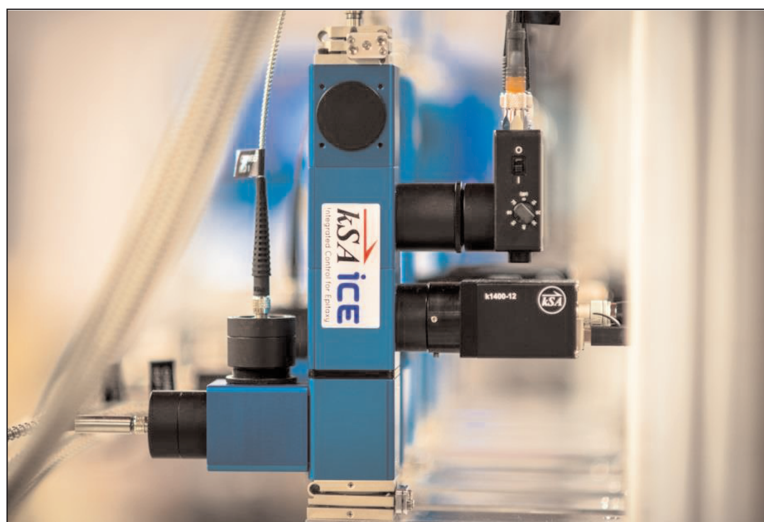
These measurements have been historically difficult to obtain, says k-Space. Taking the measurement is challenging because of variation in the reflectivity signals caused by substrate wobble. These variations are exacerbated by the relatively long substrate-to-detector distances in MBE systems (typically greater than 24") compared with metal-organic chemical vapor deposition (MOCVD) systems (typically less than 12"). This results in oscillations in both the measured reflectivity and the temperature.

The kSA Integrated Control for Epitaxy (kSA ICE) instrument provides reflectivity and ECP measurements that can be utilized during MBE growth. This results in real-time material deposition calibration and process control in both continuous and triggered modes. The optics have been configured to overcome the wobble and path length issues in MBE.

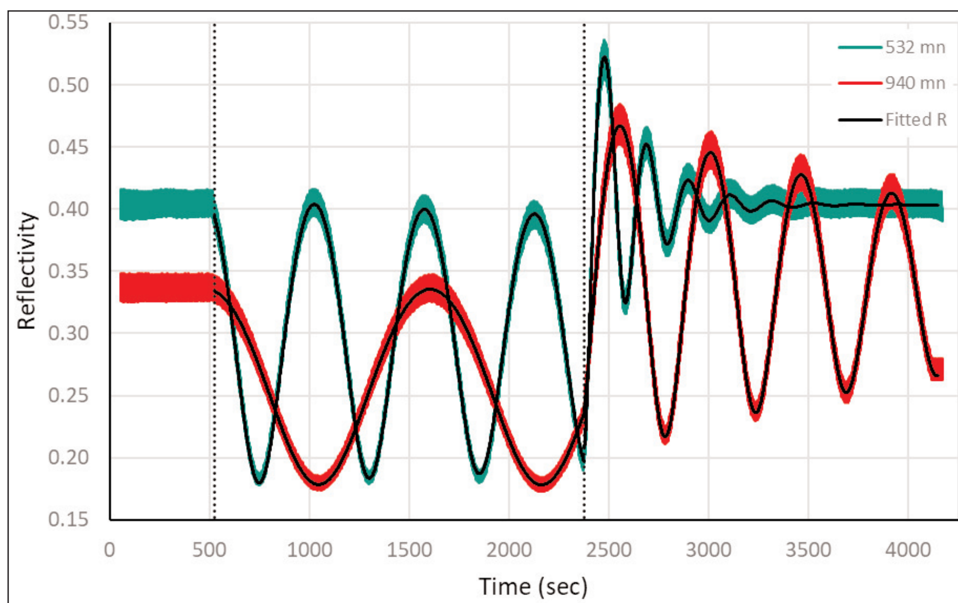
The Figure shows the simultaneous measurement of the surface reflectivity at 532nm and 940nm during the growth of aluminium arsenide (AlAs) and gallium arsenide (GaAs) films on a GaAs substrate. For a deposition with constant growth rate, the oscillation period is proportional to λ/2n. As such, the oscillation period of the 532nm reflectivity data is shorter than that of the 940nm reflectivity data, as seen in the Figure. A shorter oscillation period allows the fit to converge earlier in the growth. As a result, the shorter-wavelength 532nm-wavelength reflectivity data allows the calculation of film thickness earlier in the growth and allows characteristically thinner layers to be measured (under 350nm thick). Conversely, 940nm-wavelength reflectivity continues to produce strong oscillations beyond 350nm.

Additional data is available in the full technical paper 'Continuous Reflectivity Measurements for Growth Rate and ECP in MBE Systems'.

www.k-space.com/products/ksa-ice



The kSA Integrated Control for Epitaxy (ICE) head mounted on a reactor.



532nm- and 940nm-wavelength reflectivity during growth of 250nm of AlAs followed by 500nm of GaAs on a GaAs substrate, and the corresponding virtual interface reflectivity fits for each layer and wavelength. ('Continuous Reflectivity Measurements for Growth Rate and Emissivity-Corrected Pyrometry in MBE Systems').

kSA ICE

Modular design for:

- MOCVD
- MBE
- Sputtering

Optimized measurements for:

- Power Electronics
- VCSELs
- High Speed Electronics

What kSA ICE Measures:

- Temperature
- Reflectivity
- Growth Rate
- Stress
- Curvature

By integrating measurement modules into a single optics head, the **I**ntegrated **C**ontrol for **E**pitaxy (kSA ICE) metrology system measures real-time temperature, reflectivity, growth rate, film thickness, wafer curvature, and film stress. The kSA ICE tool can handle wafer-resolved measurement for rotation speeds up to 1,500 RPM. Keep cool while gaining insight into your deposition process. Maximize device performance and limit process variation to increase yields with kSA ICE!

k-Space Associates, Inc.
Putting Light to Work

USA • 734-426-7977 • requestinfo@k-space.com

www.k-space.com

Everlight launches UVC LED series for medical treatment, water and air purification/sterilization

Taiwan-based Everlight Electronics Co Ltd has launched its ELUC3535NUB series of UVC LED products, which use epitaxial and flip-chip technology on a sapphire substrate, for sterilization applications.

Popular markets for UV applications are curing, medical treatment, photocatalyst and counterfeit testing. Recently, rapid growth of demand in UV markets has been seen, especially in air purification and the sterilization of standing or running water. Everlight has invested in LED technology for many years and has developed UVA and UVC products. There are already existing 2016, 3535 and 4545 packages for UVA (UV black light radiation, 360–410nm) including low to high wattages and several kinds of emitting angles for individual customer options.

Packaged in inorganic quartz glass with an emission wavelength of 280nm, the new ELUC3535NUB UVC LED Series (3.5mm x 3.5mm x 1.4mm) spans three different intensity levels (2mW, 10mW and 30mW), making it suitable for applications such as medical treatment, water or air purification and sterilization of germs, viruses or mold. Furthermore, the ELUC3535NUB LEDs can be used for deodorizing and bactericidal treatment, when installed for example in a modern smart toilet. A similar effect can also be achieved by using the firm's UVA3535 (1.8W, 120ºC) LEDs in combination with titanium dioxide (TiO_2).

www.everlight.com

Crystal IS improves Klaran line of germicidal UVC LEDs to provide 20% higher performance and lower cost

Crystal IS Inc of Green Island, NY, USA, an Asahi Kasei company that makes proprietary ultraviolet light-emitting diodes (UVC LEDs), has completed technology and production improvements to its Klaran product line that provide higher-performing devices at higher yields and corresponding lower costs. The enhancements come at a key time when manufacturers are using germicidal UVC to combat water, surface and airborne pathogens.

In addition to its existing Klaran 60mW UVC LED, Crystal IS is adding a 70mW UVC LED for immediate production use and an 80mW engineering sample to its WD Series. All devices will take advantage of in-house production improvements that lower forward voltage and result in a tighter wavelength specification of 260–270nm — the ideal germicidal range. Klaran WD Series devices will be priced at under 15 cents per mW with supply agreement.

"The completed production and technology improvements fulfill the promise of Crystal IS' proprietary aluminium nitride substrates; high yields of high-output devices at deep UV wavelengths," says Eoin Connolly, VP, product management. "Klaran continues to focus and achieve key milestones which allow us to deliver the products, performance and price needed to meet the needs of global germicidal markets," he adds. "Our rigorous testing, in-house microbiological facilities and ISO 9001:2015 quality system provide the data-driven proof of the reliability, performance and efficacy of our products."

The Klaran product line leverages the unique properties of Crystal IS' aluminium nitride to provide premium germicidal UVC LEDs and associated modules to treat water, air and surfaces for healthcare, consumer appliances and commercial water treatment.

www.cisuvc.com/products/klaran

Picosun delivers production ALD systems to Asia for solid-state lighting device manufacturing

Atomic layer deposition (ALD) thin-film coating technology firm Picosun Group of Espoo, Finland has been chosen by a "major Asian customer" to deliver significant ALD production capacity for manufacturing of solid-state lighting devices.

Replacing thick, lower-quality coatings with ultra-thin but superior-quality ALD films can lead to not only material and energy savings but also longer end-product lifetime, says Picosun.

"ALD films enhance the performance and lengthen the lifetime of solid-state lighting devices," says Edwin Wu, CEO of Picosun Asia Pte Ltd. "Our Picosun P-300BV ALD system is specifically designed for these applications. It combines fast batch production capacity with vacuum loading for the highest ALD film quality and purity," he adds. "A facility of multiple P-300BV ALD tools that shall be installed in their premises will significantly strengthen our position in this [solid-state lighting] market."

www.picosun.com

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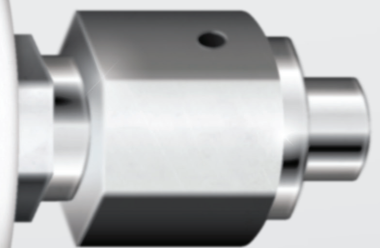

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www.appliedenergysystems.com/pure

Ecosense acquires Soraa's assets

LED technology company enters lamp replacement category

Los Angeles-based LED technology company Ecosense has acquired assets from Soraa Inc of Fremont, CA, USA, a designer and manufacturer of full-spectrum LED lamps and fixtures, including LEDs fabricated from pure gallium nitride substrates (GaN on GaN).

Ecosense acquires the Soraa name, intellectual property and lamps, including the firm's signature VIVID, BRILLIANT HL and HEALTHY product lines. The move is the Ecosense's first foray into the professional lamp category.

"This acquisition accelerates our strategy into the next wave of lighting," says Ecosense's CEO Mark Reynoso. "Soraa has an unparalleled reputation for beam and spectral quality," he comments. "Their intellectual property and technology portfolio — including ZEROBLUE, full spectrum, and healthy lighting — highly complements our own intellectual property and related technologies. We will prioritize enhancing and accelerating their antibacterial technology to market."

Soraa was co-founded by Shuji Nakamura, a 2014 Nobel Laureate in Physics for his invention of the blue LED. "Soraa is a pioneer in full-spectrum and circadian lighting," says Nakamura. "Combining with Ecosense, we significantly expand our leadership and intellectual property rights in these and related fields."

To maintain consistency and quality of service, Soraa will continue to operate as its own distinct brand.

www.soraa.com

www.ecosenselighting.com

Bridgelux launches eighth generation of COB LEDs, deliver 185lm/W efficacy at 3000K 80 CRI

Bridgelux Inc of Fremont, CA, USA (a vertically integrated manufacturer of solid-state light sources for lighting applications) has announced its eighth generation of chip-on board (COB) LED products, delivering luminous efficacy of up to 185lm/W across its V Series, Vero Series and Vero SE Series families at nominal drive current. This performance is benchmarked at the popular 3000K 80 CRI (color rendering index) point, with efficacies above 200lm/W possible at other color points across the industry's broadest range of COB products.

In addition to reclaiming the industry lead in COB efficacy, it is claimed, the products have the following additional features:

- nominal light output optimized to align with traditional lamp standards;
- standard warranty of up to 10 years;
- efficacy improvements of up to 10% compared with previous product generations;
- up to 3x overdrive capability, delivering a 30% increase in maximum lumens per LES (light-emitting surface) size;
- increased lumens per dollar, further reducing the cost of solid-state lighting;
- optical and mechanical consistency with previous generations, enabling a seamless upgrade path leveraging existing ecosystem components;
- broad range of COB size and performance options from LES 8mm to LES 29mm;
- improved alignment with industry-standard drive currents, enabling the use of economical LED drivers to further reduce costs;
- technologically equivalent with existing Bridgelux seventh-generation COB LM-80 data.

With more efficient light sources available for an entire lighting ecosystem, customers are now better equipped to meet evolving energy standards and rebate incentive programs without compromises in quality of light, says the firm.

In addition launching new Gen 8 products, Bridgelux continues to expand its portfolio of human-centric lighting solutions. New products under development include the new Vesta Thrive COB (said to be the first tunable white natural-spectrum light source); expansions in the Vesta Flex dual-channel driver and controls family to now include Casambi and Silvair control modules; and the new Vesta SE (the first dim-to-warm and tunable white COBs with integrated holders to simplify and standardize mechanical, optical, and electrical connections).

"The lighting market continues to evolve, with some suppliers reducing their focus on lighting," says CEO Tim Lester. "Bridgelux is a technology partner for our customers that remains committed to lighting. Our expanded portfolio further enhances our ability to support our customers in navigating the market transition toward human-centric lighting, the right light, in the right place, at the right time," he adds.

Bridgelux Gen 8 products are available now for sampling and ordering, with production shipments commencing

www.bridgelux.com/products/v-series

www.bridgelux.com/products/vero-series

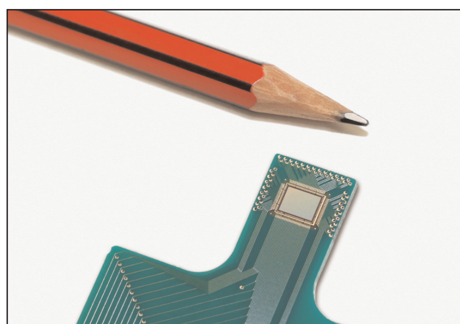
www.bridgelux.com/products/vero-se-series

Plessey extends Data-Vμ micro-LED product family with passive-matrix micro-display

UK-based Plessey, which develops embedded micro-LED technology for augmented-reality and mixed-reality (AR/MR) display applications, has added passive-matrix micro-LED displays to its Data-Vμ product family.

Following the launch of its Data-Vμ segmented micro-LED display products in 2019, Plessey has now extended the range with the introduction of passive-matrix pixelized micro-LED displays, based on the firm's proprietary monolithic gallium nitride on silicon (GaN-on-Si) technology.

These fully addressable micro-displays can provide the high-brightness/low-power image source demanded by the advanced compact optical projectors embedded in AR/MR information systems. The displays can be customized to provide the specific resolution and color that customers require to present their dynamic content specific to their applications. These applications can take advantage of the high brightness and contrast inherent in Plessey's micro-LED technology to produce visual images that can be viewed under a wide range of environmental conditions and at low power consumption.



Plessey's 48 x 36 passive-matrix micro-LED display.

Plessey has demonstrated its first monochrome passive-matrix micro-LED display with a resolution of 48 x 36 monochrome pixels using its native technology capability and a new pixel architecture that improves light extraction. The roadmap for this platform includes the development of higher-resolution displays up to 128 RGB x 128 (or 384 x 128 monochrome) by the end of 2020.

"Micro-LED displays are now the go-to technology for next-generation developments requiring power-efficient and ultra-bright displays," says senior micro-LED product sales manager Leon Baruah. "With the introduction of our Data-Vμ passive-matrix displays, applications where dynamic content needs to be displayed in a small form factor that is outdoor readable without compromising on battery life have become reality."

The Data-Vμ passive-matrix displays are designed to be driven from a driver IC, requiring no active-matrix backplane. The drive architecture, along with its small form factor, makes the Data-Vμ passive-matrix displays a suitable and cost-effective solution for AR smart glasses and head-mounted displays for navigation, sport & leisure, wearables and optical instruments where dynamic content can be displayed, reckons Plessey.

www.plesseysemiconductors.com/products/microleds

Osram's new Synios P2720 Converted Red LED improves visibility in dense fog

Osram Opto Semiconductors GmbH of Regensburg, Germany says that its new Synios P2720 CR (Converted Red) provides many benefits to manufacturers of rear combination lamps for automotive applications, such as enabling compact rear fog lamp designs. Dense fog and poor visibility repeatedly lead to serious rear-end collisions. In poor weather conditions, good visibility through a bright rear fog light is key.

The trend for both headlamps and rear combination lamps is clear: the more compact and efficient the components used, the better. While the installation space required decreases, the design options available to manufacturers greatly increases. The Synios P2720 CR LED addresses this trend of miniaturization. Despite its small dimensions, it offers what is claimed to be outstanding performance in applications.

One of the main issues with monochromatic LEDs for rear fog applications is the enormous loss of brightness (degradation) of about 50% in operating temperatures of 60–70°C. Until now, rear lamp manufacturers had to compensate for this physically induced gap by increasing the number of LEDs, which also increased the space requirements. Now the new, conversion-based Synios P2720 CR can dramatically reduce this loss of brightness to only around 10%, says Osram. Customers enjoy better performance, while manufacturers benefit because considerably fewer individual LEDs are required.

Fewer LEDs means that the required heat sink can be very compact, saving additional space and weight. Rear lamp manufacturers can choose between two different chip sizes (0.5mm^2 or 1mm^2), with typical lumen output and binning current of 49lm and 350mA and 103lm and 700mA respectively, depending on the design of the application. The space-saving package dimensions of just 2.0mm x 2.7mm x 0.6mm remain.

www.osram-os.com

Kei May Lau receives 2020 Nick Holonyak Jr Award

The Optical Society (OSA) has named Kei May Lau of Hong Kong University of Science & Technology (HKUST) as the 2020 recipient of the Nick Holonyak Jr Award for "significant contributions to hetero-epitaxy of compound semiconductors on silicon for future integrated lasers and advancing the field of light-emitting diode micro-displays".

"Kei May Lau's work on semiconductor-based optical devices and materials exemplifies the spirit of the Nick Holonyak Jr Award," comments 2020 OSA president Stephen D. Fantone, founder & president of the Optikos Corp. "Her contributions in the advancement of science and technological applications are very significant."

Lau received B.S. and M.S. degrees in physics from the University of Minnesota, Minneapolis, and her Ph.D. in Electrical Engineering from Rice University. She was on the ECE faculty at University of Massachusetts Amherst, and initiated metal-organic chemical vapor deposition (MOCVD) compound semiconductor material and device programs. Since the fall of 2000, she has been with the ECE Department at HKUST and serves as Fang Professor of Engineering. Lau is a Fellow of OSA, the Hong Kong Academy of Engineering Science and IEEE. She is a recipient of the Croucher Senior Research Fellowship (2008), and the IEEE Photonics Society Aron Kressel Award (2017).

Kei May Lau.

Lau's work focuses on the development of monolithic telecom-band diode lasers directly grown on (001) silicon substrates. She combines innovation in MOCVD-based growth of heterostructure materials with insights into both device physics and fabrication to improved device performance, to effective multi-device integration. The benefits of integrating high-performance III-V-based devices onto a silicon substrate leverages the capabilities and infrastructure of the CMOS silicon industry, extending them to photonic and electronic integrated devices/circuits at high frequencies.

Established in 1997, the Nick Holonyak Jr Award recognizes significant contributions to optics based on semiconductor-based optical devices and materials, including basic science and technological applications. It honors Holonyak Jr's contributions to optics through the development of semiconductor-based light-emitting diodes and semiconductor lasers. The award is endowed by SDL Ventures LLC as well as Donald and Carol Scifres.

www.ust.hk

www.osa.org

CST Global develops QKD emitter and detector technologies for unhackable network communications

As part of a UK government-funded project, III-V optoelectronic foundry Compound Semiconductor Technologies Global Ltd (CST Global) of Glasgow, Scotland, UK (a subsidiary of Sweden's Sivers IMA Holdings AB) has developed quantum key distribution (QKD) emitter and detector technologies, which can enable totally secure network communications. Suiting mission-critical, client-server applications (where unbreakable security codes prevent hacking and malicious attack), QKD can be applied to existing IT infrastructures and offers a high-security data transmission option within the rapidly expanding optical communications market (within which the market for edge-emitting lasers specifically is growing from $1.385bn in 2018 to $3.397bn by 2024, estimates Yole Developpement).

Developed as part of CST Global's core competence in quantum technologies, QKD is a result of CST Global's involvement in the Quantum Ring Single Photon LED (QR-SPLED) government-funded project and the 'Single Photon Infrared Detectors for Quantum Systems' project with Amythest research and Lancaster University.

QKD requires a single-photon quantum light source (QLS) to transmit data and a single-photon detector (SPD) to receive it. CST Global has both QLS and SPD technologies developed to microscale, through government-funded projects. The SPD receiver also operates at room temperature, instead of at the impractical cryogenic temperatures of previous solutions.

"High-security authentication of client-server sessions in today's IT infrastructures are encrypted via a secure HTTPS key server," notes CST Global's chief technology officer Andrew McKee. "CST Global's QKD solution will also do this, however it can encrypt every single packet of data within a session, in real time, making it significantly more secure," he adds. "However, QKD's speed allows direct client-server communications and it will detect tamper attempts, aborting 'suspect' sessions. This makes QKD-based network security totally unhackable."

Operating at room temperature, CST Global's QKD solution is potentially small enough, cheap enough and practical enough for deployment in PC, server or smartphone applications. The firm is actively seeking a commercial partner interested in developing a dedicated nanoscale chip for widespread use.

www.CSTGlobal.uk

Rockley Photonics gains investment from Ahren Innovation Capital

UK-based fund targets AI and healthcare applications

Rockley Photonics of Pasadena, CA, USA (formed in 2013 to develop a versatile, application-specific silicon photonics platform for optical integration in next-generation sensor systems and communications networks) has gained an investor in the form of Ahren Innovation Capital of Cambridge, UK, an investment fund that focuses on transformational companies at the intersection of deep tech and deep science that will penetrate, or create, massive markets. Its four broad fields of activity include the brain and artificial intelligence (AI); genetics and platform technologies; space and robotics; and efficient energy.

Rockley says that its silicon photonics platform enables fundamental advances to be made across multiple mega-trend markets. The technology has potential in sensor applications, where low-cost integrated optics solutions are sought for areas such as in machine vision and environmental sensing. Its technology also boosts performance in high-density communications applications, such as data-center computer connectivity, 5G infrastructure and AI cluster computing environments, where using photonics eliminates the performance constraints of traditional electrical connections.

"Rockley's platform aligns closely with our interests and spans very well across the application space of our target markets, especially as an enabling technology in new AI and healthcare opportunities," says Ahren's founding & managing partner Alice Newcombe-Ellis. "By starting with a clean sheet and designing a bespoke fabrication process, Rockley has created a highly versatile platform solution. Importantly, the technology can be manufactured cheaply and at scale for high-volume markets," she comments.

"Ahren's partners have exceptional credibility and their support for Rockley further validates our technology, strategy and our experienced team," says Rockley's founder & CEO Andrew Rickman. "Silicon photonics enables novel solutions that unlock extraordinary application capabilities. Our unique manufacturing processes, expertise and solutions put us several years ahead of the competition," he believes.

www.rockleyphotonics.com
www.ahreninnovationcapital.com

POET to receive Tranche 2b payment for DenseLight subsidiary by end-March

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 connection with its public offering managed by Toronto-based Cormark Securities Inc (completed on 21 March 2018), it is extending the two-year exercise period by four months (to 23 July) for a total of 12,545,350 common share purchase warrants granted to investors, all of which are exercisable at C$0.75 per share. All other terms and conditions of the warrants remain unchanged. The warrant extension, approved by the board of directors, has been accepted by the firm's Indenture Trustee and the TSX Venture Exchange.

POET also reported that the Tranche 2b payment of US$8.25m is on schedule to be paid to it (by the buyer of its Singapore-based subsidiary DenseLight Semiconductors Pte Ltd) on or before 31 March. The Overseas Direct Investment (ODI) application submitted by the buyer has been accepted by the Chinese authorities in Shanghai and approval of the transfer to POET is expected soon. The remaining Tranche 3 payment of US$5m is expected to be paid by the end of May.

In response to the potential risks associated with COVID-19, POET has taken certain preventive measures to ensure its business remains operational while also protecting employees, including working from home, social distancing among team members, sanitation of test equipment and workstations, and a split rotation schedule that reduces the impact to operations in the event that infection requires quarantining of staff.

"Although we elected not to participate in the recent Optical Networking and Communication Conference & Exhibition (OFC) in San Diego, we have been conducting multiple virtual meetings with potential customers, strategic partners and financial analysts that we had planned to see at OFC to review the benefits of the POET Optical Interposer across a number of potential applications," says president & general manager Vivek Rajgarhia. "The response has been very positive, and our discussions have focused on products in which our platform can bring tremendous value to their offerings."

Due to the uncertainty of travel, POET's board has deferred setting a date and location for its next Annual General Meeting for about 6 weeks and is considering using the 'TSX Trust Virtual Alternative' platform.

www.poet-technologies.com

Sanan IC expands foundry manufacturing services for global optical market

Large-scale foundry targets customized VCSELs and arrays, and standard products for optical communications

Sanan Integrated Circuit Co Ltd (Sanan IC) of Xiamen City, Fujian province (China's first 6-inch pure-play compound semiconductor wafer foundry) has announced the worldwide expansion of its optical portfolio. Using its materials and foundry supply network, Sanan IC aims to provide the global optical market with large-scale foundry services for customized vertical-cavity surface-emitting lasers (VCSELs) and arrays, along with standard products for optical communication applications.

Sanan IC's worldwide launch comes follows LightCounting's report that the optical transceiver market will rise at a 15% compound annual growth rate (CAGR) from 2020 through 2024. Additionally, Yole Développement analysts expect the global 3D imaging and sensing market to grow at a 20% CAGR from $5bn in 2019 to $15bn in 2025.

"Our executive team recognizes the tremendous business opportunities in serving high-growth optical communication and consumer application markets," says Sanan IC's CEO Raymond Cai. "Cutting-edge optical products and foundry services are paramount to accommodating the rapid adoption of automotive, Big Data and 5G wireless communications technologies," he adds. "Sanan IC's robust supply chain and state-of-the-art technology can meet these demands, which is why we are committed to making our components and services commercially available worldwide."

Sanan IC says that, with a broad range of wavelengths available in-house, it enables fast, cost-effective design and manufacturing of high-power VCSEL lasers, high-speed VCSEL lasers, distributed feedback (DFB) lasers, avalanche photodiodes (APD) and monitor photodiodes (MPD). Experienced engineering teams and advanced process tools enable the firm to deliver turn-key solutions. With the ability to ensure its supply chain, Sanan IC provides a dedicated capacity for gallium arsenide (GaAs) and indium phosphide (InP) epi growth, and epitaxial wafer fabrication on 2-, 4- and 6-inch platforms.

Sanan IC's portfolio of optical manufacturing technology includes a family of high-power diode lasers that deliver high brightness and provide what is claimed to be exceptional reliability for a variety of markets, such as medical, datacom, telecom and printing. Additionally, Sanan IC offers a range of foundry services for applications including:

- 2D, 3D and proximity sensors, as well as illuminators for consumer and mobile;
- HDMI 2.0 and USB 3.0 active optical cables (AOC);
- light detection & ranging (LiDAR);
- 100G, 200G and 400G high-speed, high-capacity data-center interconnect (DCI);
- Front-haul and back-haul 5G infrastructures.

www.sanan-ic.com/tech/3

Infinera breaks record with 800G transmission over 950km in live network trial

Infinera Corp of Sunnyvale, CA, USA, a vertically integrated manufacturer of digital optical network systems incorporating its own indium phosphide (InP)-based photonic integrated circuits (PICs), has completed a live network trial of 800Gb/s single-wavelength transmission at 96Gbaud over 950km across a long-haul link in a major North American network operator's production network.

Powered by its sixth-generation dual-800G Infinite Capacity Engine (ICE6) technology, the achievement is claimed to signal an industry milestone in driving down the cost per bit of telecoms networks. The trial showcased the ability of Infinera's 800G technology to enable network operators to rapidly and cost-effectively address the rising capacity demands of new services such as 5G, enhanced broadband, and cloud-based business services.

Conducted over a third-party optical line system carrying live multi-vendor traffic, the production network trial was implemented using Infinera's Groove (GX) Series, equipped with an ICE6-based sled over industry-standard G.652 fiber. The results of the trial demonstrated the performance value of Infinera's vertically integrated ICE6 optical engine, which features second-generation Nyquist subcarriers, 64QAM with per-subcarrier long-codeword probabilistic constellation shaping, and per-subcarrier dynamic bandwidth allocation.

"The success of this trial proves our ability to transmit 800G high-baud-rate signals across significant distances, which will be instrumental in driving down network costs," says chief technology officer Parthi Kandappan. "This marks another major accomplishment for Infinera's Optical Innovation Center."

www.infinera.com

AOI launches 25Gbps LWDM cooled TO-packaged lasers

Applied Optoelectronics Inc (AOI) of Sugar Land, TX, USA — a designer and manufacturer of optical components, modules and equipment for fiber access networks in the Internet data-center, cable TV broadband, fiber-to-the-home (FTTH) and telecom markets — has announced the availability (for sample requests) of 25Gbps local-area network—wavelength-division multiplexing (LWDM) cooled transistor outline (TO)-packaged laser diodes for 5G front-haul applications.

In emerging 5G networks, the front-haul link is the critical fiber-optic segment between the antenna unit (radio head) and the remotely located base station, from which connections to the wider telecom network emanate. The 25G LWDM solution for 5G front-haul allows for sharing of the existing fiber infrastructure, reducing 5G network deployment costs, saving fiber resources, and improving 5G performance. Because the remote radio heads (RRHs) are often installed outdoors in environmentally challenging locations, the ability to operate reliably over a wide operating temperature range is critical.

AOI says that its 25G LWDM TO-cans operate at industrial temperatures between −40°C and +85°C with low power consumption. The devices are housed in a temperature-controlled, hermetically sealed TO format. The output power can exceed 9dBm and an eye-mask margin (EMM) of greater than 30% is achievable with the IEEE 802.3cc standard eye mask.

"As we begin to see widespread deployment of advanced 5G mobile communications networks in 2020, we believe that AOI's ability to supply the needed LWDM channels and quantities of high-performance laser diodes is an important consideration for our customers," says David Chen, assistant VP & senior director of product management. "Our proprietary laser fabrication process and in-house epitaxy, fabrication and packaging operations allow us to develop new varieties of laser diodes with the needed temperature operating parameters, and also rapidly transition these devices into high-volume production to meet our customers' needs," he adds.

www.ao-inc.com

Furukawa develops pump source for forward Raman amplifiers, boosting speed and extending reach

Furukawa Electric Co Ltd (FEC) of Tokyo, Japan has developed FRSi4XX Series pump sources for forward Raman amplifiers that extend transmission distances in ultra-high-speed optical fiber communications further than conventional systems.

Proliferation of smartphones has led to a dramatic increase in communication traffic, including the expansion of wireless backbones, cloud computing, video streaming and the penetration of social networks. To deal with this traffic explosion, improvement in optical signal-to-noise ratio (OSNR) is becoming an important factor in soon-to-be-deployed ultra-high-speed optical fiber communications such as 400Gbps and beyond. Existing erbium-doped fiber amplifiers (EDFA), which are widely used in existing systems, do not have sufficient OSNR performance. Demand is increasing for Raman amplifiers due to their excellent noise characteristics. Forward Raman amplifiers, which make the most of the advantages of Raman amplification, are expected to be necessary for increasing transmission distances.

In the past, only the backward Raman amplifier was used due to limitations of the noise characteristics of the pump source. Furukawa Electric says that its new FRSi4XX Series pump sources make it possible to realize forward Raman amplifiers and feature high output as well as excellent low-noise characteristics.

The important characteristics of these products are high power output and low noise. Furukawa Electric says that it achieved these characteristics by leveraging the design, manufacturing technology and high-precision packaging of its indium phosphide (InP) optical semiconductor chip. The result is a pump source with a high-output chip structure and high-efficiency coupling technology. The optical output of 100mW or more was achieved through an optimized heat dissipation design.

Operating at wavelengths of 1420–1500nm with wavelength spectrum width of >25nm, the FRSi4XX pump series reduces noise by about 20dB/Hz compared with conventional pump sources for Raman amplifiers.

Combining the FRSi4XX Series with the existing FOL1439 Series yields pump sources especially well suited to forward pumping Raman amplifiers, reckons the firm.

Furukawa Electric says that, as demand for ultra-high-speed optical fiber communications continues to grow, it will further enhance the technology of this series and contribute to the construction of information and communications infrastructure in anticipation of the advancement of 5G. Sample shipments of the FRSi4XX Series are scheduled to begin in second-half 2020.

www.furukawa.co.jp/english
www.ofsoptics.com

First bufferless 1.5µm III–V lasers grown directly on silicon wafers in Si-photonics

Pulsed optical excitation leads to target of first electrically driven 1.5µm III-V lasers

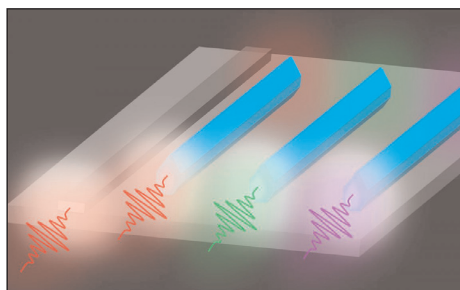
Hong Kong University of Science and Technology (HKUST) has reported what it reckons is the first 1.5µm III–V lasers grown directly, without a buffer layer, on industry-standard 220nm SOI (silicon-on-insulator) wafers using metal-organic chemical vapor deposition (MOCVD), potentially paving the way to interfacing with Si-based photonic devices and the subsequent realization of fully integrated silicon photonic circuits (Yu Han et al, 'Bufferless 1.5µm III–V lasers grown on silicon photonics 220nm silicon-on-insulator platforms', Optica, vol7, issue2, p148). Previous demonstrations required non-industry-standard bulk silicon or thick SOI wafers.

Bridging the active III-V light sources with the passive Si-based photonic devices, the development could be deployed as light sources in integrated circuits to greatly improve circuit speed, power efficiency and cost-effectiveness.

In other conventional approaches of integrating III–V lasers on silicon in the literature, III–V buffers up to a few microns thick are used to reduce the defect densities, which poses huge challenges for efficient light interfacing between the epitaxial III–V lasers and the Si-based waveguides.

Now, a team led by professor Lau Kei-May of HKUST's Department of Electronic and Computer Engineering and post-doctoral fellow Dr Han Yu have devised (for the first time, it is reckoned) a novel growth scheme to eliminate the requirement of thick III–V buffers, promoting the efficient coupling of light into silicon waveguides. The bufferless feature points to fully integrated Si-based photonic integrated circuits.

Improvements in the efficiency of conventional electronic data systems cannot catch up with the soaring data traffic, which calls for the integration of photonic functionalities onto conventional Si-based electronic platforms. Integration could produce optoelectronic integrated circuits with unparalleled speed and functionalities, and enable new applications. Yet fundamental differences between silicon and III–V materials means it is extremely challenging to directly grow III–V functionalities on the silicon.



Schematic of III-V laser array directly grown on Si-photonics 220nm SOI platform.

Lau's group at HKUST's Phonics Technology Center has endeavored to integrate III–V materials and functionalities on mainstream silicon wafers for over a decade, innovating and optimizing various approaches to improve the performance of III–V lasers grown on silicon, with the goal of progressively approaching the requirements of the industry. This work is part of their project on monolithic integration of III–V lasers on silicon.

Taking advantage of the constituent diffusivity at elevated growth temperatures, the reseachers first devised a unique MOCVD growth scheme for the direct hetero-epitaxy of high-quality III–V alloys on the 220nm SOI wafers through synergizing the conventional aspect ratio trapping (ART) and the lateral ART methods. In contrast to prevalent epitaxy inside V-grooved pockets, the method features epitaxy inside trapezoidal troughs, enabling the flexible integration of different III–V compounds on SOIs with different silicon device layer thicknesses.

Using indium phosphide (InP) as an example, the reseachers detailed the growth process and then characterized and evidenced the crystalline quality of the epitaxial III–V materials through extensive transmission electron microscopy and photoluminescence measurements. The team designed and fabricated designed and fabricated both pure InP and InP/InGaAs lasers with air-clad cavities based on numerical simulations. Testing the devices showed that the lasers could sustain room-temperature and low-threshold lasing in both the 900nm band and the technologically important 1.5µm band under pulsed optical excitation. The demonstration leads to the potential to monolithically integrate III–V lasers on the industry-standard 220nm SOI wafers in an economical, compact, and scalable way.

"If practically applied, our technology could enable a significant improvement of the speed, power consumption, cost-effectiveness and functionality of current Si-based integrated circuits," says Lau. "Our daily electronic devices, such as smartphones, laptops and TVs — basically everything connected to the Internet — will be much faster, cheaper, using much less power and multi-functional," she adds.

"The next step of our research will be to design and demonstrate the first electrically driven 1.5µm III–V lasers directly grown on the 220nm SOI platforms, and to devise a scheme to efficiently couple light from the III–V lasers into silicon waveguides and thereby conceptually demonstrate fully integrated silicon photonics circuits," Han says.

www.doi.org/10.1364/OPTICA.381745

www.ust.hk

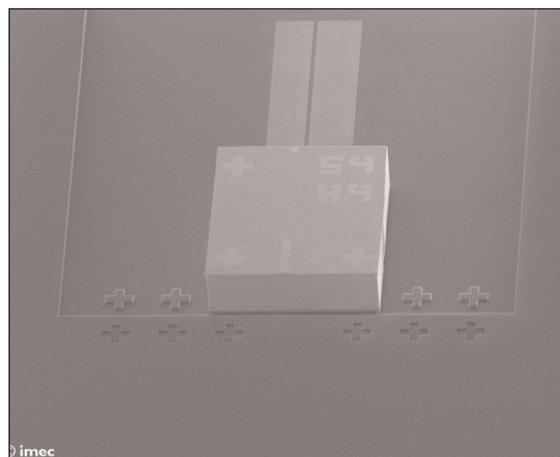
C-band InP DFB lasers from CST Global incorporated into imec's iSiPP platform

Imec collaborating with CST to extend silicon photonics portfolio with hybrid integrated InP light sources

Nanoelectronics research centre imec of Leuven, Belgium and III-V optoelectronic foundry Compound Semiconductor Technologies Global Ltd (CST Global) of Glasgow, Scotland, UK (a subsidiary of Sweden's Sivers IMA Holdings AB) have announced the integration of indium phosphide (InP) distributed feedback (DFB) lasers from CST Global's InP100 platform into imec's integrated silicon photonics platform (iSiPP).

Interfaces for hybrid integration of InP DFB lasers and reflective semiconductor optical amplifiers (RSOA) will become available as part of imec's silicon photonics prototyping services in first-half 2021, following further optimization and qualification work in 2020. This joint imec-CST Global technology offering is expected to boost the adoption of silicon photonics in cost-sensitive applications, including optical interconnects, sensing, computing and beyond.

Silicon photonics (SiPho) technology has made great progress over the past decades and is used extensively in a variety of applications — from fiber-optic communications to sensing. Technology platforms have evolved into mature vehicles and are available to industry and academia for prototyping, low-volume and higher-volume manufacturing. However, a widely available, cost-effective solution to integrate light sources in SiPho chips has been missing, hampering the adoption of SiPho in cost-sensitive markets. Since silicon itself does not emit light efficiently, light sources made of III–V semiconductors, such as indium-phosphide (InP) or gallium-arsenide (GaAs), are typically implemented as separately packaged components. Such external light sources typically suffer from higher coupling loss; a large physical form factor; and a substantial packaging cost.

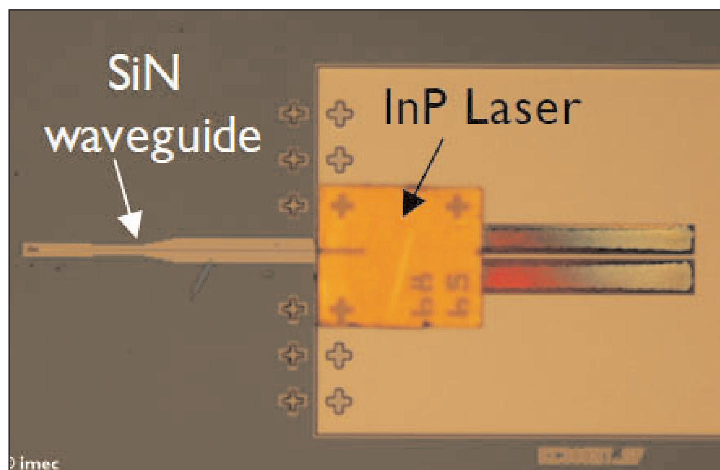


Scanning electron microscope image of InP DFB laser assembled on silicon photonics

Imec recently joined forces with CST Global to extend imec's SiPho technology portfolio with passively assembled, edge-emitting InP DFB lasers and InP RSOAs. This collaboration, which started in 2019, has now resulted in the first successful assemblies of C-band (1530–1565nm) InP DFB lasers onto imec's iSiPP platform. The InP lasers were flip-chip integrated onto the SiPho circuits through a die-to-die bonding process, aligning efficiently and coupling >5mW into the SiN waveguides on the SiPho chip.

"Our first passive laser assemblies have demonstrated excellent initial results," says Joris Van Campenhout, program director Optical I/O at imec. "Throughout 2020, we will further optimize the precision and throughput of the laser assembly process; extend the functionality to include RSOA integration at 1310/1550nm wavelengths; and perform reliability qualification. We expect that the availability of these hybrid, integrated light sources will boost industrial uptake of SiPho devices in a variety of cost-sensitive markets. Early access through imec's iSiPP200 prototyping services is anticipated by the first half of 2021," adds Campenhout.

"The hybrid integration of InP light sources (DFBs and RSOAs), designed and fabricated on CST's InP100 manufacturing platform, combined with the iSiPP platform, allow the creation of powerful photonic integrated circuits (PICs) for advanced components with improved performance and lower cost in the future," says CST Global's integration manager Antonio Samarelli. "We will continue to work closely with imec to extend the functionality and capabilities of the InP100 platform to meet the InP light source requirements of novel, advanced PICs for high-volume commercial applications.



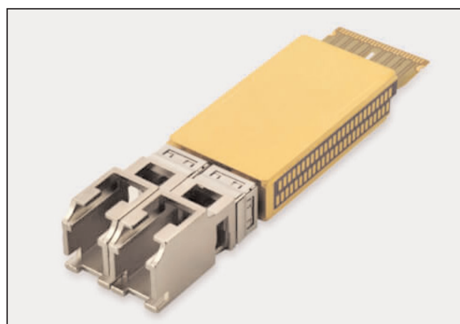
Microscope image of indium phosphide DFB laser assembled on silicon photonics chip.

www.imec.be
www.cstglobal.uk

II–VI unveils first IC-TROSA 64Gbaud coherent optics subassembly for 400ZR QSFP-DD data-center interconnects

Engineered materials and optoelectronic component maker II–VI Inc of Saxonburg, PA, USA has introduced its 64Gbaud integrated coherent transmitter-receiver optical subassembly (IC-TROSA) — claimed to be the industry's first — for the 400ZR standard in data-center interconnects.

The rapid growth in transmission capacity requirements in optical backbone networks and between data centers is driving demand for next-generation transmission platforms that can scale more economically, with increasing power efficiency and in smaller form factors. II-VI's IC-TROSA is a highly integrated coherent optics subassembly with an embedded optical amplifier that can deliver up to 0dBm of output power in ultradense pluggable form factors, including OSFP and QSFP-DD.



II–VI's new 64Gbaud integrated coherent transmitter–receiver optical subassembly (IC-TROSA).

"Building on the success of our integrated tunable transmitter–receiver assembly, we are now excited to introduce our next-generation integrated coherent optics platform, a giant leap in integration density and a new benchmark for the industry," claims chief marketing officer Dr Sanjai Parthasarathi. "Our new IC-TROSA demonstrates the inherent power of a world-class indium phosphide technology platform that not only can lead the industry in the migration to 400ZR coherent optics but also drive a broad range of use cases beyond what competing technologies can achieve, based on its highly differentiated performance in output power," he adds.

The IC-TROSA can support various modulation formats of up to 16QAM at baud rates of up to 64Gbaud in a flex-grid environment, with full C-band support.

II–VI launches 400G CFP2-DCO pluggable transceivers for high-speed backbone networks and data-center interconnects

II–VI Inc has introduced the 400G CFP2-DCO, its first module to support high-performance 400Gbps coherent transmission in a pluggable form factor for high-speed optical backbone networks and data-center interconnects.

The rapid growth in transmission capacity requirements in optical backbone networks and between hyperscale data centers is driving the demand for next-generation transmission platforms that can scale more economically, with increasing power efficiency, and in smaller form factors. II-VI's 400G CFP2-DCO is based on the latest generation of 7nm CMOS digital signal processing (DSP) technology that achieves what is said to be the state of the art in power consumption efficiency, in a small pluggable form factor, which enables a pay-as-you-grow deployment model for line-side interfaces. Each module can transport up to 400Gbps of data over a single wavelength using 64GBaud 16QAM modulation and can be tuned to 64 wavelength channels on a 75GHz grid, enabling a total transmission capacity of up to 25.6Tbps over a single fiber.

II–VI's new 400G CFP2-DCO module.

"This 400G coherent optics module leverages our mature integrated tunable transceiver assembly (ITTRA) coherent optics platform, which has been shipping for over a year," says Matthias Berger, VP, Coherent Optics business unit. "Our ITTRA is the key reason we expect to become the first in the industry to reach volume manufacturing with such a product."

For long-haul applications, the module supports 200Gbps transmission employing 64GBaud QPSK modulation, which enables significantly longer reach than existing 200G CFP2-DCO modules that use 32GBaud 16QAM modulation. For networks requiring channels on a 50GHz grid, a 200Gbps mode using 41GBaud 16QAM modulation with enhanced OSNR performance is available. The module can multiplex up to four 100G client signals and supports a mix of IEEE 100G Ethernet and ITU-T Optical Transport Network OTU4 or OTUC (FlexO) host-side interfaces. In addition, IEEE 200G Ethernet, 400G Ethernet as well as ITU-T OTUC2, OTUC3 and OTUC4 host-side interfaces are supported.

The 400G CFP2-DCO module is available for sampling and will be generally available in second-half 2020.

www.ii-vi.com

II–VI introduces high-speed indium phosphide electro-absorption modulated lasers for datacenters and 5G optical infrastructure

Engineered materials and optoelectronic component maker II–VI Inc of Saxonburg, PA, USA has launched high-speed indium phosphide (InP) electro-absorption modulated lasers (EML) for datacenters and 5G optical access infrastructure.

The upcoming combined demand for 400Gbps transceivers in intra-datacenters and for 25Gbps transceivers in fronthaul links to 5G antennas is rapidly driving a technology shift from directly modulated laser (DML) devices, deployed in high-volume today, to more advanced EML devices that maintain transmission reach at higher bit rates, says II–VI. The firm's EML devices are designed for high reliability and high signal integrity, enabling transceiver modules operating at data rates of 100, 200, 400 and 800Gbps for high-speed data-center connectivity and for optical access networks that provide fronthaul, midhaul and backhaul connectivity to 5G wireless base stations.

"Our highly proprietary electro-absorption modulator monolithically integrated with the laser and designed for non-hermetic packaging differentiates our InP technology," says Dr Charlie Roxlo, VP, Indium Phosphide Devices business unit. "Our world-class and highly reliable InP technology platform is one of the very few in the industry that has been proven with more than 100 million lasers in the field deployed over the last decades," he adds.

II-VI's portfolio of InP components includes Fabry–Perot lasers, directly modulated lasers and tunable lasers, as well as photodiodes for high-speed receivers and power monitoring. Lasers are available in LAN–WDM and CWDM wavelength plans.

II–VI's electro-absorption modulated lasers will be generally available in second-half 2020.

www.ii-vi.com

QSFP-DD800 MSA group unveils initial hardware spec

Group to act as incubator, collaborating with QSFP-DD MSA

Following its debut in September 2019, the Quad Small Form Factor Pluggable Double Density 800 (QSFP-DD800) multi-source agreement (MSA) group has released a new hardware specification for the QSFP-DD800 transceiver form factor.

The MSA group was formed to advance the development of high-speed, double-density QSFP modules, which support 800Gbps connectivity, and includes the following promoters: Broadcom, Cisco, II-VI, Intel, Juniper Networks, Marvell, Molex and Samtec.

The QSFP-DD800 MSA is focused on the next generation of the QSFP family of modules. The new QSFP-DD800 1.0 specification is intended to be incremental to the existing QSFP-DD 5.0 specification. As signal integrity and thermal performance remain imperative, the transceiver pads have been optimized to improve signal integrity for 100Gbps performance per lane without affecting backwards compatibility. The new specification additionally defines a novel 2x1 connector/cage, with cabled upper ports as an option to address signal loss issues associated with tradition PCBs. Looking ahead, QSFP-DD800 promoters will continue to work on new connector/cage variants, including 2x1 SMT versions that operate at 100Gbps per lane.

"As signal integrity and thermal management remain challenges for the optical communications industry, our MSA group is confident that its solutions will meet performance needs," says QSFP-DD800 MSA co-chair Scott Sommers.

With their superior system integration and design flexibility, QSFP modules continue to be the cornerstone in building next-generation networks and network equipment, especially as port speeds increase to 800G

"With their superior system integration and design flexibility, QSFP modules continue to be the cornerstone in building next-generation networks and network equipment, especially as port speeds increase to 800G," says co-chair Mark Nowell. "Furthermore, their ability to increase switch and routing bandwidth density without sacrificing backwards compatibility with QSFP-DD, QSFP56 and QSFP28 modules provide network operators tremendous commercial and operational advantages."

The QSFP-DD800 MSA group also says that it will act as an incubator, collaborating with the QSFP-DD MSA, to provide specifications to that group with the intention of it being included within the QSFP-DD specifications. Therefore, companies interested in joining and participating in QSFP-DD800 development are encouraged to join the QSFP-DD MSA.

www.qsfp-dd800.com

Ranovus collaborates with IBM, TE & Senko to design and deliver multi-vendor co-packaged optics for data centers

Ranovus' Odin 32 co-packaged optics to leverage IBM optical interconnects, TE's CP fine-pitch socket interposer and Thermal Bridge technology and Senko's fiber-optic connectivity

Ranovus Inc of Ottawa, Ontario, Canada (a provider of multi-terabit interconnect solutions for data-center and communications networks) has announced a strategic collaboration with IBM Inc, TE Connectivity and Senko Advanced Components Inc, providers of multi-terabit interconnect solutions, to create an ecosystem to design and manufacture multi-vendor solutions for co-packaged optics applications in data centers.

The collaboration leverages:

- Ranovus' highly scalable Odin silicon photonics engine (launched earlier in March), which incorporates the firm's multi-wavelength quantum dot laser (QDL), 100Gbps silicon photonics-based micro-ring resonator modulators and photodetectors, 100Gbps driver, 100Gbps trans-impedance amplifier (TIA) and control integrated circuits in a power-efficient and cost-effective EPIC in a single chip.
- IBM's fiber V-groove interconnect packaging technology, which is a robust and reliable assembly technique to interface optical fibers to silicon photonics devices. This process makes use of passive alignment techniques and achieves low insertion loss across a wide spectral range in both the O- and C-band regimes. The solution is scalable in physical channel count and the automated process provides a path to high-volume manufacturing of co-packaged optics.
- TE's co-packaged (CP) fine-pitch socket interposer technology, which enables integration of small chipset and optical engine component technologies into high-value co-package assemblies with reworkable and interoperable interfaces. The signal integrity performance of the CP fine-pitch socket interposer technology can be critical to 100Gbps high-density electrical packaging requirements. The integration of TE's thermal bridge technology completes the assembly by providing an innovative solution for thermal management of the switch, serializer/deserializer (SerDes) and optics necessary for high reliability and long operating life.
- Senko's fiber-optic connectivity solutions for optical coupling, on-board/mid-board and faceplate to support 100Gbps/lane-and-beyond co-packaged optics equipment designs include low-profile and precision fiber coupler assemblies, micro-sized on/mid-board connectors, reflow-compatible connector assemblies and space-saving connector options for faceplate. These will provide more efficiency, scalability and flexibility in designs for co-packaged optics equipment.

With data-center traffic growing at an unprecedented pace, the networking infrastructure needs to scale in capacity while maintaining its total power consumption and footprint, notes Ranovus. Today's disaggregated Ethernet switch IC and optical module architecture does not provide the scalability required to support the future growth of the data centers, adds the firm. Co-packaging of optics and Ethernet switch ICs is a natural next step to reduce the power consumption burden of the electrical I/Os in the data-center networking equipment. The transition of the Ethernet switch IC Ser/Des from 50Gbps to 100Gbps, in 25.6Tbps and 51.2Tbps switch configurations, presents a unique inflection point in the architecture of the Ethernet switch systems, recons the firm.

"Ranovus' Odin platform was conceived with miniaturized components such as micro-ring resonators in a monolithic electronic and photonic integrated circuit to deliver highly scalable solutions in support of single- and multi-wavelength applications," says chief technology officer Georg Roell. "We are delighted to contribute our IP and create an ecosystem to remove a major hurdle for the adoption of co-packaged optics solutions for data centers," he adds.

"IBM is enthusiastic to bring to this collaboration more than 45 years history in microelectronics packaging and its deep experience in optical packaging," says Paul Fortier, senior engineer, IBM business development. "IBM's optical assembly processes leverage our automated high-volume semiconductor packaging, and IBM's Assembly and Test division provides the co-packaged optics ecosystem with a seamless end-to-end manufacturing capability," he adds.

"TE is pleased to be able to bring decades of socket expertise to this co-packaging effort in the form of the fine-pitch CP socket technology," notes TE Connectivity technologist Nathan Tracy. "In addition, TE's thermal bridge technology is a key enabler to the high-density packaging and extreme thermal management necessary for co-packaging," he adds.

"Senko is pleased to contribute our product designs and IP to enhance the design capability, scalability and flexibility for the co-packaged optics embedded products," says Tiger Ninomiya, business development/product line manager at Senko. "Innovative optical connectivity solutions are key to making co-packaged optics' solutions a success in the market."

www.ranovus.com
www.ibm.com/assembly
www.te.com

Ranovus launches single-chip silicon photonic engine to support ML/AI workloads for data center & 5G mobility

Ranovus Inc of Ottawa, Ontario, Canada (a provider of multi-terabit interconnect solutions for data-center and communications networks) has launched its Odin platform, which scales the firm's 100Gbps-per-lambda silicon photonics engine from 800Gbps to 3.2Tbps in a single chip supporting both module and co-packaged optics solutions.

The Odin platform incorporates a multi-wavelength quantum dot laser (QDL), 100Gbps silicon photonics-based micro-ring resonator modulators and photodetectors, 100Gbps driver, 100Gbps transimpedance amplifier (TIA) and control integrated circuits supported by a tier-1 packaging ecosystem.

"ML/AI [machine learning/artificial intelligence] are the driving forces behind innovation in our society. They have created new compute, storage and networking paradigms inside and outside the data center," says chairman & CEO Hamid Arabzadeh. "The massive growth in data traffic fueling the algorithms requires scalable and power-efficient networking technologies. Odin platform delivers 50% power consumption/Gbps reduction and 75% cost/Gbps reduction over today's solutions," he adds. "Odin 8 marks the beginning of the road to multi-terabit co-packaged optics for compute, storage and networking solutions."

Highlights of Ranovus' Odin 8 silicon photonics engine are:

- the lowest power consumption/Gbps and cost/Gbps solution in the industry, it is claimed;
- supports for ML/AI applications with 0.4ns low latency and a protocol agnostic engine;
- support for a transmission distance of 10m to 2km in CWDM and DWDM applications;
- eight optical channels of 100Gbps/64Gbps/50Gbps PAM4 or 50Gbps/32Gbps/25Gbps NRZ;
- support for DR & FR configurations;
- support for QSFP-DD and OSFP module form factors;
- support for 25.6Tbps and 51.2Tbps Ethernet Switch configurations.

"Intra-data-center traffic is growing at a rate that outpaces anything seen outside of the data centers and is expected to triple in the next five years. This growth in traffic is driving global energy consumption, for power and cooling, that is simply not sustainable at the current trajectory," says John Martinho, senior VP R&D. "At Ranovus, we're dedicated to developing energy- and space-efficient technologies to address this critically important challenge - starting with our Odin optical engine platform," he adds. "We're proud to have brought together a tier-1 ecosystem of partners and industry veterans to make these innovations possible."

www.ranovus.com

Broadex sampling 400G QSFP-DD DR4 transceiver based on silicon photonics

Optoelectronic component maker Broadex Technologies Co Ltd of Jiaxing, China (which has R&D and production facilities in Shanghai and Chengdu as well as in Edinburgh, UK) is sampling high-performance 400G QSFP-DD DR4 transceivers, in both 500m and 2km variants, based on a new silicon photonics (SiPh) platform.

The modules use SiPh chips that integrate a number of active and passive optoelectronic components, 3D packaging technology and 7nm digital signal processing (DSP) chips. Packaged with proprietary low-loss optical coupling techniques, the modules feature what is claimed to be excellent signal quality and channel consistency with very low bit error rate of 10^{-9} without forward error correction (FEC) and TDECQ (Transmission Dispersion and Eye Closure Quaternary) as low as 0.6dB. The Broadex modules are said to be uniquely suited to enable data-center operators to address increasing bandwidth demand by upgrading 100G-centric network to 400G.

Broadex's 400G QSFP-DD DR4 silicon photonics module

"Broadex has been working with industry-leading partners for the past year to develop a 400G SiPh transceiver that offers superb product performance and improved yield to enable high-volume production," says CEO Dr Wei Zhu. "Results obtained so far, including live interoperability tests, indicate that we are on the right path to provide data-center customers with a very cost-effective product to support their growing bandwidth demand," he adds. "400G EML-based solutions have been challenged to meet the volume expectations, which has become a constraint on the evolution of data-center networks toward higher-bandwidth interconnects. With the development of SiPh technology and its inherent potential in volume manufacturing, we expect our SiPh modules will become the preferred solution."

Broadex's 400G SiPh transceivers are available for sampling now and are expected to begin volume production in second-half 2020.

www.broadex-tech.com

Lumentum expands datacom laser chip portfolio for hyperscale data center and 5G wireless applications

Lumentum Holdings Inc of San Jose, CA, USA, which makes photonics products for optical networking and lasers for industrial and consumer markets, has introduced three new high-speed datacom laser chips, broadening its portfolio to enable the growth of future hyperscale data centers and 5G wireless.

The expected strong growth of data in hyperscale data centers and 5G wireless networks is driving increasing requirements for volume, reliability, cost and speed in datacom laser chips. Lumentum says that it is addressing these requirements by leveraging decades of experience in the industry developing advanced photonic solutions.

"To sustain the expected growth in these markets, customers critically need an experienced supplier that can provide high performance, high quality and scalability," says senior VP & general manager, Datacom, Walter Jankovic. "We leverage our high-volume manufacturing capability, unmatched materials, and laser device expertise in InP and GaAs, to meet our customer expectations for chip innovation at scale."

Lumentum provides high-performance externally modulated lasers (EMLs) for 100G PAM4 applications, enabling data centers to increase their bit rate and lower their overall power consumption. The firm says that its 50G PAM4 vertical-cavity surface-emitting lasers (VCSELs) provide high performance with customer value and production capacity. Additionally, Lumentum's newly developed 50G PAM4 directly modulated lasers (DMLs) enable users to lower their overall cost by offering the equivalent performance of an EML for 50G and 200G applications in a simpler and lower-cost DML format.

Details of the new products are:

- *100G PAM4 uncooled EMLs for next-generation data centers*
Lumentum's PAM4-optimized 53Gbaud EMLs enable full C-temp transceiver designs without using a thermo-electric (TE) cooler. With expertise in complex EML technology, the firm has developed an industry-first uncooled, self-hermetic EML. Available to sample in third-quarter 2020, this laser chip targets the transition in data-center infrastructure from 100G to 400G by enabling a wide-temperature range and high-performance 2km PAM4 modules.
- *50G PAM4 VCSELs for high-speed short-reach optical networks*
Enabled by its 6-inch GaAs wafer foundry and its experience producing high-reliability 3D sensing VCSELs at high volume, Lumentum's 50G (28Gbaud) VCSEL provides what is claimed to be unprecedented uniformity at scale. Available to customers in second-quarter 2020, the VCSEL is suitable for non-hermetic use from 0ºC to 80ºC, delivers very high yields, and is RoHS10 and Telcordia GR-468 compliant.
- *50G PAM4 DMLs for 5G mid-haul, backhaul and hyperscale data centers*
Lumentum says that its DMLs use a sophisticated cavity design to operate over wide and demanding temperature ranges. Offering higher bandwidth, the 50G PAM4 (28Gbaud) DMLs (available now for sampling) provide the equivalent performance of an EML but in a smaller and more cost-effective footprint.

www.lumentum.com

Lumentum launches high-power pump lasers for undersea optical

Lumentum has launched a series of 980nm single-mode pump lasers that use chips based on its field-proven, proprietary, high-reliability technology but offering operating power of 250–1600mW, enabling high-density erbium-doped fiber amplifier (EDFA) designs.

"Lumentum is supporting the industry's need for ultra-high-reliability, high-power and scalable pump lasers for pluggable EDFAs," says Doug Alteen, senior VP, general manager, Telecom Transport.

The 5200 Series is designed for demanding undersea optical use that require ultra-high reliability when pumping EDFAs in submarine repeaters and branching units.

"The new 5200 Series addresses the critical need to maintain extreme high reliability while providing higher power pumping," says Xia Hong, senior director, product line management, Optical Communications. "Lumentum addresses these market needs with a design lifetime of over 25 years."

The new uncooled laser offers increased operating power up to 800mW. Also, through new advances in chip technology and high-reliability packaging, the 5200 Series (available in July) boosts overall optical performance.

The H11 Series of uncooled 3-pin low-profile planar pump lasers with up to 250mW output power greatly reduces the overall pump laser size and power consumption. This laser series employs both an innovative DFB laser chip (which integrates a high-power laser and grating into a single high-reliability laser die) and an improved package design. Available in May, the H11 provides a noise-free, narrowband spectrum under temperature, drive current, and optical feedback changes.

The new D2 Series dual-chip 980nm pump laser provides up to 1.6W total optical output in a low-profile 14-pin butterfly package. Available in July, it incorporates a next-generation chip and semi-autonomous assembly technology, improving power and density.

Emcore introduces Optiva Q/V-Band (50–60GHz) and Next-Gen Extended L-Band fiber-optic links

Emcore Corp of Alhambra, CA, USA — which provides mixed-signal products for the aerospace & defense and broadband communications markets — has introduced its Optiva Q/V-Band fiber-optic links for applications from 50MHz to 60GHz, and Optiva Next-Gen Extended L-Band fiber-optic links featuring bandwidth to 6GHz.

The new transmitter and receiver modules for the Optiva platform are suitable for antenna remoting, interfacility links, electronic warfare (EW) systems, broadband delay lines, signal processing systems and other high-dynamic-range applications.

Emcore's latest additions to the Optiva platform were previewed at the Satellite 2020 event in Washington DC (10–12 March).

Building on Emcore's existing Optiva RF (radio frequency) and microwave fiber-optic transport platform, the new transmitter and receiver modules are compatible with Optiva's modular, rack-mount or flange-mount configurations. The Optiva platform includes a wide range of SNMP-managed transmitters, receivers, optical amplifiers, RF and optical switches, passive devices, video, audio, data and Ethernet products. The new Q/V-Band unamplified microwave transmitter and receiver pairs are suited to support higher-frequency bands from 50GHz to 60GHz. They utilize Emcore's high-performance, ultra-low RIN (relative intensity noise) source laser technology and high optical input power capable photodiodes. The Next-Gen L-Band links are optimized to provide transparent IF, extended L-Band, S- and C-Band signal transport out to the 6GHz frequency range.

"Our new Optiva Q/V-Band fiber-optic links represent significant breakthroughs in microwave transmission technology for aerospace & defense and commercial applications," says David Wojciechowski, vice president & general manager of Defense Optoelectronics. "By leveraging our advanced engineering capabilities in satellite communications, Emcore provides cutting-edge, high-performance fiber-optic transmitter-receiver products demanded by our defense customers, including new satellite applications requiring Q/V-Band fiber-optic solutions," Wojciechowski adds. "The new Q/V-Band product will represent a major improvement in cost and performance over copper-based solutions for these extreme higher frequency applications."

At Satellite 2020, Emcore also debuted its new Outdoor Enclosure that houses its 3U 19" Optiva rack-mount 16-slot chassis in a fan-cooled, weatherproof, environmental IP-rated, wall- or pole-mounted container. The Optiva platform also includes a variety of other rack-mount, compact table-top, or wall-mountable enclosure options and is completely modular and hot-swappable.

www.emcore.com

Emcore launches Model 1997 6GHz uncooled coaxial laser module for 5G wireless

Emcore has introduced the Model 1997 1310nm and 1550nm CWDM 6GHz uncooled coaxial DFB (distributed feedback) laser module for next-generation, wireless linear fiber-optic links.

The laser module features extended bandwidth to 6GHz and is optimized for 5G, DAS (distributed antenna systems) and small-cell applications.

With the rollout of 5G wireless networks well underway, 2019 saw 5G's first commercial deployments from Verizon, AT&T, T-Mobile and Sprint, and smartphone makers will continue to rollout 5G models throughout 2020. As an ultra-linear, coaxial model optimized for 5G and a variety of wireless infrastructure fiber-optic link applications, Emcore's Model 1997 6GHz uncooled DFB laser module is designed to enhance bandwidth and signal integrity for delivery of consistent, reliable wireless signals in temperature-controlled environments. The 1997 is packaged in a compact, hermetic TOSA (transmitter optical sub-assembly) with monitor photodiode and optical isolator for flexible integration into DAS and small-cell modules. It differs from Emcore's 1998 6GHz cooled DFB laser by eliminating the thermoelectric cooler (TEC) and flex circuit connector to provide a lower-cost solution for indoor use. It delivers outstanding optical performance over a temperature range of −40°C to +75°C.

"Our new 1997 laser expands Emcore's line of optical components for extended-bandwidth, high-speed wireless applications," says Gyo Shinozaki, VP & general manager of Broadband. "With 6GHz bandwidth and low-noise operation, the 1997 will deliver maximum high-speed signal integrity for emerging 5G DAS and small-cell networks," he adds.

The Model 1997 and Emcore's complete line of lasers and optical receivers were scheduled to be on display at the Optical Networking and Communication Conference & Exhibition (OFC 2020) in San Diego Convention Center (10–12 March).

www.emcore.com

Open Eye Consortium makes available single-mode spec to public, and multi-mode draft spec to participating members

MSA adds six new contributing members

The Open Eye Consortium multi-source agreement (Open Eye MSA) has announced the availability of its 53Gbps single-mode specification to the general public, which defines the requirements for 53Gbps-per-lane analog PAM-4 solutions for 50G SFP, 100G DSFP, 100G SFP-DD, 200G QSFP and 400G QSFP-DD and OSFP single-mode modules in data-center applications.

The Open Eye MSA aims to accelerate the adoption of PAM-4 optical interconnects scaling to 50Gbps, 100Gbps, 200Gbps and 400Gbps by expanding on existing standards to enable optical module implementations using less complex, lower-cost, lower-power and optimized analog clock & data recovery (CDR)-based architectures in addition to existing digital signal processing (DSP) architectures.

Live and online Interoperability demonstrations of products based on the new specification were due to be showcased during the Optical Networking and Communication Conference & Exhibition (OFC 2020) in San Diego, until the Covid-19 Coronavirus outbreak intervened.

Further, the Open Eye MSA has announced the draft of its multi-mode specification available to its members for comments, with general availability to the public targeted for release in Fall 2020.

Finally, the Open Eye MSA has added six new contributing members: Broadex Technologies, HiLight Semiconductor, Renesas, Sicoya, TE Connectivity and Trumpf.

MACOM and Semtech Corp initiated the formation of the Open Eye MSA, with 34 current members in Promoter and Contributing membership classes.

Promoters include: Applied Optoelectronics Inc., Cambridge Industries Group (CIG), Juniper Networks, Luxshare-ICT, MACOM, Mellanox Technologies, Molex, and Semtech Corp.

Contributors include: Accelink, Anritsu, Broadex Technologies, Cloud Light Technology, ColorChip, Fujitsu Optical Components, HiLight Semiconductor, InnoLight, Inopticals, Keysight Technologies, Marvell, Maxim Integrated, MultiLane, O-Net, Optomind, Renesas, SAMTEC, Sicoya, Source Photonics, Tektronix, TRUMPF and four further members.

www.openeye-msa.org

MACOM launches dual-channel 96Gbaud TIA and quad-channel modulator driver for 600 & 800Gbps optical networking

MACOM Technology Solutions Inc of Lowell, MA, USA (which makes semiconductors, components and subassemblies for analog RF, microwave, millimeter-wave and photonic applications) has announced the availability of its new dual-channel 96GBaud transimpedance amplifier (TIA) and quad-channel modulator driver for coherent optical networking applications.

Increased demand for data capacity in metro and data-center interconnect (DCI) applications is being driven by trends like the Internet of Things (IoT), autonomous vehicles (AVs), virtual reality (VR) and artificial intelligence (AI). As market demand moves to higher data rates for lower overall cost-per-bit, coherent optical systems are operating at higher symbol rates and with more complex modulation schemes to support data rates of 800Gbps and higher on a single wavelength.

This move to higher data rates drives the need for modulator drivers and TIAs with ever increasing levels of performance. MACOM says that its new MATA-009806 dual-channel TIA and MAOM-009408 quad-channel driver offer the high bandwidth, low noise and low power consumption to enable integrated coherent receivers (ICRs), high-bandwidth coherent driver modulators (HB-CDMs) and integrated coherent transmit-receive optical sub-assemblies (ICTROSAs) operating at up to 800Gbps in telecom and DCI applications.

The MATA-009806 is a dual-channel linear TIA for coherent receivers supporting baud rates up to 96Gbaud and complex modulation formats such as 64QAM. With built-in automatic gain control (AGC) and transimpedance gain of up to 5kΩ, the TIA has 60GHz of bandwidth and ultra-low noise to support applications from long haul to DCI. The device is available in bare die form.

The MAOM-009408 is a high-performance quad-channel modulator driver also supporting 96Gbaud symbol rates. It has up to 19dB of gain with 15dB of gain range and a maximum output voltage of $3V_{pp}$ differential. The device is designed to be directly DC coupled to an optical modulator for maximum bandwidth, minimum size and minimum power dissipation. The device is available in bare die form.

www.macom.com/opto

MACOM launches 25G APD photodiode and 25G Fabry–Perot laser for next-gen 5G & data-center networks

MACOM Technology Solutions Inc of Lowell, MA, USA (which makes semiconductors, components and subassemblies for analog RF, microwave, millimeter-wave and photonic applications) has announced the availability of its 25G avalanche photodiode (APD) and 25G Fabry–Perot (FP) laser optical components for 5G wireless and data-center applications.

The APD28A is a back-illuminated 25G APD covering both O- and C-bands with a usable wavelength range of 1250–1650nm. The photodiode features greater than 20GHz (3dB) bandwidth, with very high sensitivity of –22dBm when coupled to a low-noise amplifier (LNA) for 25G NRZ and 50G PAM-4 transmission applications.

The device performance enables the design of optical sub-assemblies and transceivers suitable for 5G wireless mid-haul and long-haul networks, and extended-reach (ER4) applications for 100Gbps, 200Gbps and 400Gbps data-center applications.

MACOM will offer the 25G APD as a bare die and in chip-on-carrier format to provide maximum design flexibility to customers.

The MAOD-131F25 is a directly modulated high-speed 25Gbps 1310nm Fabry–Perot laser diode with a wide operating temperature range of –40ºC to +95ºC. The device leverages MACOM's patented and proven etched facet technology (EFT) enabling scalability to high-volume manufacturing. The 25G FP laser is suited to enabling 5G LTE front-haul short-reach applications as well as low-cost 100Gpbs parallel single-mode fiber (PSM4) application for data centers.

MACOM will offer the 25G Fabry–Perot laser in a TO-Can package to complement customer requirements and accelerate time to market.

www.macom.com/opto

MACOM extends TIA portfolio spanning 100–800G

MACOM has announced the availability of two new transimpedance amplifiers (TIAs) optimized for use in optical networking applications ranging from 100Gbps DR1 to 800Gbps DR8 and FR8, available now in flip-chip and wire-bonding packaging options for fast, flexible deployment in QSFP, QSFP-DD and OSFP optical modules.

The rapid evolution to single-lane 100G and multiple-lane 200G, 400G and 800G connectivity is increasing demand for high-performance, power-efficient optical components needed to maximize bandwidth density in the Cloud data center. MACOM says that its extended TIA family, complemented by a comprehensive portfolio of seamlessly interoperable MACOM components, is helping customers accelerate this transition.

The MATA-05817 delivers low-noise performance of less than 2μA RMS typical and supports bandwidth up to 35GHz. The TIA supports high-throughput optical data links in a very low power profile, optimal for use in high-density optical data-center interconnects. The device is intended for 50G, 100G, 200G and 400G receivers using multi-level modulation such as PAM4.

The MATA-38134 is a quad 26/53GBaud linear PAM4 TIA with automatic gain control (AGC) and integrated AGC loop. The TIA consumes very little power and is primarily targeted at single-mode fiber applications. The TIA has 500_m anode-to-anode spacing, which allows customers to place two devices within the QSFP-DD form factor, enabling 800Gbps applications.

Both devices include RSSI for photo-alignment and power monitoring and I2C control of bandwidth, output amplitude, peaking, LOS, gain and other parameters.

www.macom.com/applications/

MACOM live streams product demos in lieu of OFC

In lieu of the Optical Networking and Communication Conference & Exhibition (OFC 2020) in San Diego (8–12 March) due to increased concerns over the spread of the COVID-19 virus, MACOM conducted product demonstrations directly from its US design centers to its worldwide customers in private, one-on-one interactive demonstrations by video conference.

MACOM utilized video conferencing to showcase its newest optoelectronic and photonic products and components. Available to customers on 8–12 March during regular show hours, demonstrations were hosted by MACOM's optical and high-speed data design and applications engineering teams. Customers could ask questions and interact with MACOM staff during the demo.

Live streaming video demonstrations included:

- *100Gbps DR/FR PAM4 Product Demonstration*.
- *Secure 50Gbps PAM4 Mid Haul for 5G Wireless*.
- *100Gbps PAM4 Customer Interoperability*.
- *200/400Gbps PAM4 Open Eye MSA Solutions*.

www.macom.com/opto

NeoPhotonics unveils complete L-band coherent optics solution to double optical fiber capacity

NeoPhotonics Corp of San Jose, CA, USA (a vertically integrated designer and manufacturer of silicon photonics and hybrid photonic integrated circuit-based lasers, modules and subsystems for high-speed communications) has announced an L-band suite of coherent optical components, including its 64GBaud L-band high-bandwidth coherent driver modulator (HB-CDM), 64GBaud L-band intradyne coherent receiver (ICR) and ultra-narrow-linewidth L-band tunable laser micro-ITLA (integrated tunable laser assembly). Together with NeoPhotonics standard C-band coherent components, the new products enable customers to double the capacity of optical fiber links.

The C-band is the primary band for telecoms, with wavelengths centered around 1550nm. The L-band uses wavelengths centered around 1590nm and is primarily used to complement the C-band to increase data capacity, especially in long-haul networks. By adding channels in the L-band, operators can double the capacity of an optical fiber.

NeoPhotonics' 64Gbaud coherent components and tunable lasers enable single-channel 600G data transmission over data-center interconnect (DCI) distances of about 80km using 64 QAM (quadrature amplitude modulation). These components also support 400G over metro distances of 400–600km using 64GBaud and 16 QAM or 200G over long-haul distances of greater than 1000km using 64GBaud and QPSK (quad phase-shift keying).

NeoPhotonics' L-band external cavity laser (ECL) micro-ITLA incorporates the same laser architecture as the firm's C-band laser for a pure optical signal with an ultra-narrow linewidth and very low phase noise. In coherent systems, any error in the phase of the signal and reference lasers, due to the laser's linewidth, can cause data errors, making narrow linewidth critical in systems using higher-order modulation.

NeoPhotonics' 64Gbaud L-band HB-CDM co-packages an indium phosphide -based Mach–Zehnder (MZ) quadrature modulator chip with a linear, quad-channel, differential 64GBaud driver. Both the C-band and L-band versions of the HB-CDM are designed to be compliant with the Optical Internetworking Forum (OIF) Implementation Agreement OIF-HB-CDM-01.0 'High Bandwidth Coherent Driver Modulator'.

NeoPhotonics' 64Gbaud L-band micro-ICR incorporates an integrated co-mixer chip and four balanced photodiodes with four differential linear amplifiers to provide four output channels at 64GBaud. The form factor of the high-bandwidth coherent receiver is designed to be compliant with the OIF Implementation Agreement for Micro Integrated Intradyne Coherent Receivers; IA # OIF-DPC-MRX-02.0.

For applications that require more capacity than provided by the standard C-band but do not require the full L-band, each of these components is available in a C++ version, which supports tuning across the full Super C-band covering 6.0THz of spectrum or up to 50% more than standard systems. These C++ components can support 80 channels at 75GHz channel spacing, which effectively increases the capacity of an optical fiber by as much as 50% over standard C-band-only systems at comparable distances.

"We are pleased to add L-band versions to our existing suite of coherent components, thus providing customers with a complete solution to their fiber capacity requirements, whether C-band, C++ band or L-band," says chairman & CEO Tim Jenks. "Our ultra-pure tunable laser design and our high-performance coherent modulator and receiver designs are very flexible and excel in different spectral regimes to provide the highest speed over distance performance," he concludes.

www.oiforum.com

www.neophotonics.com/optical-amplifiers-64gbaud-16-64qam

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NeoPhotonics announces general availability and volume production of high-bandwidth coherent driver modulator for 64GBaud cloud & data-center interconnect applications

NeoPhotonics Corp of San Jose, CA, USA (a vertically integrated designer and manufacturer of silicon photonics and hybrid photonic integrated circuit-based lasers, modules and subsystems for high-speed communications) has announced general availability and volume production of its 64GBaud high-bandwidth coherent driver modulator (HB-CDM).

The CDM brings together NeoPhotonics' 64GBaud intradyne coherent receiver (ICR) and ultra-narrow-linewidth tunable laser to enable customers to implement single-channel 600G data transmission over data-center interconnect (DCI) distances of about 80km using 64 QAM. These components also support 400G over metro distances of 400–600km using 64GBaud and 16 QAM or 200G over long-haul distances of greater than 1000km using 64GBaud and QPSK.

NeoPhotonics' HB-CDM is implemented in a small-form-factor (25mm x 12mm x 5mm) package that co-packages a linear, quad-channel, differential 64GBaud driver with an indium phosphide (InP)-based Mach–Zehnder (MZ) quadrature modulator chip. It provides efficient coherent multi-level modulation formats, such as DP-QPSK, DP-16QAM and DP-64QAM, to support coherent transmission up to 64GBaud. The HB-CDM is compliant with the OIF's Implementation Agreement OIF-HB-CDM-01.0 'High Bandwidth Coherent Driver Modulator', and assures users a 3dB EO bandwidth of greater than 40GHz. The compact size fits in a CFP2-DCO pluggable module.

The HB-CDM is also available in a 'C++' CDM modulator version, which supports tuning across the full 'Super C-band' covering 6.4THz of spectrum or up to 50% more than standard systems. The C++ CDM modulator, ultra-narrow-linewidth tunable C++ LASER micro-ITLA (integrated tunable laser assembly) and 64Gbaud C++ ICR receiver are combined in NeoPhotonics' C++ CFP2-DCO transceiver, which is claimed to be the first pluggable transceiver module able to deliver as much as 34 Terabits of capacity per fiber. This module can support 85 channels of 64Gbaud data at 75GHz channel spacing and effectively in raises the capacity of an optical fiber by as much as 50% over standard systems at comparable distances.

"The HB-CDM is based on our indium phosphide photonic integration platform and delivers the high performance for demanding applications," says chairman & CEO Tim Jenks. "Combined with our silicon photonics integration platform we can provide customers with the optimized solutions to meet their network requirements for the highest speeds and at volume scale," he concludes.

www.neophotonics.com

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Acacia sampling 400G pluggable transceiver modules

Acacia Communications Inc of Maynard, MA, USA (which develops and manufactures high-speed coherent optical interconnect products) is sampling multiple variants in its family of 400G pluggable optical transceiver modules including 400ZR, OpenZR+ and Open ROADM MSA.

The firm's 400G pluggable module family features an expansive list of interoperability solutions in QSFP-DD, OSFP and CFP2-DCO pluggable form factors for cloud data-center interconnects (DCIs) and service provider networks. These pluggable solutions were designed to enable network operators to address increasing bandwidth demand through a simplified network architecture, reducing both capital and operational expenditures.

"Acacia's vision has always been focused on driving down the level of power consumption, size and cost of coherent interconnects and we are proud of the significant advancements we have made in low-power digital signal processor (DSP) and 3D siliconization technologies," says Mehrdad Givehchi, a founder of Acacia and VP of Hardware and Software. "By supporting both QSFP-DD and OSFP form factors, our DCI customers are able to choose their preferred solution to access our technology," he adds.

"Our new 400G pluggable modules are based on our Greylock 7nm DSP, which is our third generation of coherent DSP supporting low-power pluggable modules," says 400G Pluggable product line manager Torben Neilsen. "Our 3D siliconization approach, which leverages high-volume electronics manufacturing processes, benefits from the maturity of our silicon photonics technology and our vertical integration."

Acacia's new 400G pluggable module family builds on the technology that Acacia has demonstrated in the coherent module market, having shipped the following products since 2014: >200,000 coherent silicon photonic integrated circuits; >400,000 coherent DSP ports; and >125,000 pluggable DCO modules.

400G pluggable modules represent a key architectural change in high-bandwidth data-center interconnects because they can be plugged directly into switches and routers offering the same density for both coherent DWDM and client optics in the same chassis. This architectural change helps network operators support their growing bandwidth demands in a more cost-efficient manner.

"We're excited to be successfully passing traffic in the lab with the Acacia 400G-OSFP-ZR module in our 7000 Series switches and routers," notes Hacene Chaouch, distinguished engineer at Arista Networks. "400ZR is critical to meeting customer demand for growing data-center interconnect bandwidth and we believe the thermal and optical performance of Acacia's coherent platform in the OSFP form factor will provide network operators with a very reliable and power efficient solution," he adds.

"Interoperable 400G solutions have the potential to transform cloud DCI and traditional operator architectures and create new applications for coherent optics at the edge of the network," comments Andrew Schmitt, directing analyst at Cignal AI.

Acacia's 400G pluggable module family is sampling now and is expected to begin volume production in second-half 2020.

www.acacia-inc.com

C-CMIS IA completed for management of DCO modules

The Optical Internetworking Forum (OIF) has announced completion of the Coherent Common Management Interface Specification (C-CMIS) Implementation Agreement (IA), which is an extension to the CMIS (QSFP-DD/OSFP/COBO) management spec, specifically targeting digital coherent optics (DCO) modules.

"The C-CMIS IA is an important part of the developing 400ZR ecosystem," says Ian Betty, a board member of both Ciena and OIF. "It defines additional management registers, and monitors, together with new functionality, mechanisms or behaviors, as needed."

Augmenting the existing CMIS spec (which focused on addressing direct-detect client optics), the C-CMIS IA provides register definition for coherent modules in pages and parameters that were previously reserved. Users that have previously implemented software to manage optical modules using CMIS will be able to quickly add support for these coherent pages and parameters. This release of the C-CMIS IA is targeted at the 400ZR application.

The technology and complexity of coherent modules requires additional monitoring parameters for use in field applications. This additional monitoring is primarily focused on forward error correction (FEC) monitoring and optical/analog monitoring including items like chromatic dispersion, differential group delay and electrical signal-to-noise ratio (eSNR). The C-CMIS IA provides specifications to monitor the standard parameters in a normative manner while taking advantage of the flexibility of the CMIS specification to monitor any additional proprietary parameters.

"The current IA is focused on supporting the OIF 400ZR IA, which supports a single data path with eight-lane host electrical interface for a 400GBASE-R PCS signal and a single-lane 400G coherent media interface (with a new signal format called 400ZR)," says Betty. "We expect future versions to include more complex metro modules and may even extend these management features to other form factors."

www.oiforum.com

First Solar manufacturing operations continuing at Ohio, Malaysia and Vietnam facilities

In light of recent developments related to the COVID-19 (Novel Coronavirus) pandemic, 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 provided an update regarding its manufacturing operations in Wood County in Ohio, Kulim in Malaysia and Ho Chi Minh City in Vietnam.

On 22 March, the State of Ohio, where First Solar's Perrysburg and Lake Township manufacturing plants are located, issued a 'Stay at Home' order, exempting, among other things, essential businesses and operations from its scope. At this time, it is First Solar's understanding that its manufacturing facilities in these locations are permitted to operate under the order.

Similarly, the government of Malaysia, where the Kulim manufacturing plants are located, has implemented a wide-ranging suspension of public activities. Since the implementation of this suspension and at this time, First Solar's understanding is that these measures do not impact the continuity of its manufacturing operations in the country.

First Solar's manufacturing operations at its Ho Chi Minh City, Vietnam facilities are not impacted by government-mandated restrictions on movement at this time. The firm is continuing to monitor the situation at all of its facility locations.

First Solar says that it has already implemented a wide range of measures intended to inhibit the spread of the COVID-19 virus at its global manufacturing, administrative and other sites and facilities, including those in the USA, Malaysia and Vietnam.

www.firstsolar.com

Four California projects sold by First Solar go to Longroad Energy

First Solar says that Longroad Energy is the acquirer of four solar projects with a combined capacity of $160MW_{AC}$. Longroad Energy is a US-based renewable energy developer, owner and operator, with a multi-gigawatt portfolio of wind and solar projects across the USA. First Solar had previously disclosed the transaction without identifying the acquirer.

Backed by a long-term power purchase agreement (PPA) with community choice aggregator (CCA) Marin Clean Energy (MCE), the Little Bear Solar projects in Fresno County, California, range in capacity from $20MW_{AC}$ to $50MW_{AC}$ and are designed to have a low impact on local land and water resources, and the environment. They are expected to be completed by the end of fourth-quarter 2020. In addition to creating about 500 jobs during contruction, Little Bear Solar is also expected to benefit local businesses.

"MCE's customers have made the important choice to consume carbon-free electricity, and it is only fitting that these projects will be powered by lowest carbon solar modules available today," says Longroad's chief operating officer Michael Alvarez.

The projects will be powered by First Solar's Series 6 module technology. Designed and developed at the firm's R&D centers in California and Ohio, and produced in just 3.5 hours using fully integrated manufacturing processes, each large-format Series 6 module leverages First Solar's proprietary thin-film technology, and has a carbon footprint that is up to six times lower than crystalline silicon PV panels manufactured using conventional, energy-intensive production methods, it is reckoned.

"CCAs are playing a growing role in the democratization and decarbonization of California's electricity," comments First Solar's chief commercial officer Georges Antoun. "With demand being driven primarily by environmentally conscious consumers, we see a tremendous opportunity to support the growth of this segment with our portfolio of responsibly developed projects, powered by the world's lowest-carbon solar module technology."

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Monolithic indium arsenide quantum dot avalanche photodiode on silicon

Researchers claim the first device with low dark current and high gain.

Researchers in the USA, China and Hong Kong have developed monolithic indium arsenide (InAs) quantum dot (QD) avalanche photodiode (APD) structures on (001) silicon (Si) with low dark current and high gain [Baile Chen et al, ACS Photonics, published online 8 January 2020].

The team from University of California Santa Barbara (UCSB) in the USA, ShanghaiTech University in China, Hong Kong University of Science and Technology, and Chinese University of Hong Kong, claim that the device is the first monolithic InAs QD APD on silicon with low dark current, which is suitable for optical fiber O-band (1260–1360nm) communications. They comment: "These QD-based APDs enjoy the benefit of sharing the same epitaxial layers and processing flow as QD lasers, which could potentially facilitate the integration with laser sources on a silicon platform."

"When the high gain and low dark current performance up to 323K (50°C) are considered, these APDs hold great potential for applications in energy-efficient interconnects within super-computers and data centers," the team writes.

The substrate was gallium arsenide (GaAs)-on-V-grooved-Si (GoVS) produced using metal-organic chemical vapor deposition (MOCVD) — see Figure 1. The grooves in the (001) Si enabled the reduction of threading dislocations through aspect ratio trapping (ART). Further growth used molecular beam epitaxy (MBE) to produce a dot-in-well (DWELL) structure. The QDs consisted of a 5-layer stack. The final dot density was $6x10^{10}/cm^2$. The barrier matrix for the dots and the well barriers consisted of aluminium gallium arsenide (AlGaAs).

APD fabrication created waveguide-shaped devices (Figure 2). The mesas were etched with inductively coupled plasma. Sidewall passivation consisted of 12nm atomic layer deposition (ALD) aluminium oxide (Al_2O_3) and 1μm silicon dioxide (SiO_2) to suppress current leakage. The metal contacts were palladium/titanium/palladium/gold and palladium/germanium/palladium/gold. The structure included standard 150μm-pitch ground–signal–ground (GSG) pads. The devices were cleaved to produce optical entry facets without anti-reflective coatings.

The room-temperature (300K) dark current for a 3μmx50μm device was 0.1nA ($6.6x10^{-5}A/cm^2$) under

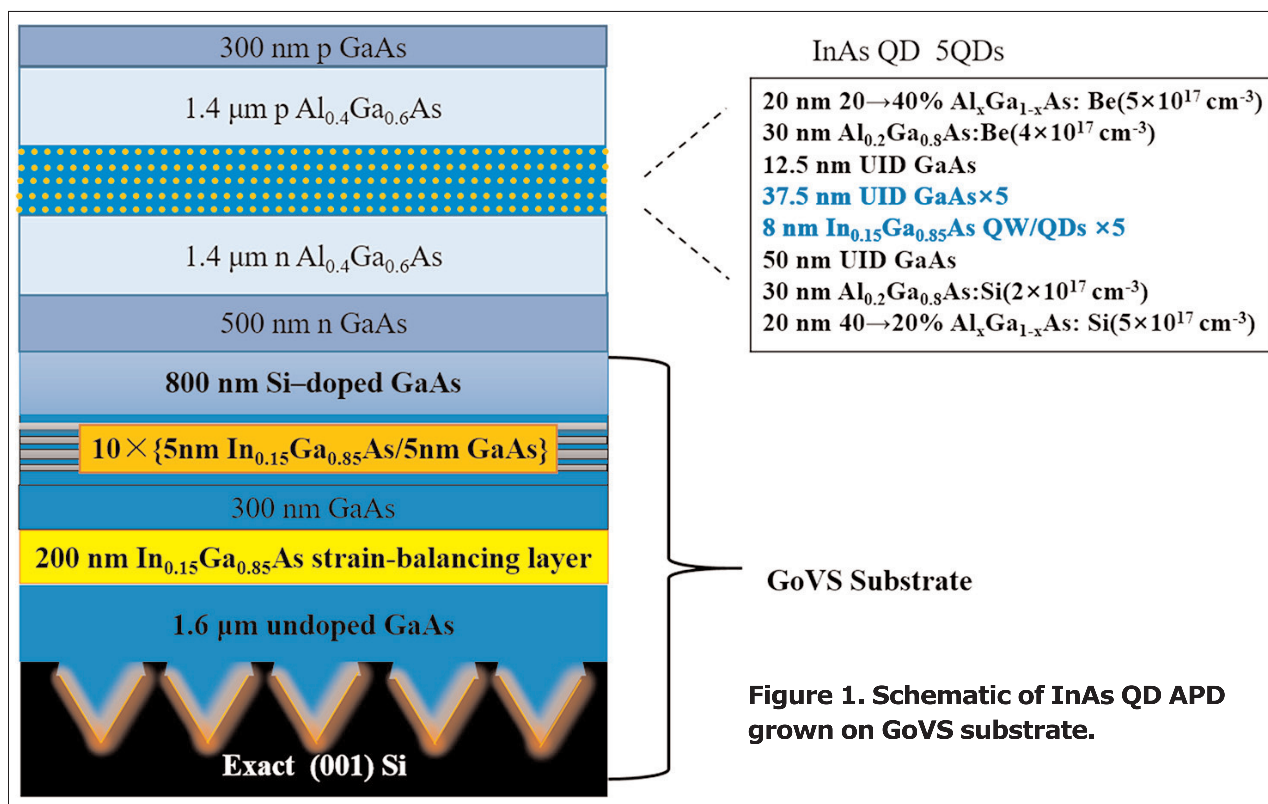

Figure 1. Schematic of InAs QD APD grown on GoVS substrate.

−5V bias. The researchers attribute the low value to high crystal quality and good surface passivation of the mesa side-walls. With the APD near breakdown (99%), the dark current was 1.3nA at -15.9V bias. An increase in breakdown voltage with temperature indicated to the team that avalanche rather than tunneling was the main mechanism. The parasitic capacitance of the device was 517fF at room temperature.

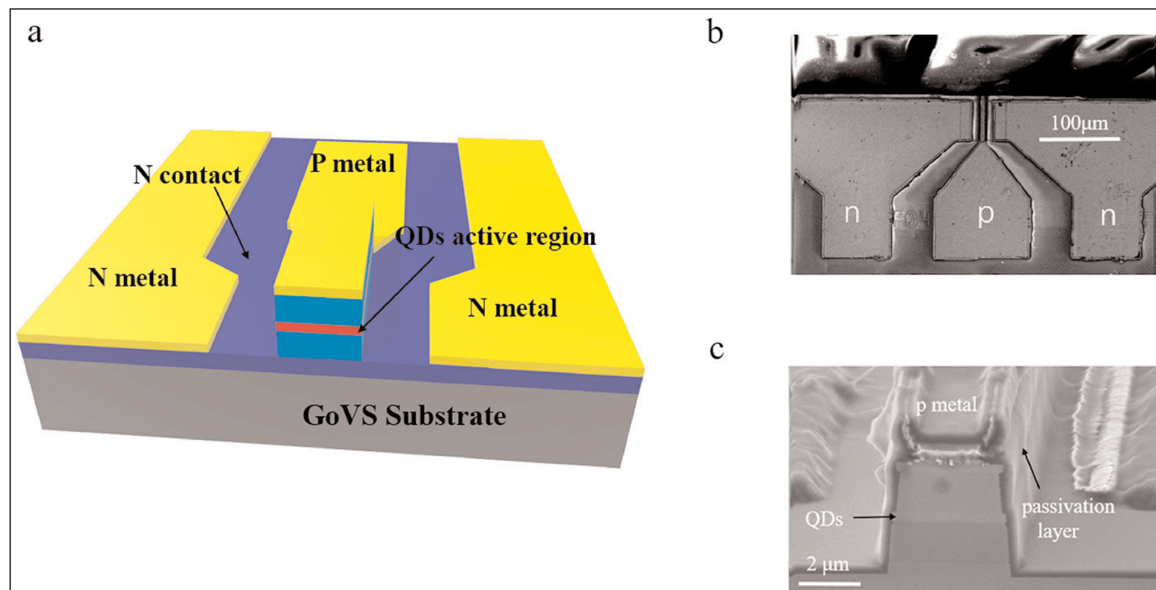

Figure 2. (a) Schematic of fabricated waveguide photodetector. (b) Top-view and (c) cross-sectional scanning electron microscope views.

The peak avalanche gain for 1300nm-wavelength light was 198 at 293K (20°C), relative to the 'unity gain' performance at −5V bias. The peak reverse bias was −15.97V. The dark current at that bias was 33nA. The peak gain reduced to 73 at 323K (50°C).

The researchers note that the 33nA dark current value is "more than two orders of magnitude lower than that of Si/Ge APDs, InGaAs/InAlAs APDs on Si, and the recent InAs QD APDs heterogeneously integrated on Si".

Noise was a problem with the device – the excess noise figure reached more than 60 with the gain at 8. The researchers comment: "The excess noise is high due to the mixed injection in the APD device, and further optimization for minimizing the noise performance is necessary for future work." The team also suggests that one way to overcome this would be to use separated absorption, charge and multiplication avalanche photodiode (SACM-APD) structures, aiming at low noise and high speed.

The response to 1310nm light input (−20dBm power) was 0.234A/W with −5V bias. The response cut off at around 1360nm, corresponding to the approximate bandgap of the InAs QDs. With the reverse bias at −15.9V, the response was 4.8A/W at 1310nm, representing an avalanche gain of about 20. The cut-off wavelength red-shifted at the increased reverse bias due to quantum-confined Stark effects — "which shifts the electron states to lower energies and the hole states to higher energies, respectively, in the QD layers," as the team puts it.

The response to modulated signals showed a 3dB bandwidth of 2.26GHz with the bias at −6V, reducing to 2.06GHz at −15.9V. The researchers attribute the reduction to avalanche build-up time at the higher reverse bias. The resistance–capacitance (RC)-limited bandwidth was estimated at 5.16GHz. The researchers plan to look at improving the RC performance using semi-insulating silicon substrates or thick benzocyclobutene (BCB)/SU8 layers to reduce parasitic capacitance effects.

The performance with pseudorandom binary sequence modulation at −3dBm power produced 'open-eye' diagrams up to 8Gbit/s data rates. With 2.5Gbit/s sequences the bit-error rate (BER) was significantly reduced at −15.9V bias (two orders of magnitude relative to −5V, Figure 3). ■

https://dx.doi.org/10.1021/acsphotonics.9b01709

Author: Mike Cooke

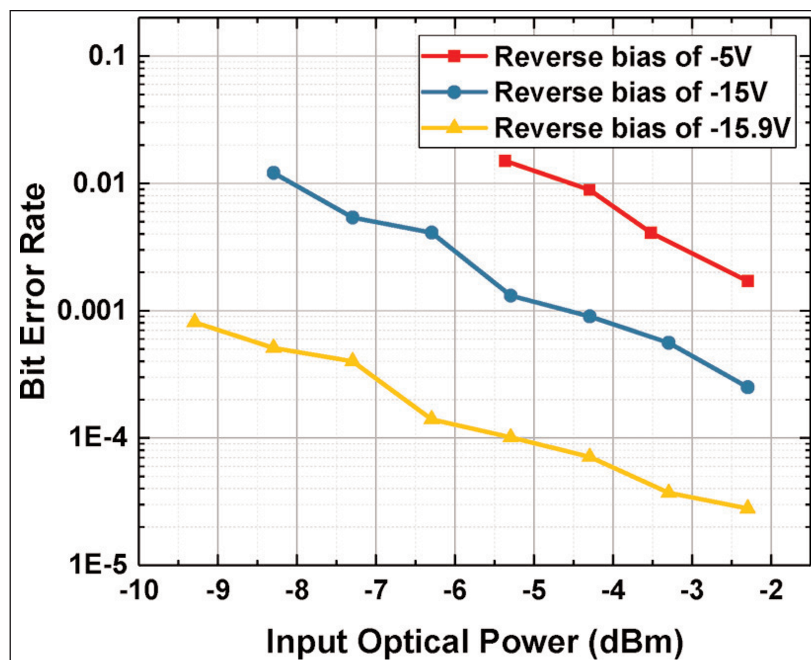

Figure 3. BER versus input optical power.

III-V photodetectors integrated with SOI transistors

Researchers see potential for high-resolution multi-color imagers in self-driving automobiles, time-of-flight sensing, and industrial surveillance.

Researchers based in Korea have monolithically integrated indium gallium arsenide (InGaAs) photodiodes (PD) with silicon-on-insulator (SOI) metal-oxide-semiconductor field-effect transistors (MOSFETs) [Dae-Myeong Geum et al, IEEE Electron Device Letters, vol41, issue3, p433, March 2020].

The researchers from Korea Advanced Institute of Science and Technology (KAIST), Korea Institute of Science and Technology (KIST) and Hanyang University see the advantage from their monolithic three-dimensional (M3D) process as arising from the maturity of the InGaAs material process knowledge, compared with more recent laboratory work on devices using carbon nanotubes, transition-metal dichalcogenides, and so on.

In particular, "III–V materials can respond to the very long-wavelength region (VLWIR) not only visible and [short-wavelength] SWIR using [antimonide] Sb-based materials and type-II band alignment structures," the team contends. They see their work as an important step for future high-resolution multi-color imagers. Such devices could find application in self-driving automobiles, time-of-flight sensing, and industrial surveillance. The photodiode/MOSFET combination should allow implementation of read-out integrated circuits (ROICs) on top of image signal processor (ISP) layers, creating more compact 3D devices (Figure 1).

The SOI section used a 365nm silicon dioxide (SiO_2) insulation layer. The MOSFET gate stack was built from hafnium aluminium oxide (HfAlOx) insulator and titanium nitride (TiN) electrodes. The structure was covered with sputtered SiO_2 interlayer dielectric.

The surface was planarized using chemical mechanical polishing (CMP), before deposition of 40nm Al_2O_3 as bonding material. The InGaAs photodiode epitaxial material was also prepared for bonding with 40nm Al_2O_3 deposition. The Al_2O_3 surfaces were activated with oxygen plasma treatment to enable bonding.

The indium phosphide (InP) substrate was removed from the InGaAs photodiode material before formation of the photodiode electrodes and mesas/pixels. The top p^+-InP contact was platinum/titanium/platinum/gold (Pt/Ti/Pt/Au). The bottom n^+-InGaAs contact consisted of palladium/germanium/gold. Finally, connection was made between the photodiode cathode (n^+-InGaAs) and the SOI MOSFET source terminal.

The reported process was carried out at room temperature, although the team reports that previous similar processing at 350°C resulted in "no degradation" in performance. In the present case, it was found that the performance of a 9μm-gate-length MOSFET was little changed by the bonding and photodiode

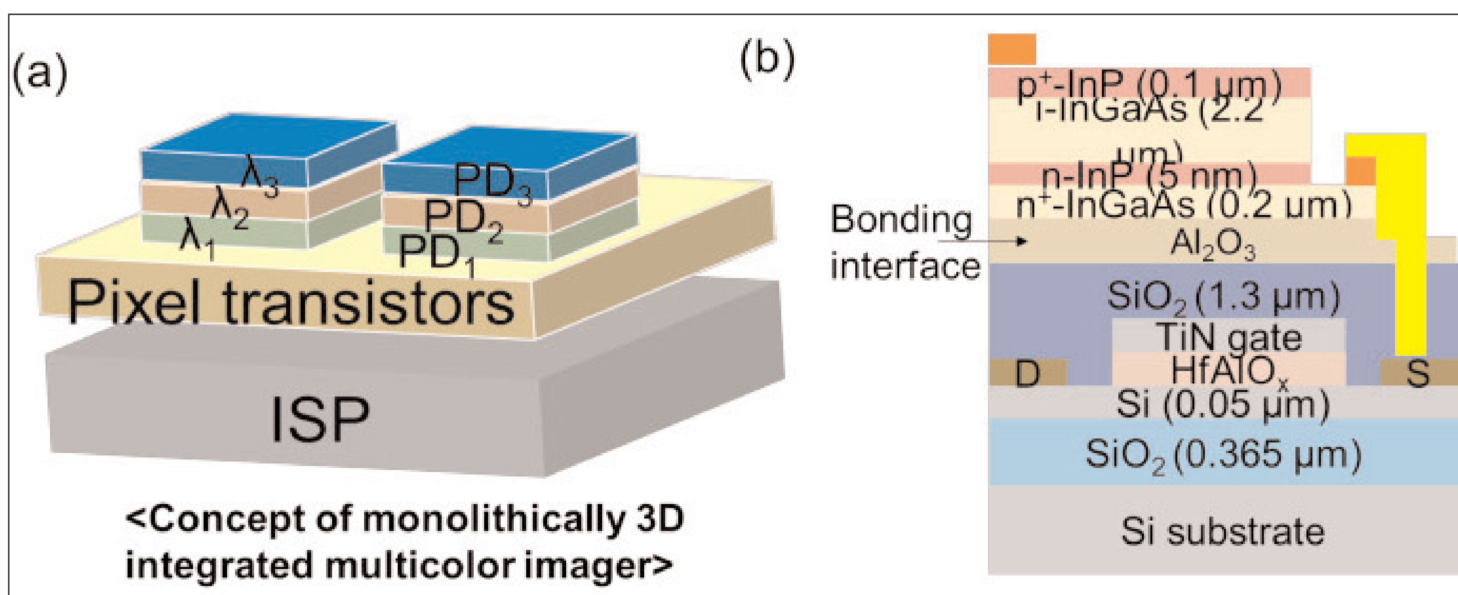

Figure 1. (a) M3D integrated high-resolution multi-color imager system concept. (b) Schematic of fabricated InGaAs photodiodes on SOI MOSFETs.

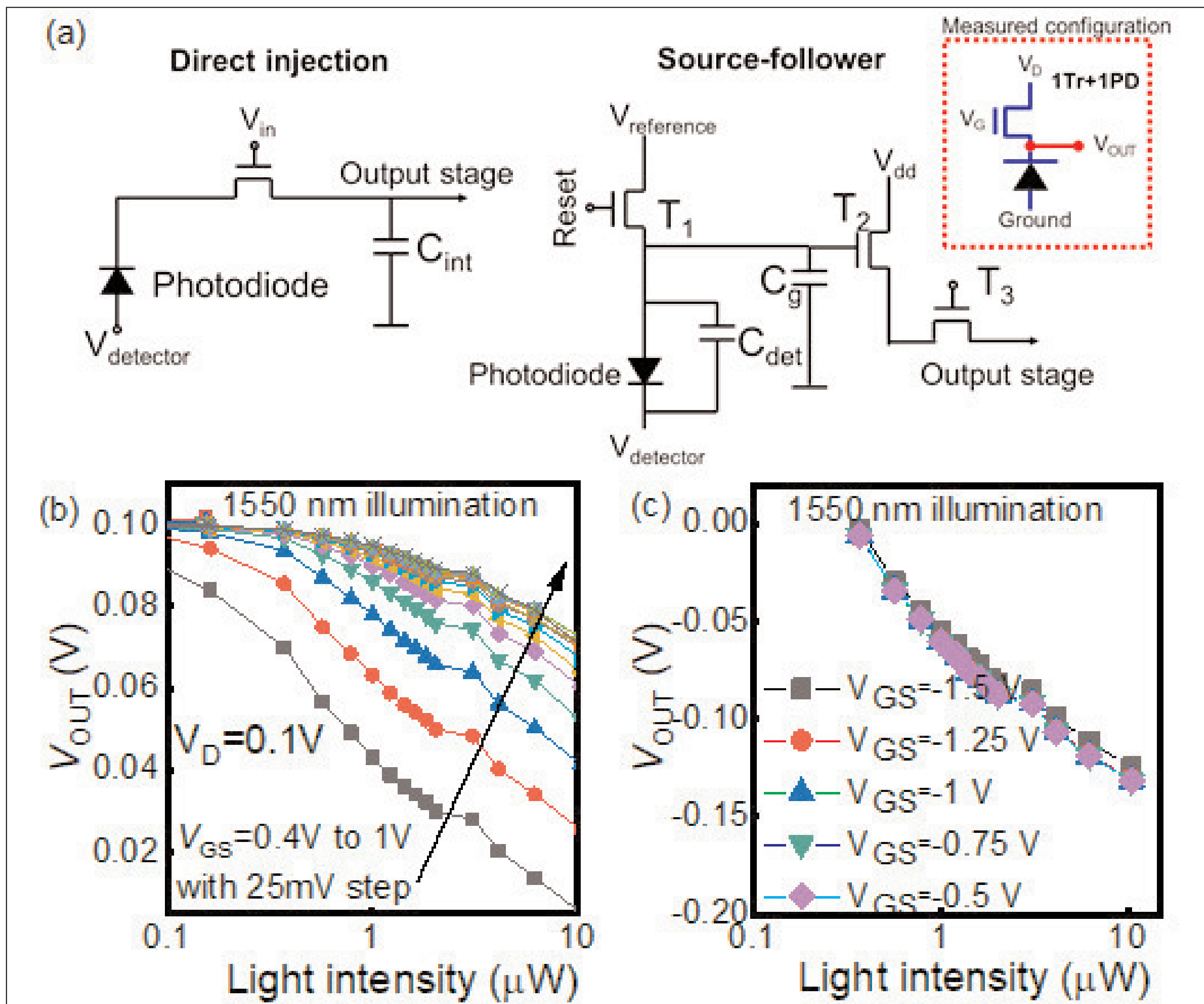

Figure 2. (a) Unit cell architectures of readout circuits and measuring devices as shown in inset. (b) Electrical response for DI operation (c) Electrical response for SFD operation.

fabrication processes, in terms of drain current and subthreshold swing.

The InGaAs photodiode demonstrated a forward/reverse ±1.5V bias dark current ratio of 10^4. The device showed a clear response under reverse bias when illuminated by 10.4μW 1550nm laser light. Shorter wavelengths in the range 785–980nm also showed a reasonable linear response. The response for 1500nm was stronger (0.7A/W) due to it being close to the band edge of the InGaAs material. Fitting with power-law current–power relations also suggested linear behavior with near-unity exponents. The fitted exponent of the illumination power was 0.97 for 1550nm light — the deviation from unity, the researchers suggest, could be explained by the presence of defects.

The external quantum efficiency (EQE) was 60% under 1550nm illumination. The value is declared to be "quite good", considering that there was no anti-reflection coating. The team says that the performance was comparable to conventional InGaAs photodiodes.

The MOSFET–photodiode combinations were wired together into typical ROIC configurations (Figure 2): direct injection (DI) and source follower per detector (SFD). The team explains: "While photo-generated carriers are directly injected via the source on the output stage in the DI method, SFD uses the integration of photo-generated carriers in a capacitor during a specific period."

With the drain at 0.1V bias, the gate potential was varied between 0.425V, subthreshold, and 1V under 1550nm illumination (Figure 2). Negative gate potentials between −0.5V and −1.5V, related to SFD operation, had little effect on the device response. ■

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Author: Mike Cooke

3D imaging and sensing market growing at 20% CAGR to $15bn in 2025

Rear 3D sensing in mobiles is to become the leading application, reckons Yole Développement.

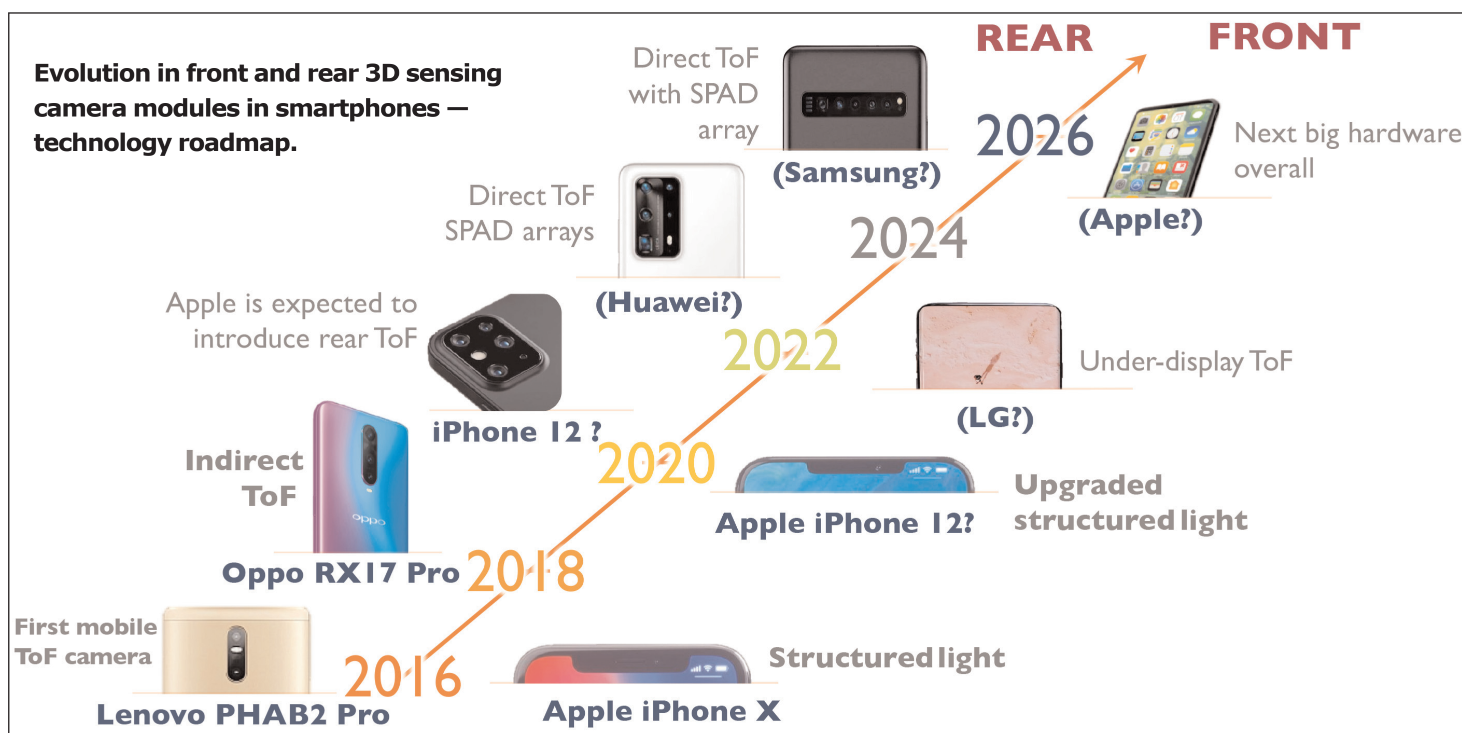
The global 3D imaging and sensing market is expanding at a compound annual growth rate (CAGR) of 20% from $5bn in 2019 to $15bn in 2025, forecasts market research and strategy consulting firm Yole Développement in its annual technology & market analysis '3D Imaging and Sensing'.

With the introduction of the iPhone X in September 2017, Apple set the standard for technology and application for 3D sensing in the consumer space. Two years later, Android phone makers have taken a different approach, using time-of-flight (ToF) cameras (instead of structured light) and are placing them on the rear of the phone.

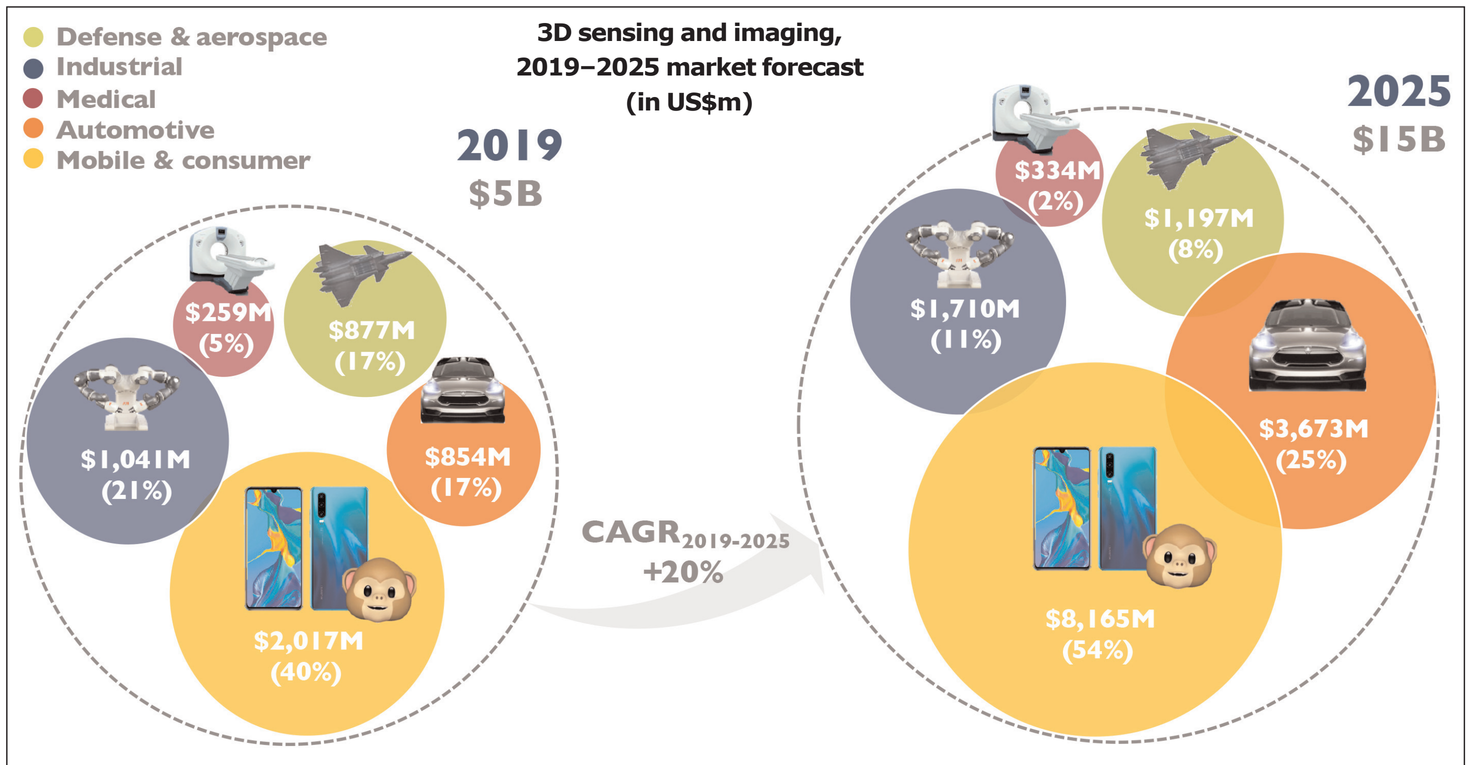
"Compared to structured light, ToF modules only needs a vertical-cavity surface-emitting laser (VCSEL) and a diffuser on the emitter, which is less complex," says Richard Liu, technology & market analyst in the Photonics, Sensing & Display division at Yole and based in Shenzhen, China. "ToF sensors have now improved a lot thanks to the back-side illumination (BSI) technique," he notes. "They have also gained a cost advantage within a maturing ecosystem. This is the main reason why ToF has won the favor of Android phone makers."

Without doubt, the main trend in 3D sensing is the switch in adoption from the front to the rear of the phone and mass adoption of the ToF camera. According to Yole's report, rear attachment will surpass front attachment, with the penetration rate reaching about 42% in 2025.

3D rear sensing in mobiles are expected to diversify in application. First used for photography, to enhance 'bokeh' (blur effect) and zoom capabilities, it will expand into augmented reality (AR) and gaming. Beyond smartphones, ToF camera modules have a broad application market ahead of them, including intelligent driving, robots, smart homes, smart TVs, smart security and virtual reality (VR)/AR. Currently,



Evolution in front and rear 3D sensing camera modules in smartphones — technology roadmap.



the application of ToF sensing technology in these fields is still in its infancy.

The significance of the 3D sensing market means that the transition from imaging to sensing is happening now. Artificial intelligence (AI)-powered devices and robotics are gaining a better understanding of their surroundings, and developing a new level of interaction with humans. Stereo cameras for ADAS (Advanced Driver Assistance Systems) represent a highly anticipated application of 3D imaging and sensing technology.

"The most important component in this application, light detection & ranging (LiDAR), is now focused on by a large number of suppliers," notes Liu. "There is a wide range of LiDAR technologies to choose from, making the field a very competitive one."

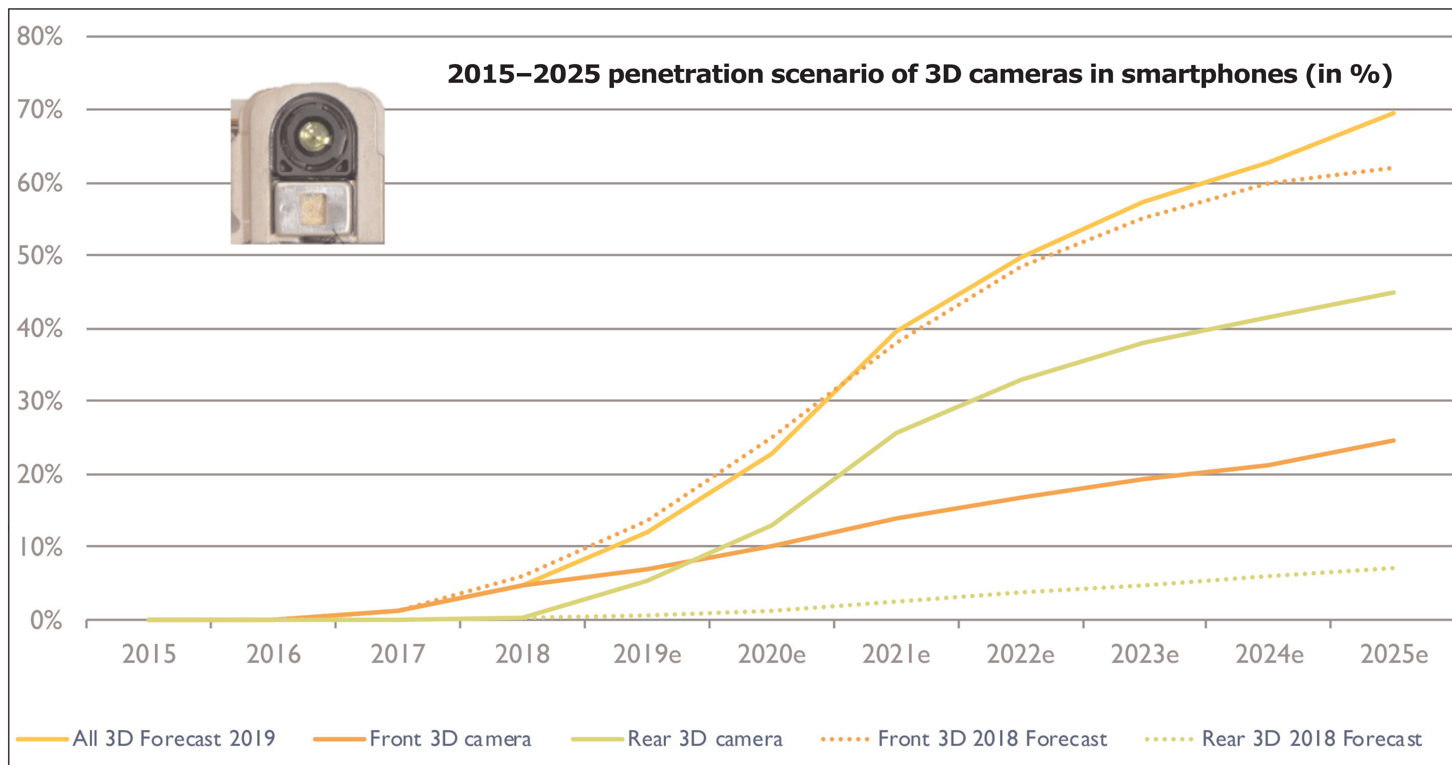
In addition to automotive ADAS and industrial AGVs (automatic guided vehicles) in the logistics industry, face recognition and face payments in commercial sectors have also been very successful. As such, 3D sensing technology is moving towards ubiquity. Technology providers of global shutter image sensors, VCSELs, injection-molded and glass optics, diffractive optical elements (DOEs), and semiconductor packaging are all benefiting.

So what is the impact of ToF's adoption on the supply chain? "The mobile 3D sensing supply chain is changing rapidly," notes Pierre Cambou, principal analyst, Imaging, at Yole. "As structured light technology was introduced in iPhones in 2017, companies like Lumentum, ams and ST Microelectronics won this first round. Later, Princeton Optronics (ams) and Finisar were prepared to gain VCSEL market access, so the market did quickly become more competitive," he adds.

In 2019, Finisar was acquired by II–VI, contributing to the consolidation of industrial business. During this period, there were several other big mergers, such as Philips Photonics being acquired by Trumpf and ams swallowing Osram. Trumpf and ams are both actively moving into the Android camp's 3D camera supply chain, providing VCSELs to Samsung and Huawei respectively.

In China, another player is entering the 3D sensing ecosystem: The VCSEL output beam of the flood emitter for ToF requires no coding and is therefore easier to produce. This has helped the Chinese supplier Vertilite to join the market. Already, in 2019, the company won orders from Huawei for 3D sensing. This move was also driven by the policy of China to cultivate local supply chains in the midst of the US–China trade conflict.

ToF arrays are key components for mobile rear 3D sensing. ToF camera technology was first applied to the Phab2 Pro smart phone in 2016, which used pmd and Infineon's TOF array. A year before that, Sony bought SoftKinetic, a Belgian gesture-recognition company with its well-known DepthSense ToF sensing system. This move brought Sony from a position of zero market share in 3D sensing receiver chips to 45% by the time that ToF camera modules took off in 2019. With its strong technology and supply capabilities, Sony is expected to continue to maintain its leadership position in ToF. But, as there has always been competition in this area of CMOS image sensor (CIS) chip manufacturing, competition will increase. Together with partner Infineon Technologies, pmd recently announced a matching chip. Yole's analysts expect CIS giant Samsung and STMicroelectronics to bring to market their own indirect ToF array sensors in 2020.



2015–2025 penetration scenario of 3D cameras in smartphones (in %).

Samsung already adopted ToF technology notably in its Galaxy Note 10+. It has been deeply analyzed by System Plus Consulting, sister firm of Yole in the reverse engineering & costing report, Samsung Galaxy Note 10+ 3D Time of Flight Depth Sensing Camera Module.

Generally speaking, the competition remains very intense among a small group of CIS players. In the medium-term Yole expects more opportunities for mergers & acquisitions (M&A) as automotive LiDAR applications may come into play. There are a large number of highly competitive emerging companies. There are also a few Chinese startups, such as Hesai Technology, RoboSense, and LeiShen Intelligence. The underlying semiconductor products are the same: CIS chips, VCSEL, MEMS, wafer-level optical elements. ■

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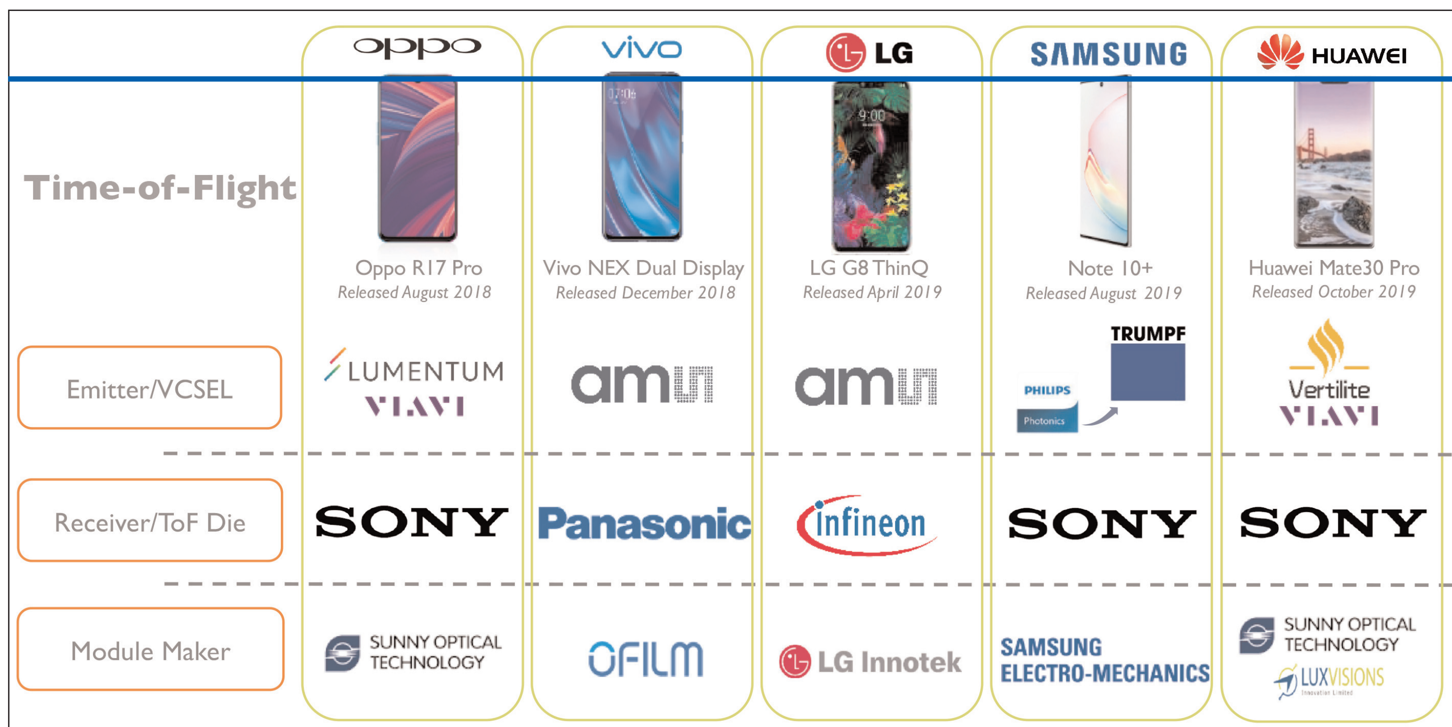

3D sensing and imaging: main players in supply chain

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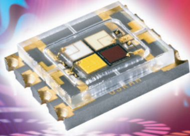

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Indium phosphide buffers on silicon for III–V laser diodes and data photonics

Researchers reduce the surface defect density to $4.5x10^7/cm^2$.

Bei Shi and Jonathan Klamkin of University of California Santa Barbara (UCSB) in the USA have been developing techniques to grow indium phosphide (InP) buffer layers on top of on-axis (001) silicon (Si) with a view to silicon photonics (SiPh) and, in particular, III–V laser diodes [J. Appl. Phys., vol127, p033102, 2020].

Reducing defect levels in the III–V semiconductor materials that can generate light is key to successful lasing with high efficiency. Shi and Klamkin used a range of techniques to reduce the surface defect density to $4.5x10^7/cm^2$, along with producing laser diode structures aimed at the 1550nm infrared optical fiber communications range. Defects such as misfit (MD) and threading (TD) dislocations arise from lattice and thermal mismatches between the various material layers being grown.

The researchers point to "the ever-important need for on-chip light sources for high-capacity silicon photonic transceivers for hyperscale data centers and sensing applications". Other potentials include microwave photonics, free-space laser communication, and light detection and ranging (LiDAR) based on III–V lasers, photodetectors, modulators and transistors.

Shi and Klamkin used a gallium arsenide (GaAs)-on-V-grooved Si (GoVS) template created by metal-organic chemical vapor deposition (MOCVD). The InP was grown in a three-step process: 435°C low-temperature (LT) nucleation, 45nm at 545°C medium temperature (MT), and 950nm at 600–630°C high temperature (HT).

Atomic force microscopy (AFM) and electron-channeling contrast imaging (ECCI) suggested that there was a trade-off between surface roughness and defect density, dependent on the thickness of the nucleation layer.

The researchers explain: "With a thinner LT-InP, more pinholes appear on the surface due to an inferior surface coverage following the InP nucleation although the surface roughness tends to be lower. In contrast, a better coverage together with apparent step flows can be obtained with the thicker InP nucleation, yet the surface defect density is higher, on the order of $10^9/cm^2$, which can be attributed to the higher possibility of MDs evolving into TDs with the thicker LT-InP nucleation."

Shi and Klamkin settled on a LT-InP thickness of 30nm as an optimum.

The effect of dislocation filtering was also studied, using strained-layer superlattices (SLSs). Four such SLSs were grown separated with 300nm HT-InP. The SLS structure consisted of 10 pairs of 13nm/19nm InGaAs/InP. Again there was a trade-off between undesirable features — at low SLS growth temperature the surface roughness of a final 500nm n-InP layer

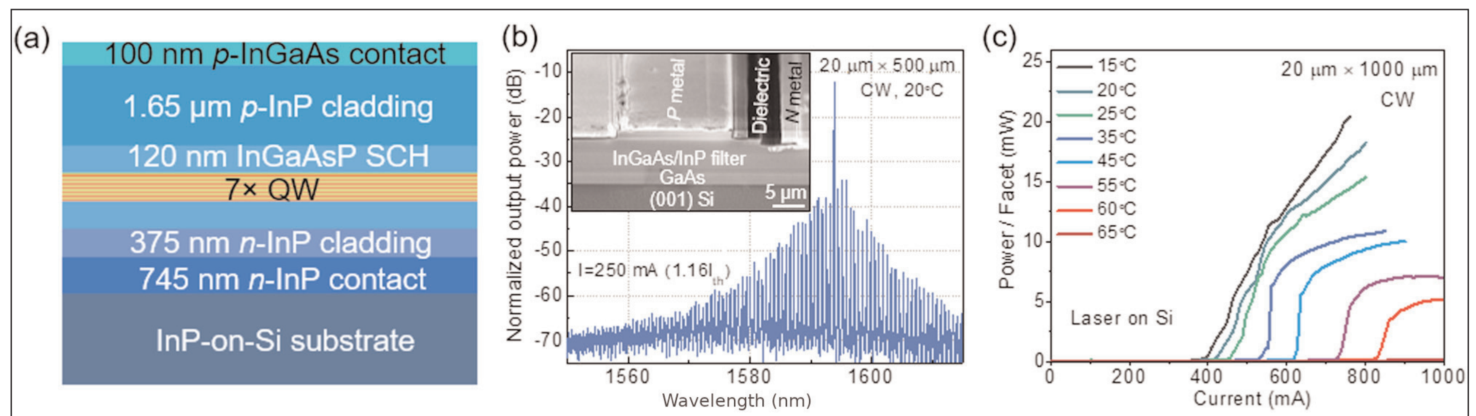

Figure 1. (a) Schematic of laser epistructure. (b) Room-temperature CW lasing spectrum at 250mA injection current – primary lasing peak at ~1593nm. Inset: 70°-tilted scanning electron microscope image of as-cleaved facet. (c) Temperature-dependent power-current curves under CW pumping.

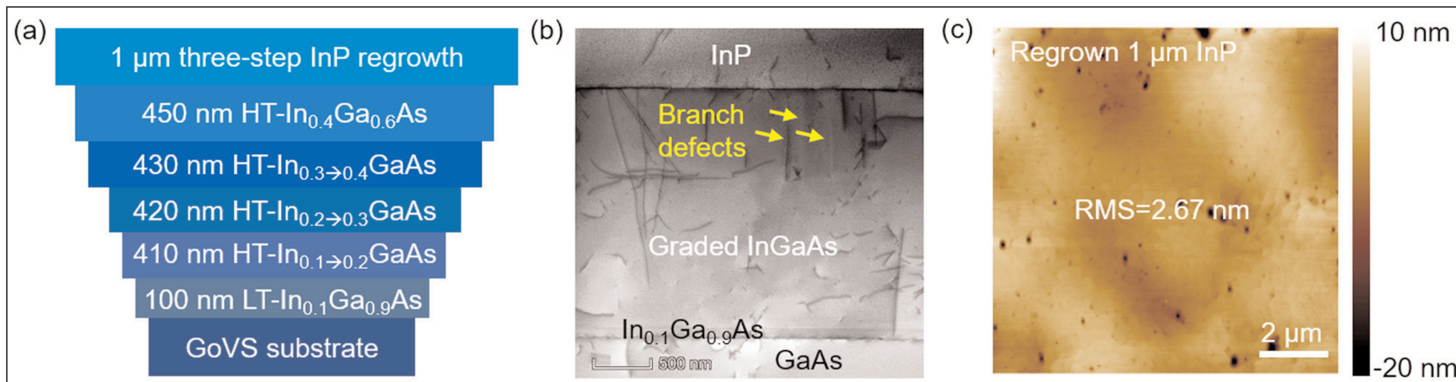

Figure 2. (a) Schematic of 1µm InP layer regrown on graded InGaAs buffer. (b) Close-up view of the $InP/In_{0.4}Ga_{0.6}As$. (c) 10µmx10µm AFM image after 1µm InP regrowth, with some pinholes identified.

increased; high-temperature SLS growth, on the other hand, tended to generate stacking faults.

Surface roughness as low as 3.79nm root-mean-square was measured by AFM with 600°C SLS growth. Before SLS growth, the defect density was of the order $10^{10}/cm^2$. By varying the InGaAs composition, surface defect densities could be reduced to $7.9x10^7/cm^2$, at the cost of a rougher surface with a number of 'hillocks'.

Shi and Klamkin also produced a laser structure using an InP/Si pseudo-substrate with $1.15x10^8/cm^2$ defect density to grow seven 6.3nm $In_{0.73}Ga_{0.27}As_{0.85}P_{0.15}$ quantum wells separated by 8nm $In_{0.73}Ga_{0.27}As_{0.52}P_{0.48}$ barriers (Figure 1). Fabry–Perot ridge-waveguide laser diodes were fabricated. The wafer was thinned and cleaved into laser bars before mounting on a ceramic carrier for testing.

The continuous-wave (CW) laser threshold current of $2.05kA/cm^2$ for a 20µmx1000µm device is described as "reasonable". The output power reached 18mW/facet without coatings. The CW operation was possible up to 65°C. Comparison devices produced on InP substrate had a threshold of $0.675kA/cm^2$ and CW operation was maintained up to 95°C. Wall-plug efficiencies of 2.7% were achieved for the device on silicon, compared with 15% on InP.

Shi and Klamkin found red-shift effects at higher current injection due to self-heating. The researchers comment: "The heating originates from the reduced injection efficiency on silicon as a result of the residual threading dislocations inside the active region and the larger series resistance than lasers realized on conductive InP substrates (1.7Ω on Si and 0.8Ω on InP)."

The devices on silicon may also suffer from reduced heat dissipation arising from defects at InP/GaAs interfaces and residual stain in the InP buffer. Despite the reduced performance, Shi and Klamkin hope their work "advances the field toward the monolithic integration of InP-based on-chip light sources in the SiPh platform."

The researchers also reduced defect densities earlier on in the growth by transitioning from the GaAs template to an In0.4Ga0.6As buffer before growing an InP buffer using the three-step process (Figure 2). The LT and HT values were 495°C and 600°C, respectively.

A relatively thin 1.8µm InGaAs buffer was found to have a defect density of $2x10^8/cm^2$, compared with just $2x10^6/cm^2$ for a structure grown on pure GaAs substrates. The defect density in three-step InP buffers grown on the structure was $4x10^8/cm^2$, a factor of two lower than with direct growth on GoVS. Increasing the HT to 650°C reduced the defect density to $5x10^7/cm^2$ in one sample. Adding four SLS structures separated by 250nm HT-InP layers reduced the dislocation density to $4.5x10^7/cm^2$ for the final 500nm InP surface layer.

Shi and Klamkin comment: "Although the surface is rougher for the InP buffer on the graded InGaAs layer, improved laser characteristics can be anticipated due to the lower defect density." ■

https://doi.org/10.1063/1.5127030

Author: Mike Cooke

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Aluminium gallium nitride on silicon carbide for UV light-emitting diodes

Researchers boost light extraction with potassium hydroxide surface roughening of thin-film flip-chip devices.

University of California Santa Barbara (UCSB) in the USA has been using silicon carbide (SiC) substrates to grow aluminium gallium nitride (AlGaN) structures aimed at 278nm deep ultraviolet (UV-C, 100–280nm wavelength) light-emitting diodes (LEDs) [Burhan K. SaifAddin et al, ACS Photonics, 7 (2020), 3, p554]. The researchers used surface roughening of thin-film flip-chip devices to boost light-extraction efficiency (LEE) by a factor of 3 over smooth-faced LEDs.

"The ability to grow AlGaN LEDs on SiC with low TDD [threading dislocation density] opens new ways to fabricate high-brightness, high-power UV LEDs with high LEE," the team comments. The 260–280nm wavelength range enables efficient disinfection by breaking up DNA and RNA molecules of pathogens.

The researchers are keen to combat antibiotic-resistant bacteria such as Clostridium difficile (C. diff.), which is indeed difficult to kill using chemical methods. By contrast, UV disinfection reduced C. diff. levels by 30%, according to University of North Carolina researchers in 2010.

Fabricating efficient UV-C LEDs has been challenging due to a number of factors. Material quality can be improved by using SiC rather than sapphire, due to a closer lattice and thermal expansion match. However, UV-C light is strongly absorbed in SiC, unlike sapphire, due to its narrower bandgap. Indeed, sapphire is often used for UV-C LEDs for this reason.

Low-pressure metal-organic chemical vapor deposition was carried out on 2-inch 6H SiC on the silicon face of a c-plane (0001) crystal orientation. The AlGaN layers

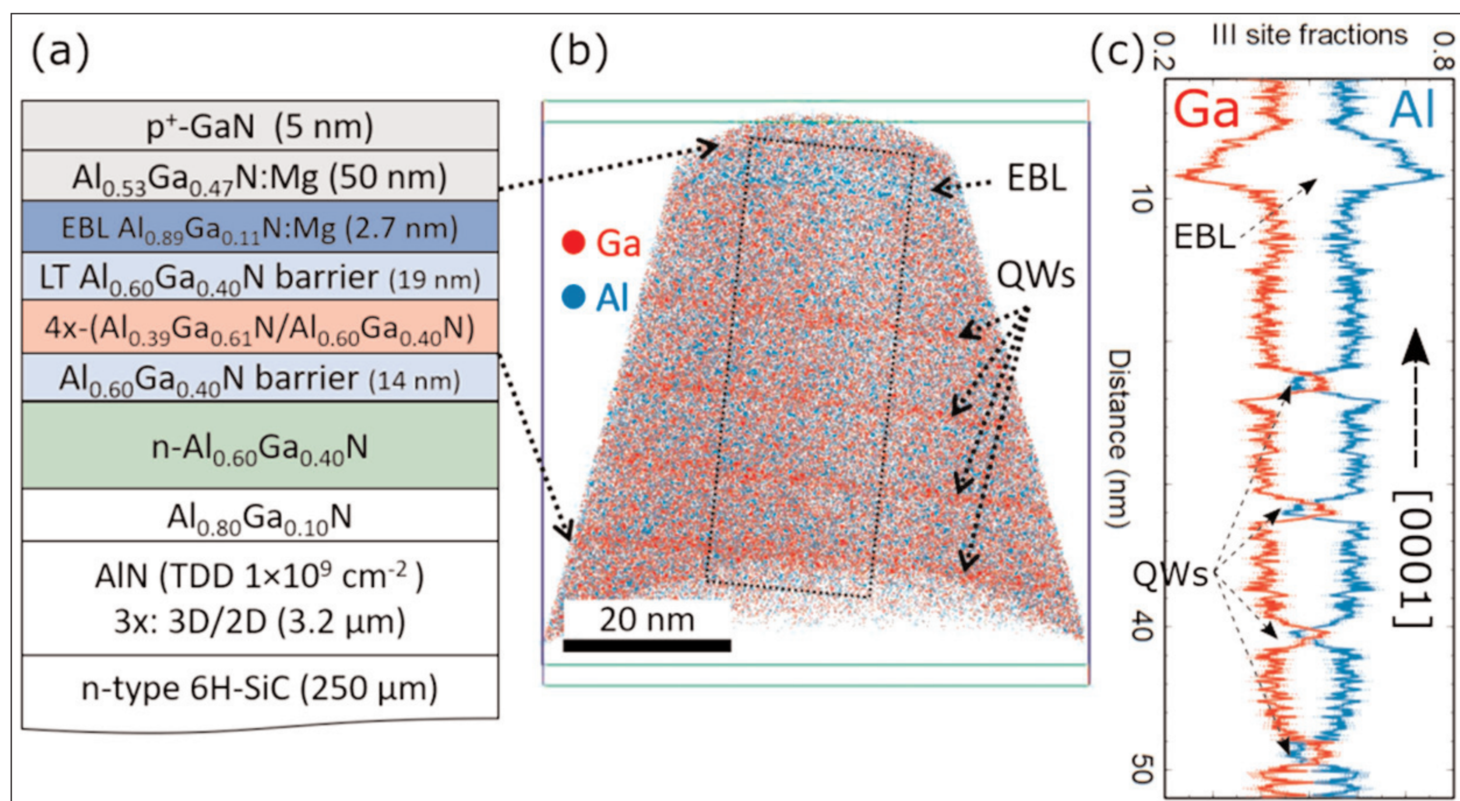

Figure 1. (a) Schematic of the UV-C LED structure. (b) APT 3D reconstruction of active layer showing EBL layer and four MQWs; (c) 1D concentration profile extracted from APT reconstruction along [0001] direction. Sampling volume dimension 20nmx20nmx50nm from dotted rectangle in (a).

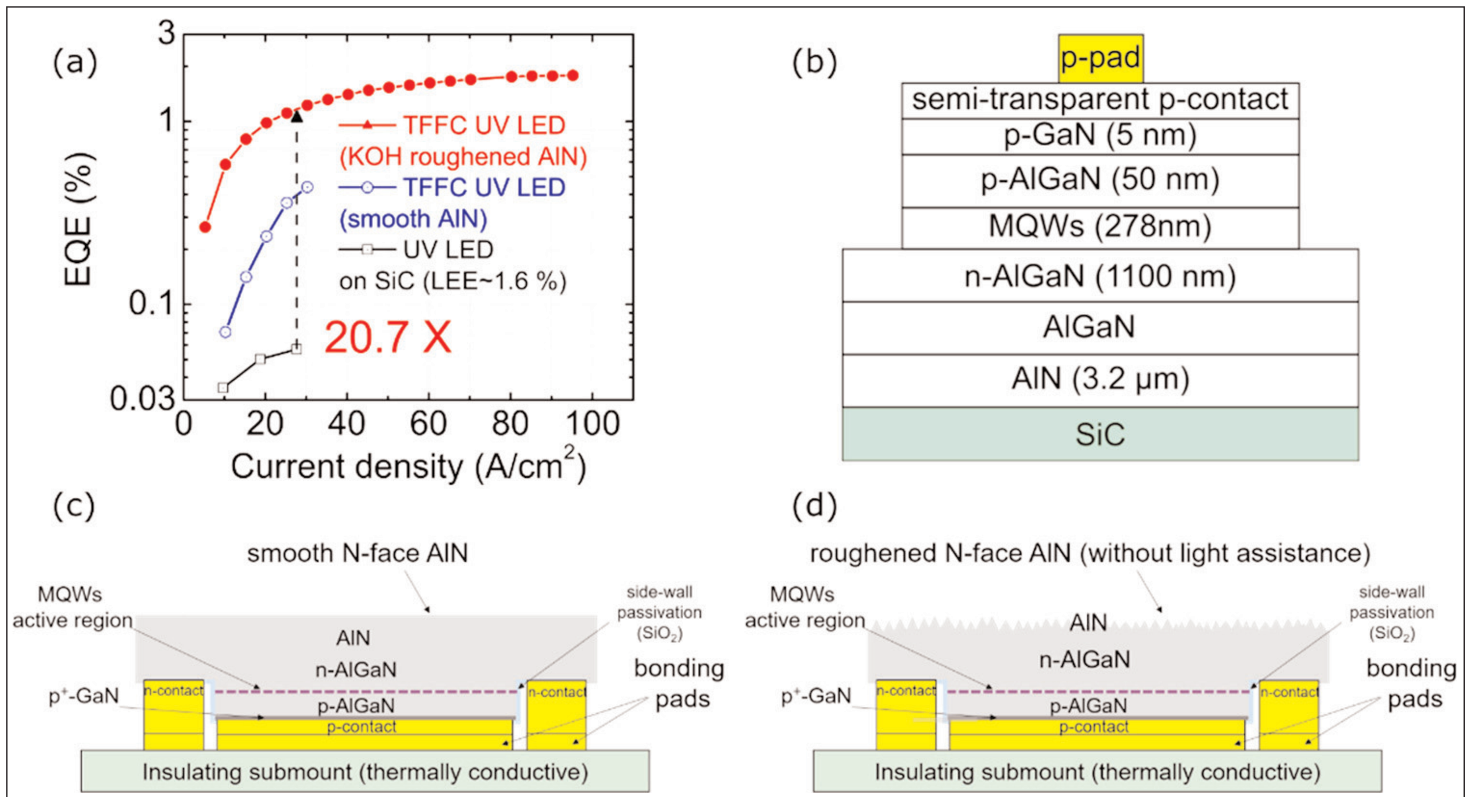

Figure 2. (a) EQE as function of current density for different 278nm UV LEDs processed from same epitaxial sample. (b) Unflipped UV LED on SiC schematic with p-side up. (c,d) Thin-film flip-chip (TFFC) UV LED (area ~0.1mm^2), (c) before and (d) after surface roughening.

began with a 3.2μm AlN buffer grown in steps at 1200°C and 1000°C (Figure 1). The Al content was reduced with an 1100nm $Al_{0.8}0Ga_{0.2}0N$ interlayer, and then 550nm n-$Al_{0.6}0Ga_{0.4}0N$ grown at 1175°C. The multi-quantum well (MQW) region consisted of four pairs of 2.7nm/9nm $Al_{0.39}Ga_{0.61}N/Al_{0.60}Ga_{0.40}N$ wells/barriers. The structure also included an AlGaN electron-blocking layer (EBL).

The AlN buffer was crack-free due to a "novel substrate pretreatment" (annealing in ammonia/hydrogen at 1250°C) and a multi-step 3x(3D/2D) growth process reported by UCSB in 2018. The AlN buffer also achieved a reduced threading dislocation density of ~10^9/cm^2.

The researchers used atomic probe tomography (APT) to study the material, in what the team claims was its first use on UV-LED structures.

The material was then fabricated into thin-film flip-chip devices in TO-39 headers. The SiC growth substrate was removed using a sulfur hexafluoride plasma etch. The team used potassium hydroxide solution to roughen the flipped AlN light-emission surface, increasing light output by reducing reflection back into the LED material. Also, the p-GaN thickness was reduced as much as possible, since the material is absorbing of UV-C radiation. These two measures, along with increasing the reflectivity of the p-contact, are estimated to increase the light-extraction efficiency by a factor of 3 over smooth-surface devices.

At 95mA injection current, the roughened UV-C LED had 7.6mW (82mW/mm^2) light output power and 1.8% external quantum efficiency. The slope efficiency was 89μW/mA. The turn-on voltage was 4.3V. The LEE was estimated at 33%, the highest reported for AlGaN LEDs, the team claims. ■

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GaN-on-silicon platform for low-cost high-power electronics

Mike Cooke reports on recent research towards devices for high-voltage and high-frequency power switching and RF wireless transmission amplification.

An interesting recent feature of gallium nitride (GaN) electronic development is the use of silicon substrates, often in the form of commercial epitaxial wafers from suppliers like China-based Enkris Semiconductor or Japan's NTT Advanced Technology Corp. It is almost understood that, to compete on cost, the devices will need to be deployed on silicon, and many research papers now do not even bother rehearsing the reasons or challenges. The main reasons are low material costs and availability of large-diameter wafers for mass production. Challenges include higher defect levels arising from mismatches in terms of the crystal lattices and thermal expansion of silicon and III-N materials.

GaN high-electron-mobility transistors (HEMTs), also known as heterostructure field-effect transistors (HFETs), are being developed for high-voltage, high-density, high-frequency power switching and radio-frequency (RF) wireless transmission amplification. Normally-on or 'enhancement-mode' (E-mode) transistors are particularly sought for reduced power consumption and enabling fail-safe high-voltage power switching operation. Also, the normally-off mode simplifies gate-driver circuit design. The high voltage and power handling is based on GaN's high critical electric field before breakdown.

The predominant n-channel devices that have been developed largely depend on the creation of 'two-dimensional electron gas' (2DEG) channels, which arise near the interface between GaN and a barrier layer, often aluminium gallium nitride (AlGaN). The 2DEG occurs due to band-bending effects arising from contrasts in the charge distribution in the chemical bonds holding the Ga, Al and N atoms together. Without special measures, the 2DEG channel conducts when the gate potential is 0V, giving a normally-on 'depletion-mode' (D-mode).

Here, we look at recent developments using the GaN/Si platform.

Dual-layer silicon nitride threshold engineering

Researchers in China, Hong Kong, USA and Canada have used two silicon nitride (SiN_x) layers on GaN HEMTs to push the threshold 1V in the positive direction, while reducing off-state leakage and maintaining on-current [Wei-Chih Cheng et al, Semicond. Sci. Technol., vol35, p045010, 2020]. The dual-layer SiN_x acts as a stressor, depleting the 2DEG channel under the gate, and as passivation to reduce off-state leakage through the AlGaN barrier layer. Although the presented devices were all normally-on, more positive threshold voltage (V_{th}) could eventually lead to normally-off transistors.

The team involved researchers from China's Southern University of Science and Technology (SUSTech), Hong Kong University of Science and Technology (HKUST–Washington State University in the USA, University of British Columbia in Canada, GaN Device Engineering Technology Research Center of Guangdong, China, and China's Key Laboratory of the Third Generation Semi-conductor.

The epitaxial material used for the transistors was grown by metal-organic chemical vapor deposition (MOCVD) on 6-inch-diameter <111> Si at Enkris Semiconductor. The devices (Figure 1) were electrically isolated using inductively coupled plasma (ICP) mesa etching. Annealed titanium/aluminium/titanium/gold (Ti/Al/TI/Au) formed the ohmic source-drain contacts. The gate consisted of patterned nickel/gold (Ni/Au).

The two layers of SiN_x were deposited using dual-frequency plasma-enhanced CVD (PECVD). The low-stress passivation layer has an unintentional tensile stress of 0.3GPa. The layer used a process avoiding the low-frequency plasma excitation step, to reduce surface damage from nitrogen ion bombardment. The addition of low-frequency plasma excitation for the second layer produced a high-compressive-stress −1GPa film.

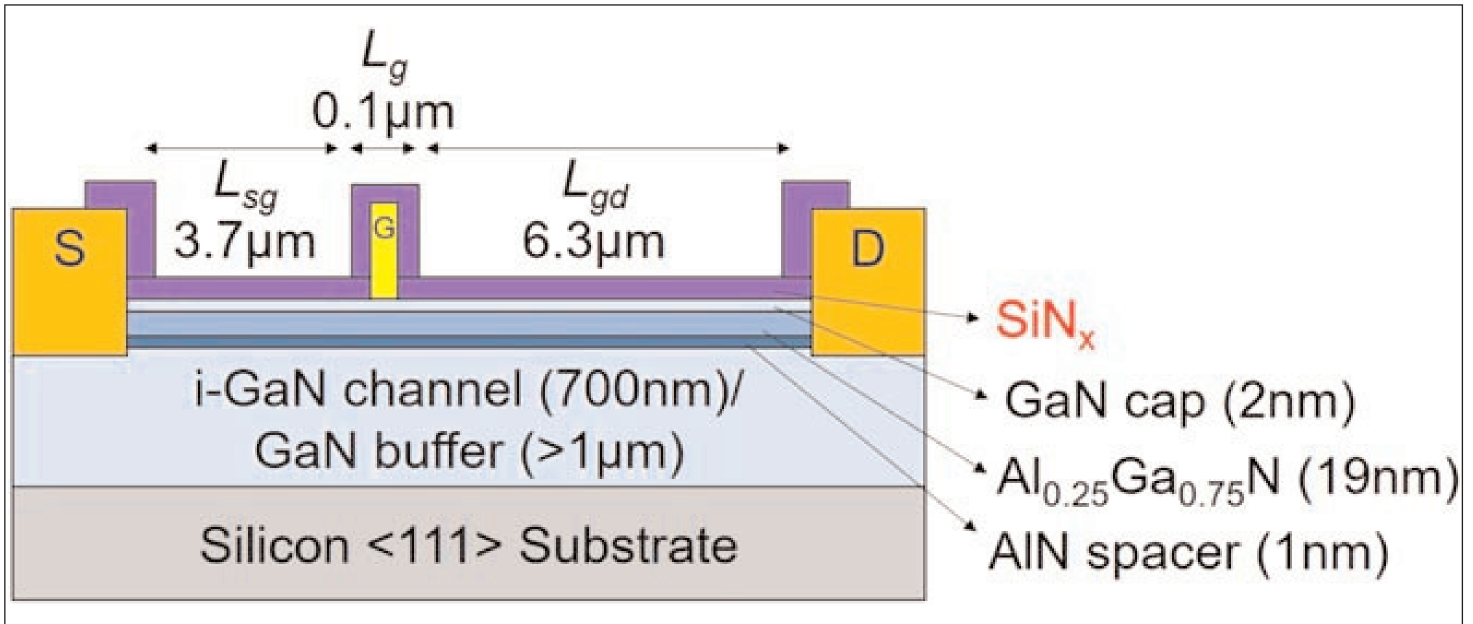

Figure 1. Device structure of AlGaN/GaN HEMT showing gate (L_g), source-to-gate (L_{sg}), and gate-to-drain (L_{gd}) lengths/spacings. Channel consisted of unintentionally doped GaN (i-GaN).

The presence of 200nm stressed SiN_x enabled the V_{th} to be pushed 1V in the positive direction. Combining the stressor with a 14nm passivation layer increased the on-current to the level of a baseline (BSL) device, which had a 200nm SiN_x passivation layer without stressor.

The combined 200nm/14nm stressor/passivation transistor achieved a maximum on-current of 1A/mm (Figure 2). The peak transconductance was 280mS/mm with 7V drain bias, putting the device in the saturation region. The drain current was comparable with the baseline transistor, while the transconductance was higher by around 30mS/mm.

RF measurements gave a cut-off (f_T) of 36GHz, while the stressed device without passivation only achieved 20GHz. The BSL component had a comparable f_T of around 36GHz.

Surface damage also adversely affected the off-current (I_{off}) in the stressed devices without passivation. Adding passivation thicker than 7nm reduced the off-current leakage even below that of the baseline device.

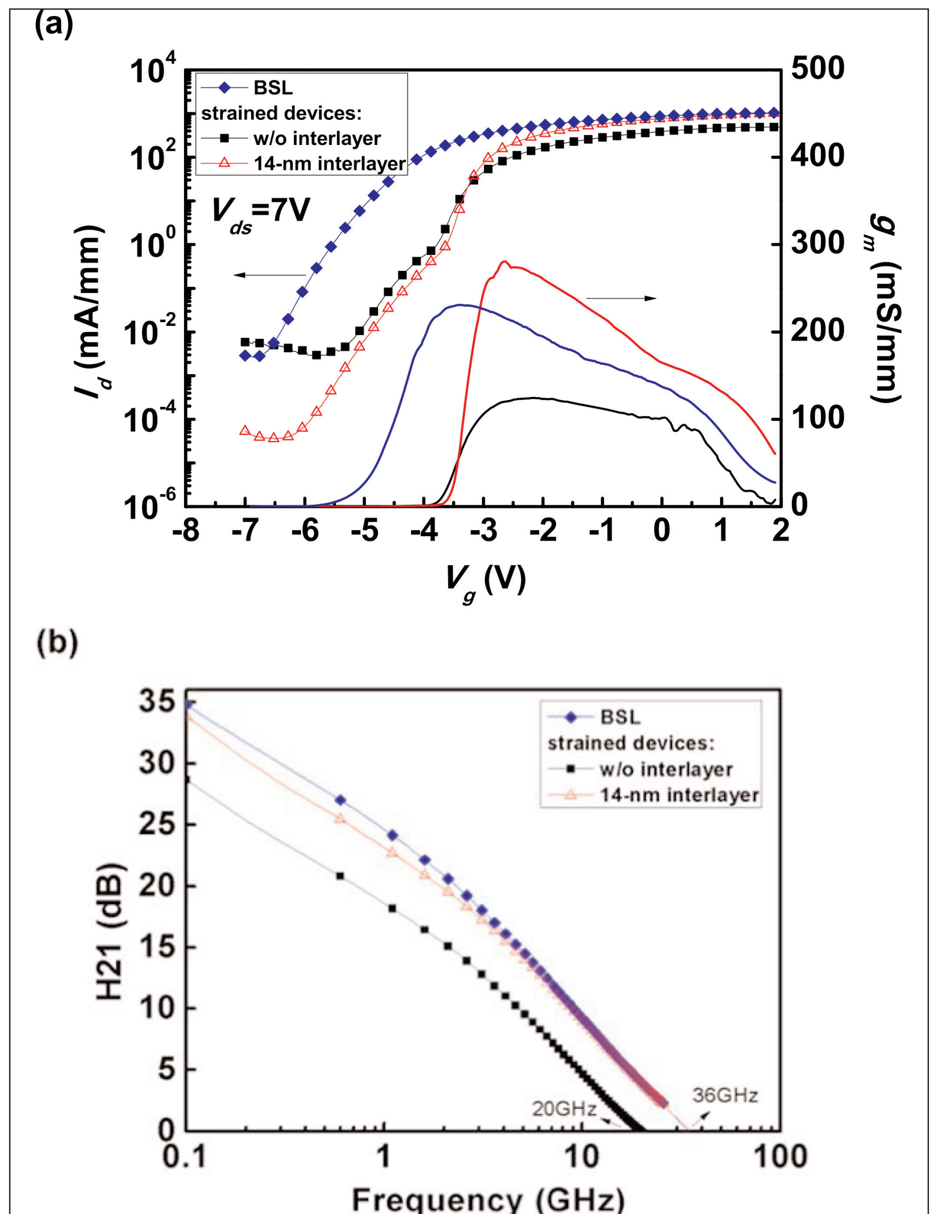

Figure 2. (a) Transfer characteristics of BSL and strained devices at 7V drain bias. (b) H_{21} current gain of BSL and strained devices biased to 7V drain and 1V above gate threshold.

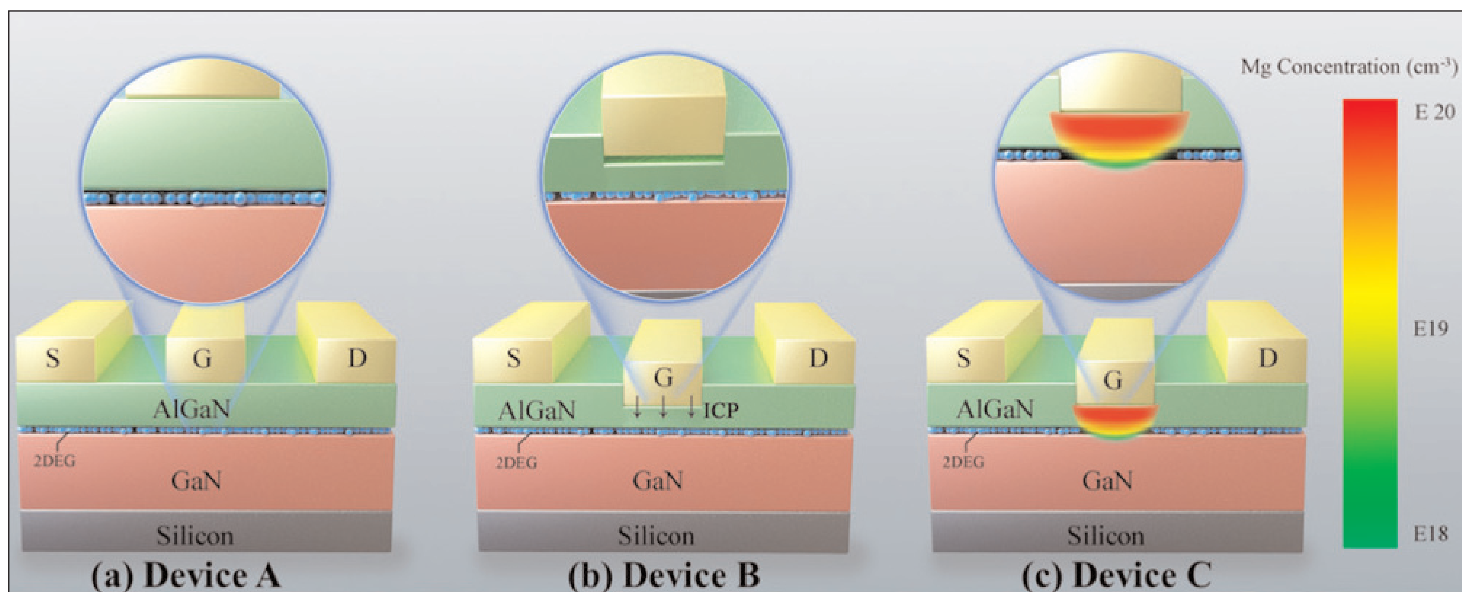

Figure 3. Schematics of (a) bare-bones as-grown device A, (b) device B with etched recessed gate, and (c) device C with Mg diffused gate stack after etching treatment.

Magnesium thermal diffusion for p-gates

South China University of Technology has developed a simplified fabrication process for normally-off AlGaN-barrier GaN-channel HEMTs with a p-type gate stack [Lijun Wan et al, Appl. Phys. Lett., vol116, p023504, 2020]. Introducing p-type material above the channel in the gate region of the device is one technique for depleting the 2DEG, cutting off current flow at 0V gate potential.

The p-type doping under the gate electrode was achieved by magnesium (Mg) thermal diffusion rather than the more usual inclusion as a precursor in the epitaxial material growth process. The team sees their work as "commercially promising" for manufacture of normally-off HEMTs with low gate leakage. The method successfully increased the Vth into positive values, creating a normally-off device.

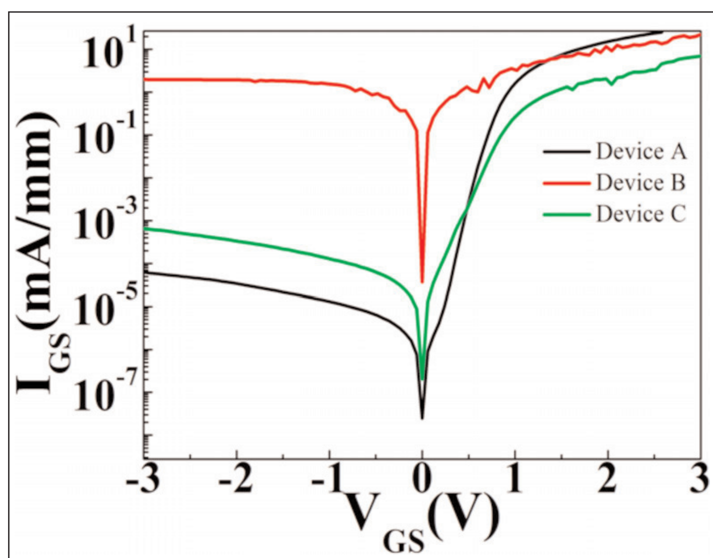

Figure 4. Gate current density (I_{GS}) as function of voltage (V_{GS}) for devices A–C.

The device was based on epitaxial material with 4.7µm buffer, 300nm undoped GaN channel, 15nm $Al_{0.15}Ga_{0.85}N$ barrier, 2nm GaN cap layers on silicon. The transistor fabrication began with 5 seconds of ICP etch in the gate region, before depositing a 50nm layer of Mg with electron-beam evaporation. The underlying AlGaN was p-type doped with the Mg by rapid thermal annealing at 600ºC for a minute. Further annealing in air at 250ºC for a minute created a magnesium oxide (MgO) passivation layer.

The source-drain ohmic contacts consisted of annealed Ti/Al/Ni/Au. Mesa etching with ICP formed the electrical isolation of the devices. A Ni/Au gate electrode on the MgO completed the transistor.

The rapid ICP etch before Mg deposition roughens the surface and introduces defects, allowing the metal atoms to penetrate/diffuse more deeply into the AlGaN barrier layer in the gate region during the thermal anneal. Atomic force microscopy (AFM) suggested that the etch depth was around 6nm, removing the GaN cap and partially etching and recessing the AlGaN.

Three device types were tested (Figure 3): A was a conventional HEMT without ICP etch or Mg diffusion; B was a HEMT with ICP etch, recessing the gate, but no Mg in the gate region; and, finally, C had the full gate stack with ICP etch and Mg diffusion.

The V_{th} for transistors A-C, in order, were −1.5V, −0.4V and +1.4V. The corresponding peak transconductances were 68mS/mm, 105mS/mm and 97mS/mm. Although the gate control, as represented by the peak transconductance, fell back somewhat for device C, the value was still higher than for the bare-bones HEMT A.

The process did hit the drain saturation current from 275mA/mm and 300mA/mm for devices A and B, respectively, with C only managing 173mA/mm. The gate potential in these measurements was +3V. The

researchers suggest a depleted 2DEG may be caused by holes injected from the Mg-diffused layer.

The gate leakage currents with 0V gate were $3.7x10^{-5}$mA/mm and $2x10^{-7}$mA/mm for devices B and C, respectively (Figure 4). Transistor C still had only $6.5x10^{-4}$mA/mm gate leakage with the gate at +0.4V. The researchers credit the passivating effect of MgO on surface trap states from the etch processing for the good performance.

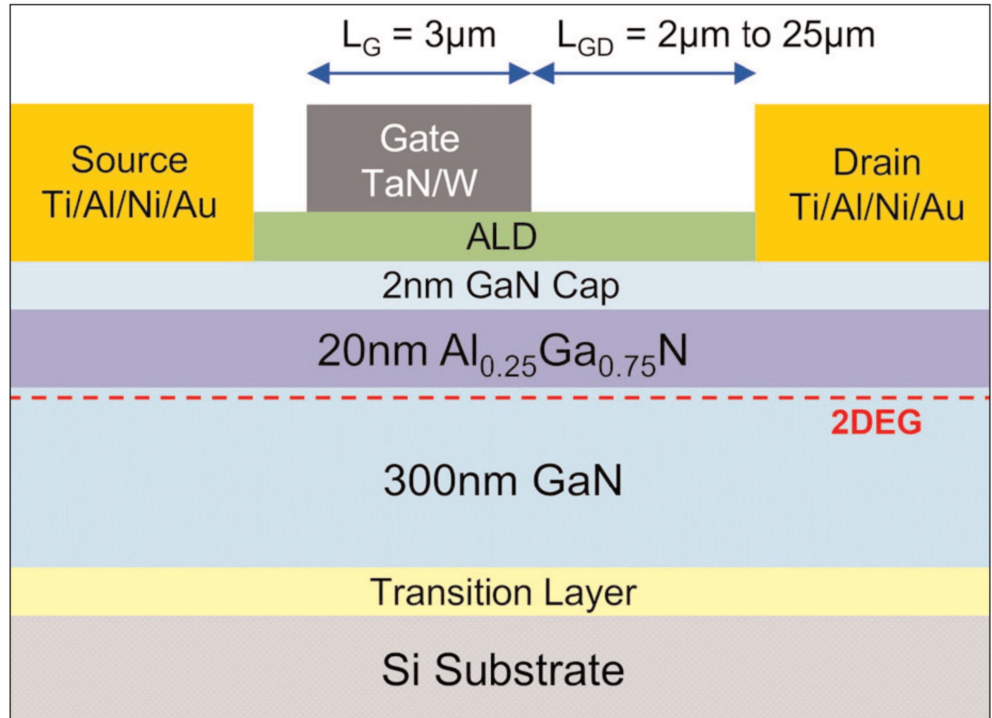

Figure 5. Schematic cross section of AlGaN/GaN MOS-HFET.

Ozone precursor for hafnium dioxide dielectric

North Carolina State University in the USA has been studying ozone (O_3) as means to improve hafnium dioxide (HfO_2) dielectric deposition for AlGaN-barrier insulated-gate metal-oxide-semiconductor HFETs (MOS-HFETs) on silicon substrate [Faisal Azam et al, IEEE Transactions on Electron Devices, vol.67, p881, 2020].

The researchers used AlGaN/GaN epitaxial material on <111> Si, supplied by Japan's NTT Advanced Technology Corp. The device was fabricated using a single dielectric for both gate insulation and surface passivation of the source/drain access regions, much simplifying the processing (Figure 5).

The fabrication sequence was: mesa reactive-ion etch (RIE), deposition and annealing of Ti/Al/Ni/Au source–drain electrodes, ultrasonic and wet surface cleaning of gate and access regions, atomic layer deposition (ALD) of hafnium dioxide (HfO_2) gate/passivation dielectric, post-deposition annealing in nitrogen, and RF sputtering of tantalum nitride/tungsten (TaN/W) gate electrode.

The HfO_2 atomic layer deposition process used tetrakis(dimethylamino)hafnium (TDMAH) as the Hf precursor. For the oxygen component, the team studied the benefits of ozone (O_3) over the more usual water (H_2O). In capacitance-voltage measurements at 10kHz on MOS structures, the effect of using O_3 was to reduce threshold hysteresis by about a factor of two. The team attributes the improvement to reduced charge trapping in defects and possible O_3 AlGaN surface passivation and enhanced interface quality.

The use of O_3 oxidation also tended to shift the threshold from around −12V, for H_2O precursor, to −6V, depending on ALD process details. This might be related to H^+ ions, i.e. protons, being incorporated in the AlGaN surface. Such an effect was absent with O_3.

The researchers also varied the ALD process, alternating the HF precursor with either a single- or double-pulse of oxidant. The single-pulse resulted in a slightly higher capacitance above threshold, compared with the double O_3–O_3 pulse ALD recipe. The researchers suggest that this could be due to variation in thickness of the dielectric layer, or change in dielectric constant with the degree of crystallinity.

The MOS-HFETs reached 340mA/mm maximum saturation drain current with O_3 dielectric, compared with 240mA/mm for H_2O oxidation. The gate potential was 4V. The higher value for O_3 dielectric was attributed to a cleaner HfO_2/AlGaN interface with less surface states affecting the 2DEG conduction channel.

The specific on-resistance with the gate at 3V over pinch-off was reduced by 20% from using O_3 oxidation in a device with 15µm gate–drain distance. "This is a significant enhancement in the performance that should directly translate to lower conduction loss, i.e. higher efficiency in power switching applications," the team writes.

The V_{th} for devices with H_2O, O_3 and no (i.e. a Schottky HFET) dielectric were −12.1V, −4.7V and −2.95V, respectively. The more negative threshold for H_2O dielectric is again blamed on proton incorporation in the AlGaN barrier.

The O_3 oxidant also benefited transconductance, giving a peak value of 112.6mS/mm, compared with 81.38mS/mm for H_2O-based dielectric. Gate leakage was also reduced by more than an order of magnitude by using an O_3 ALD process: $5.4x10^{-6}A/cm^2$, compared with $1.7x10^{-4}A/cm^2$ when H_2O oxidant was used. Studies of the effect of temperatures up to 200ºC on device performance also showed greater stability of on-resistance and V_{th} in the O_3 ALD devices. ➤

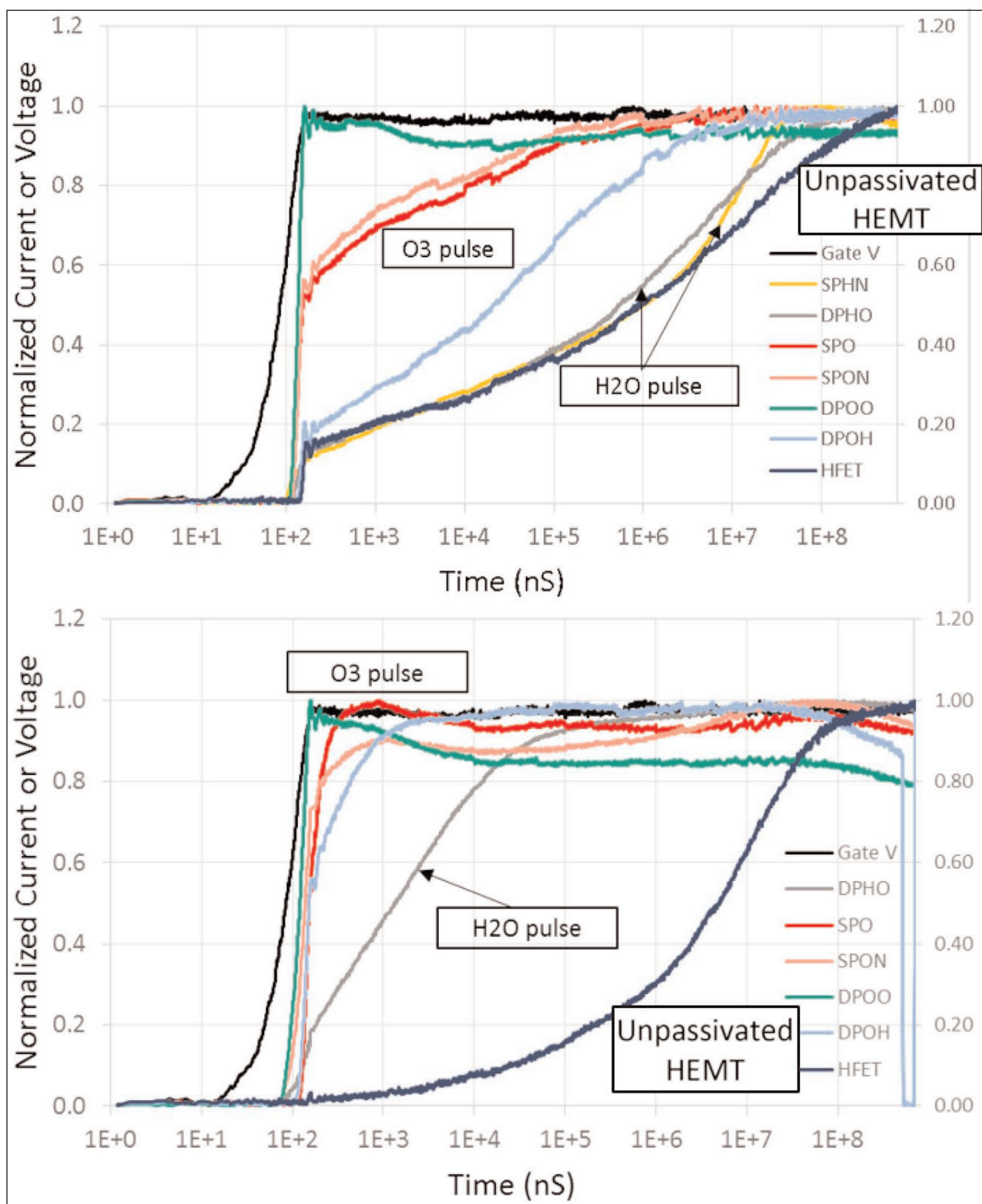

Figure 6. DC/RF dispersion: gate lag at (a) room temperature and (b) elevated temperature, 150ºC.

High-temperature reverse-bias stress testing was carried out for 1000s at 150ºC with 150V drain bias and the gate at 3V below threshold. The H_2O transistors showed a +2.5V drift in threshold (V_{th}) over the test period. The O_3 dielectric reduced this to less than 0.5V.

The current collapse recovery was assessed by applying short pulses with 100ns rise time (Figure 6). The O_3 devices performed significantly better than H_2O or bare Schottky HFETs. "Specifically, H_2O oxidant took 20ms to achieve 90% drain current recovery, whereas O_3 oxidant took ~0.1ms to achieve 90% drain current recovery, an extraordinary 200x potential improvement," the team reports.

The reduced current collapse of the O_3 and H_2O oxidant devices, compared with the unpassivated Schottky HFET, was maintained at 150ºC high temperature. Indeed, the passivated devices showed reduced current collapse, while the Schottky HFET's performance worsened further. Devices where the O_3 was applied in two pulses between the Hf pulse in the ALD process showed "near-ideal behavior", according to the researchers.

Complementary p-channel transistors

Hong Kong University of Science and Technology (HKUST) report on p-channel metal-oxide-semiconductor field-effect transistors (MOSFETs) produced on GaN-on-Si substrates [Zheyang Zheng et al, IEEE Electron Device Letters, vol.41, p26, 2020]. The researchers used commercial 8-inch-diameter GaN-on-Si wafers with epitaxial structures designed for 650V normally-off p-GaN gate power HEMTs (Figure 7).

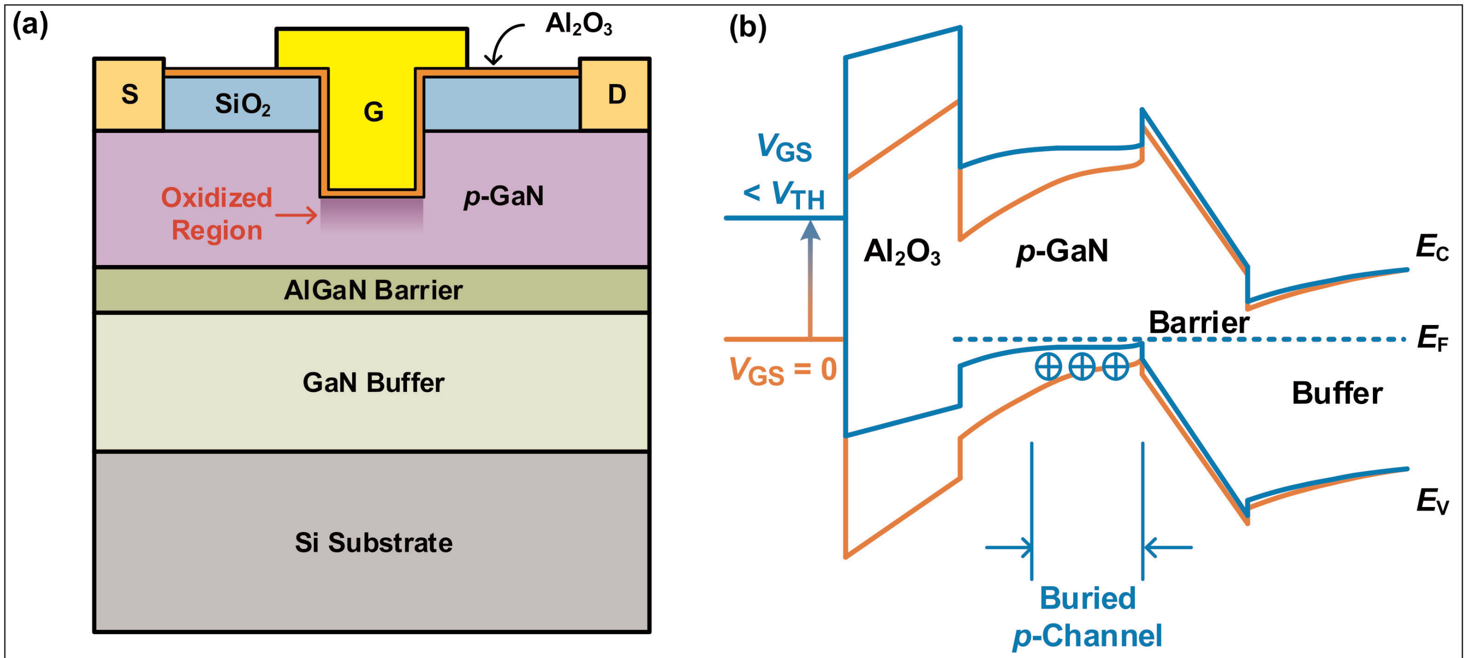

Figure 7. Schematic of (a) E-mode GaN pFET ($L_{GS}/L_G/L_{GD}$ = 4/2/4μm) and (b) energy band diagram at gated region of buried p-channel with 0V (OFF) and beyond threshold (ON) gate potentials (V_{GS}).

As has been seen above, devices with n-type channels with negatively charge carriers (electrons) have been intensively developed in recent years, but the creation of p-channels would enable complementary integrated circuit (IC) designs, which would further reduce power loss in logic control systems. Although some progress has recently been made in developing an analogous two-dimensional hole gas (2DHG) for p-channels, effective devices remain to be achieved. The HKUST work focuses instead on using p-GaN material achieved using magnesium doping.

The GaN-on-Si material included ~12nm AlGaN barrier and ~85nm p-GaN top layer. The undoped GaN buffer was ~4.5μm thick. The structure was found to have a hole sheet density of $1.23x10^{13}/cm^2$ and mobility $10.2cm^2/V$-s, according to Hall measurements.

The HKUST p-channel devices were fabricated with 500°C-annealed Ni/Au ohmic source–drain contacts evaporated onto the p-GaN, which had previously been subjected to a 5-minute buffered oxide etch, presumably to improve the surface and remove contaminants. The gate recess was defined by a 200nm PECVD silicon dioxide (SiO_2) hard mask, which

Affinity	Platform	V_{TH} [a] (V)	lg(I_{ON}/I_{OFF}) [b]	I_{ON} [c] (mA/mm)	SS (mV/dec)
Notre Dame [10]	p-/i-GaN /AlN Al_2O_3 MOS gate	0.89 (−80 V)	3 (−80 V)	3.87 (−80 V)	1415
RWTH [9]	p-/i-GaN/AlInGaN/ GaN/AlN, Schottky gate	−1.12 (−8V)	7 (−8V)	6.79 (−8V)	91.3
AIST [5]	p-/i-GaN/AlGaN/GaN Al_2O_3 MOS gate	> 4	N.A.	4.00	N.A.
RWTH [11]	p-/i-GaN/AlInGaN/ GaN/AlN, Schottky gate	−0.5	8	1.81	77
HRL [6]	p-/i-GaN/AlGaN/GaN AlN/SiN_x MIS gate	−0.36 (−0.1V)	6 (−0.1V)	1.65	304
AIST [7]	p-/i-GaN/AlGaN/GaN SiO_2 MOS gate	−0.75	3	0.09	817
Cornell [12]	p-/i-GaN/AlN SiO_2 MOS gate	1.32	4	9.10	1027
MIT [13]	p-GaN/AlGaN/GaN Al_2O_3 MOS gate	2.60 (−0.5V)	5 (−0.5V)	1.40	399
This work	p-GaN/AlGaN/GaN Al_2O_3 MOS gate	**−1.7**	**7**	**3.38**	**230**

[a] extracted at $|I_D|$ = 10 μA/mm and V_{DS} = −5 V unless otherwise specified.
[b] (orders of magnitude) with V_{DS} = −5 V unless otherwise specified.
[c] at V_{DS} = −5 V and with overdriven V_{GS}, unless otherwise specified.

Table 1. Benchmark of p-channel GaN FETs.

also served as surface passivation. The p-GaN recess was formed using ICP RIE.

An oxygen plasma treatment increased the surface roughness at the bottom of the recess from 0.36nm root-mean-square to 0.41nm, according to atomic force microscopy. The recess depth was found to be about 54nm, leaving ~31nm of p-GaN material above the AlGaN barrier for the channel.

The gate structure was completed with 20nm ALD aluminium oxide (Al_2O_3) insulation and 400ºC-annealed Ni/Au metal electrode. The electrical isolation of the devices was from fluorine ion implantation rather than mesa etching. The researchers used fluorine implant to avoid current leakage along rough mesa sidewalls. The implant occurred between the Al_2O_3 and gate metal deposition steps.

The device demonstrated a V_{th} of −1.7V, giving normally-off enhancement-mode behavior at 0V gate. The oxygen plasma treatment enabled the negative threshold — without the treatment, the device became depletion-mode with the threshold at +2.2V. The on-current of the enhancement-mode device was 67% that of the depletion-mode transistor without oxygen plasma treatment.

The on-resistance for the E-mode device was a "relatively large" 2.4kΩ-mm at low drain bias. This reduced somewhat at −5V drain to 1.6kΩ-mm. The maximum drain current was 6.1mA/mm at −10V drain. The off-current with 0V gate was 1.2×10^{-7}mA/mm. The team sees this low off-current as "delivering an ultra-low static power consumption required in CMOS logic gates."

The researchers compared their device with others previously presented in the scientific literature (Table 1).

Hydrogen-terminated diamond transistors

École polytechnique fédérale de Lausanne (EPFL) and Lake Diamond SA in Switzerland claim the first p-channel hydrogen-terminated diamond transistors (HTDTs) on GaN-on-Si templates that demonstrate high-power device performance comparable with other HTDTs on polycrystalline and even monocrystalline diamond [Reza Soleimanzadeh et al, IEEE Electron Device Letters, vol41, p119, 2020].

The researchers suggest that the integration of p-channel HTDTs with n-channel GaN transistors opens "a pathway for future complementary power switch and logic applications". The diamond layer is also thermally conductive, allowing improved thermal management of GaN devices in high-power-density applications. The team sees the potential for complementary logic operation, gate drivers and complementary power switches in integrated power inverters and converters.

The researchers used an AlGaN GaN-on-Si template as used for the fabrication of n-channel HEMTs. The template was prepared for diamond deposition by applying layers of 30nm SiN and 5nm Si. These layers were designed to protect the template material from the harsh diamond deposition environment, along with enhancing

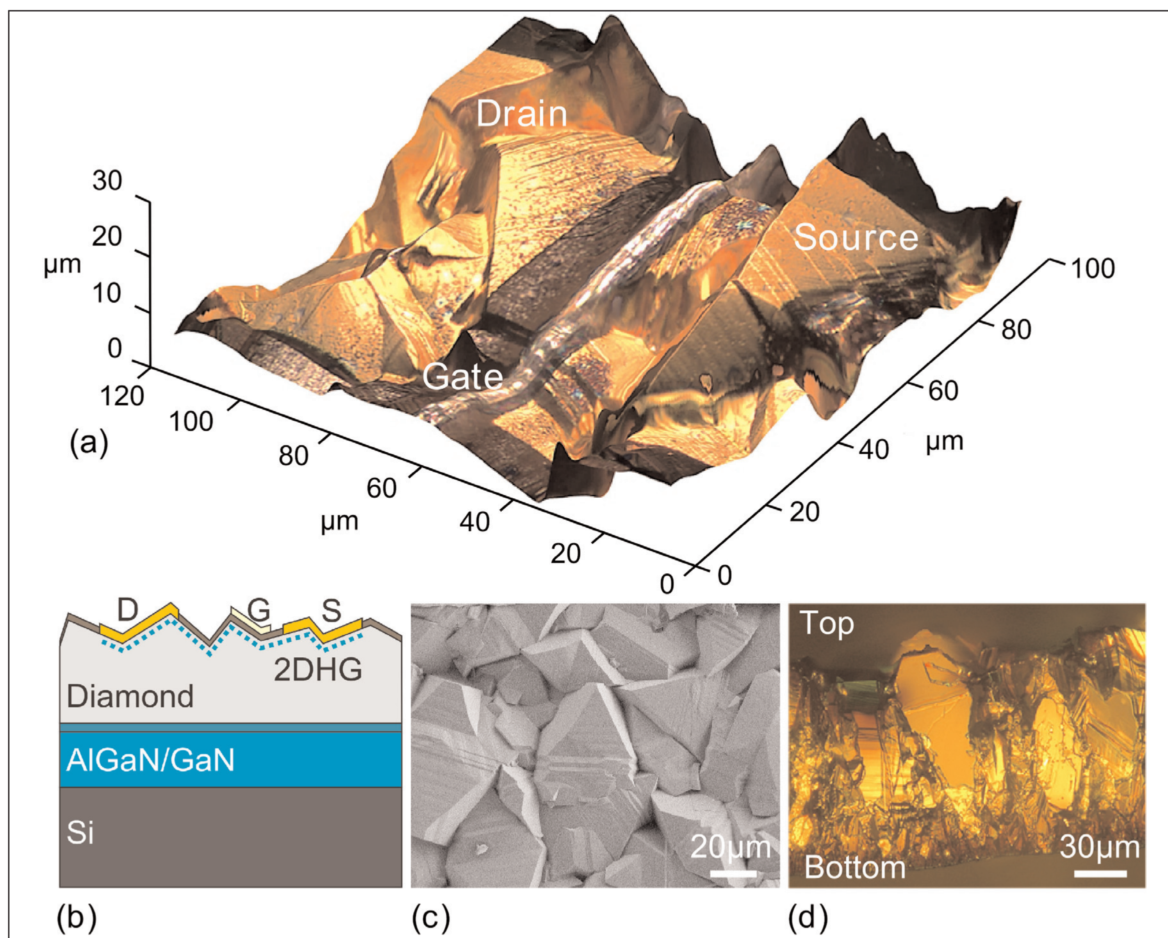

Figure 8. (a) Three-dimensional (3D) optical microscope image of fabricated HTDT, constructed using focus stacking. (b) Schematic of HTDTs. (c) Top-view SEM image of diamond surface. (d) Cross-sectional optical microscope image of diamond layer showing larger grain sizes at top.

adhesion and thermal conductivity between the materials.

The polycrystalline diamond deposition was seeded with 1–150μm nanoparticles applied in isopropanol solution. The main diamond deposition consisted of microwave-plasma CVD (MPCVD) at 800ºC. The plasma power was 3.5kW. The carbon source was 5% methane at 140mbar pressure. Trace quantities of nitrogen and argon were added to improve the growth rate. The carrier gas is not mentioned, but hydrogen is one gas that is used in such processes elsewhere.

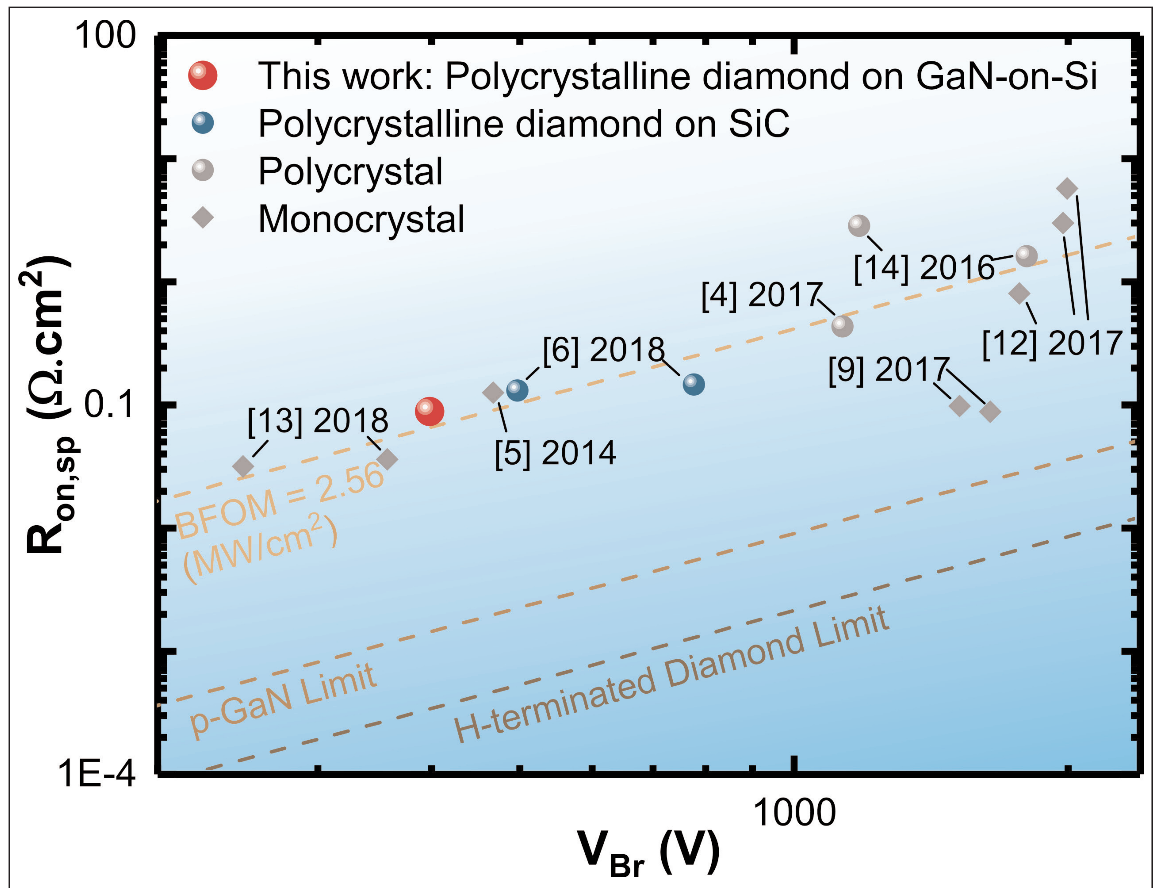

Figure 9. Benchmark of specific-on resistance ($R_{on,sp}$) and breakdown voltage (V_{Br}) of this work with heteroepitaxial material on silicon carbide (SiC), as well as polycrystalline and monocrystalline substrate HTDTs.

Microscopic analysis of the diamond layer showed grains of average size 34μm, smaller than the 100μm grains often reported for the technique. The grains are smaller in the nucleation region, becoming larger at the surface of the 130μm-thick diamond layer.

Further transistor (Figure 8) processing consisted of surface hydrogenation with 650ºC 2.8kW hydrogen plasma, deposition of 200nm-thick Au ohmic contacts, wet-etch Au removal from non-contact areas, 800W oxygen plasma treatment to isolate devices, 200ºC ALD of 80nm aluminium oxide as gate oxide and surface termination, and deposition and plasma-etch patterning of 300nm-thick Al gate electrode.

The hydrogenation resulted in a p-type conductivity with ~10^{14}/cm^2 hole density, according to Hall measurements. The 1.3cm^2/V-s mobility resulted in a sheet resistance of 50Ω/square. The mobility was adversely affected by impurity scattering, the small grain sizes, and the rough surface — values of 3cm^2/V-s have been measured for holes in single-crystal diamond.

The fabricated transistor with 4μm gate length achieved an on/off current ratio of 10^9. The source–gate and gate–drain distances were 2μm and 8μm, respectively. The on-current reached −60mA/mm. The specific on-resistance of 84mΩ-cm^2 is described as "low". The leakage current was "very low" at less than 1μA/mm, even near breakdown.

The breakdown of the device occurred at −400V. The lateral critical field was estimated to be 0.4MV/cm, according to studies using isolated contact pads separated by varying distances. The researchers report that monocrystalline diamond has achieved lateral breakdown fields of 1MV/cm.

The effective lateral thermal conductivity came out at 900W/m-K in samples where the silicon substrate was removed from the backside of the diamond/GaN layers. The diamond grain size in the sample was 3μm on average.

Comparing the performance with other polycrystalline and monocrystalline devices (Figure 9), the researchers observe that "there is still a gap between the performance of current HTDTs and their theoretical limits, which highlights the significant potential for improvement of this technology."

At the same time, the device exceeds the performance of GaN-based p-channel transistors in terms of "6-times higher current density, 4-orders of magnitude higher on-off ratio and more than 6-times higher thermal conductivity". ■

The author Mike Cooke is a freelance technology journalist who has worked in the semiconductor and advanced technology sectors since 1997.

TSMC's GaN-on-Si patents supporting ST's strategic move towards power GaN adoption in automotive use

At least 12 key TSMC inventions relate to GaN-on-Si power applications.

As announced in February, STMicroelectronics of Geneva, Switzerland is collaborating with Taiwan Semiconductor Manufacturing Corporation (TSMC, the world's biggest silicon wafer foundry) to accelerate the development of gallium nitride (GaN) technology for power applications, and more specifically for automotive applications (converters and chargers for hybrid and electric vehicles).

With this recent manufacturing partnership, STMicroelectronics has joined the series of companies that have trusted TSMC for volume production of GaN power devices, including market leader GaN Systems, as well as VisIC and Navitas Semiconductor (focusing on GaN power IC technology). STMicroelectronics will begin by sampling discrete GaN power devices, to be followed soon by GaN IC products based on TSMC's GaN-on-Si process technology.

TSMC's GaN-on-Si technology was reviewed in Knowmade's 'GaN-on-Si Patent Landscape Analysis' (released in January), which covers about 40 patent families (inventions) related to this technology, regrouping more than 130 patents filed worldwide, mainly in US (70+) and China (25+).

"TSMC has leading GaN-on-silicon manufacturing expertise, and we have identified at least 12 key inventions narrowly related to power applications," says Remi Comy PhD, Knowmade's technology and patent analyst, Compound Semiconductors and Electronics. Indeed, TSMC was actively filing GaN-on-Si patents for power applications between 2012 and 2017 and has strongly focused on the USA (20+ granted patents).

The patent portfolio protects technological approaches providing improved GaN-on-Si buffer resistivity, using three main approaches:

- p-type conductivity dopants in graded buffer layers and ungraded buffer layers (US patent 8,791,504);
- diffusion-blocking layer between the buffer layer and the silicon substrate (US patent 9,245,991);
- multi-strained superlattice structures (SLS) to overcome the limitations due to carbon doping of the buffer layers (US patent 10,109,736).

Next, TSMC focused its patenting activity on removing the breakdown voltage limitations due to the surface gate–drain region, inserting buried dielectric portions in the AlGaN barrier (Figure 1a), in addition to the use of field-plate structures (Figure 1b) and an AlGaN barrier with Al-graded composition (US patent 10,522,532).

Interestingly, TSMC's latest GaN-on-Si developments for power applications focused on the fabrication of GaN power integrated circuits (ICs) via US patent

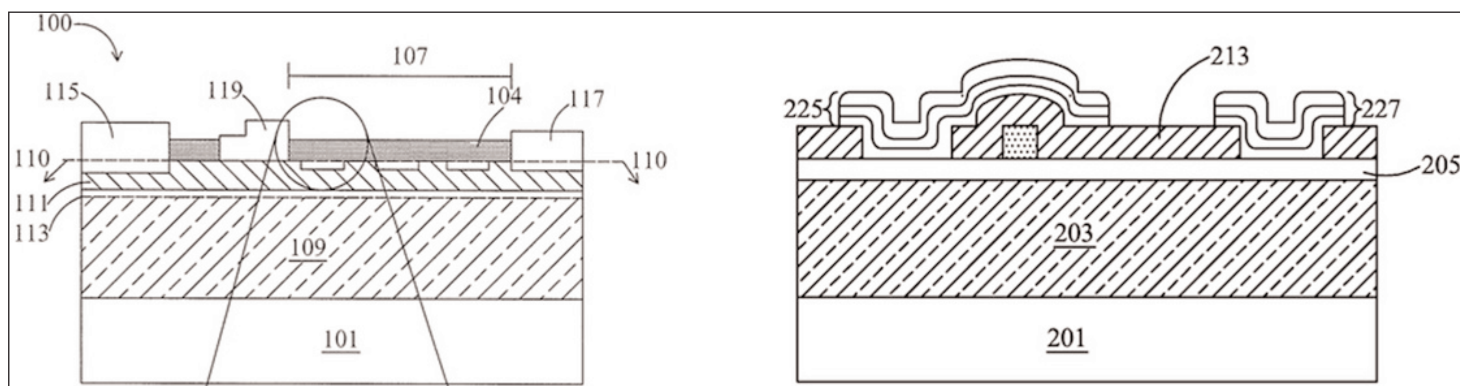

Figure 1: (a) GaN HEMT with one or more dielectric plug portions in the barrier between the gate and the drain (US patent 8,884,308). (b) Substrate breakdown voltage improvement for group III-nitride on silicon substrate (US patent 9,111,904).

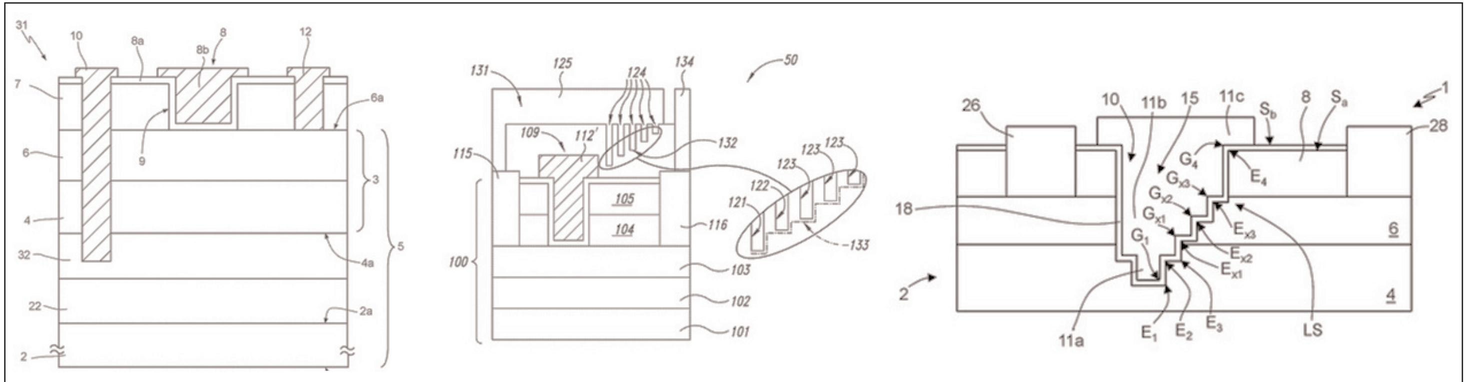

Figure 2: Normally-off structures patented in 2017-2018 by STMicroelectronics (US patents 10,566,450, 10,050,136 and 10,522,646).

9,793,389, related to the isolation of adjacent GaN-on-Si power devices, and US patent 10,522,532 related to the formation of through-GaN vias (TGVs).

In the 'GaN-on-Si Patent Landscape Analysis', Knowmade also analyzed the patent portfolio of STMicroelectronics, which is still strengthening its IP position in the power GaN patent landscape. In 2017–2018, ST focused on GaN device technology, especially normally-off transistor structures (Figure 2).

STMicroelectronics' normally-off transistor structures (US patents 10,516,041, 10,566,450 and 10,522,646) are based on a tri-layer epitaxial stack NiO/AlGaN/GaN, the selective removal of NiO in the gate region and the deposition of a gate dielectric (AlN, Al_2O_3 or SiO_2) on the AlGaN barrier (with or without recess). The buffer region may include a first carbon-doped buffer layer for increasing the breakdown voltage and a second p-type buffer layer for limiting the degradation of dynamic on-resistance due to the first buffer layer. It can be combined with the presence of a sloped field plate in order to further reduce dynamic on-resistance phenomenon, implemented with the advantageous method described in US patent 10,050,136.

Previously — in 2018 — STMicroelectronics started a joint R&D program with The French Alternative Energies and Atomic Energy Commission (CEA), focused on the development of GaN power devices on 200mm silicon substrates, in view of establishing a pilot manufacturing line in 2020 in STMicroelectronics' foundry in Tours, France.

CEA is also a well-established IP player in the GaN-on-Si patent landscape, with more than 40 patented inventions. Over the last three years, it has intensified its GaN-on-Si patenting activity in the field of power applications with six additional inventions. CEA first focused on enhancement-mode device technology (Figure 3a) and then focused on the epi-structures in order to enhance the vertical breakdown voltage. Its recent GaN-on-Si patenting activity also includes an IP collaboration with automotive player Renault regarding power GaN device technology (Figure 3b).

"Following the R&D collaboration between STMicroelectronics and CEA since 2018, and the recent announcement of partnership between STMicroelectronics and TSMC, we expect an acceleration of their respective patenting activity on power GaN-on-silicon in the next months," says Remi Comyn of Knowmade. ■

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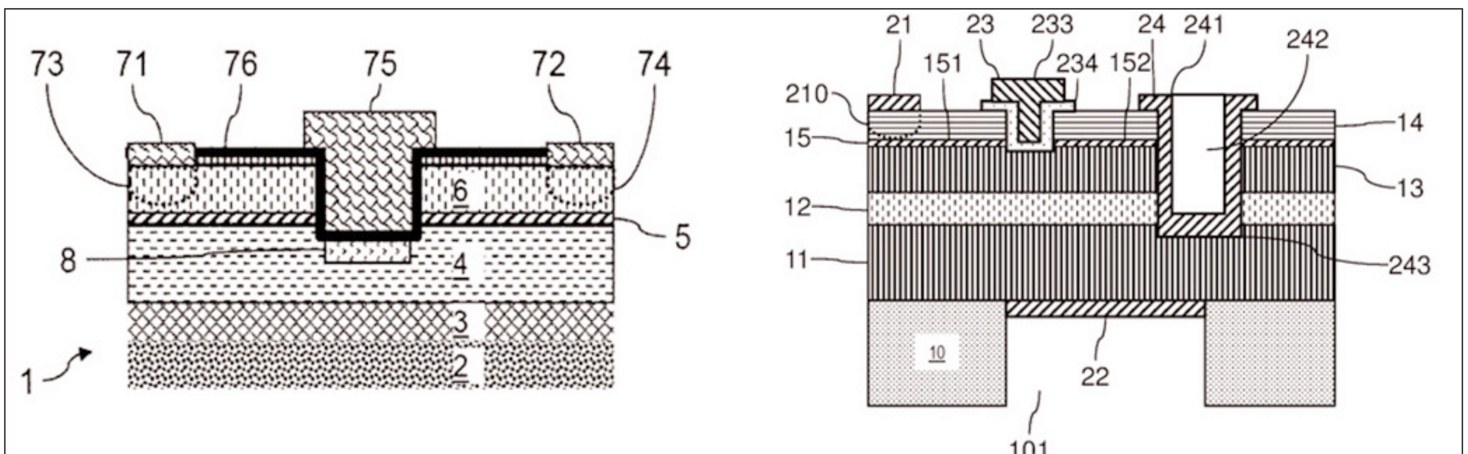


Figure 3: (a) Method for forming an implanted area under the gate region, for a normally-off heterojunction transistor (US patent 10,164,081). (b) III-N heterojunction transistor with a vertical structure (WO patent application 2018/100262).

Growing ε polytype gallium oxide with gallium nitride

Researchers' first investigation suggests "very promising" opportunities for new high-voltage high-electron-mobility electronics.

Researchers based in Germany and Italy have been exploring the growth of ε-polytype gallium oxide (ε-Ga_2O_3) combined with gallium nitride (GaN) on sapphire substrates with a view to deployment in high-electron-mobility transistors (HEMTs) [Stefano Leone et al, Journal of Crystal Growth, vol534, p125511, 2020].

GaN-based high-frequency and high-voltage power devices are moving to wider commercial deployment in AC–DC inverters, power supplies, 600V switches, and the generation of communications and radar radio signals. The combination of GaN with ferroelectric ε-Ga_2O_3 could lead to interesting further electronic opportunities.

The ε-Ga_2O_3 material also has a strong spontaneous charge polarization, arising from the crystal structure and stronger ionic character of the chemical bond. Such polarization could give rise to two-dimensional electron gas (2DEG) HEMT channels with very high carrier density. There are, of course, also strain-dependent piezoelectric effects to be expected.

Ferroelectricity has mainly been deployed in non-volatile memory devices up to now, but recent research has also used the property to create 'negative capacitance' gate stacks. Such negative capacitance enables the subthreshold swing to go lower than the standard thermal limit of 60mV/decade. Such sharply switching devices are of interest in silicon electronics for low-voltage operation and low power consumption. Of course, GaN-based electronics is not so interested in low voltage.

One factor that has to be considered is that the ε polytype crystal structure is more stable and the ε form of Ga_2O_3 decomposes above 700°C. This restricts the thermal budget of processes involving the material.

The team from Fraunhofer Institute for Applied Solid State Physics (IAF) in Germany, University of Parma in Italy, Institute of Materials for Electronics and Magnetism (IMEM-CNR) in Italy and Albert-Ludwigs Universität Freiburg in Germany focused on growth using metal-organic chemical vapor deposition (MOCVD) since it is the technique most favored in manufacturing. The researchers claim that their work is the first investigation of GaN/ε-Ga_2O_3 MOCVD.

The team employed two separated MOCVD reactors for deposition of ε-Ga_2O_3 and GaN. The material surfaces were exposed to air on transfer between the chambers. The GaN deposition used trimethyl-gallium (TMGa) and ammonia (NH_3) precursors in hydrogen carrier gas. The substrate was mainly on-axis sapphire: (001) aluminium oxide (Al_2O_3). The ε-Ga_2O_3 was deposited in a cold-wall system at 610°C. The precursors for this were TMGa and water (H_2O) in hydrogen carrier gas.

The GaN growth rate at 1050°C was around 1μm/hour. The ε-Ga_2O_3 deposition was at about half that rate, 500nm/hour. Some samples included a 10nm silicon nitride (SiN) passivation layer for studying electronic properties towards the fabrication of HEMTs. The SiN was deposited using inductively coupled plasma CVD, using silane (SiH_4) and NH_3.

The ε-Ga_2O_3 polytype has an orthorhombic (pseudo-

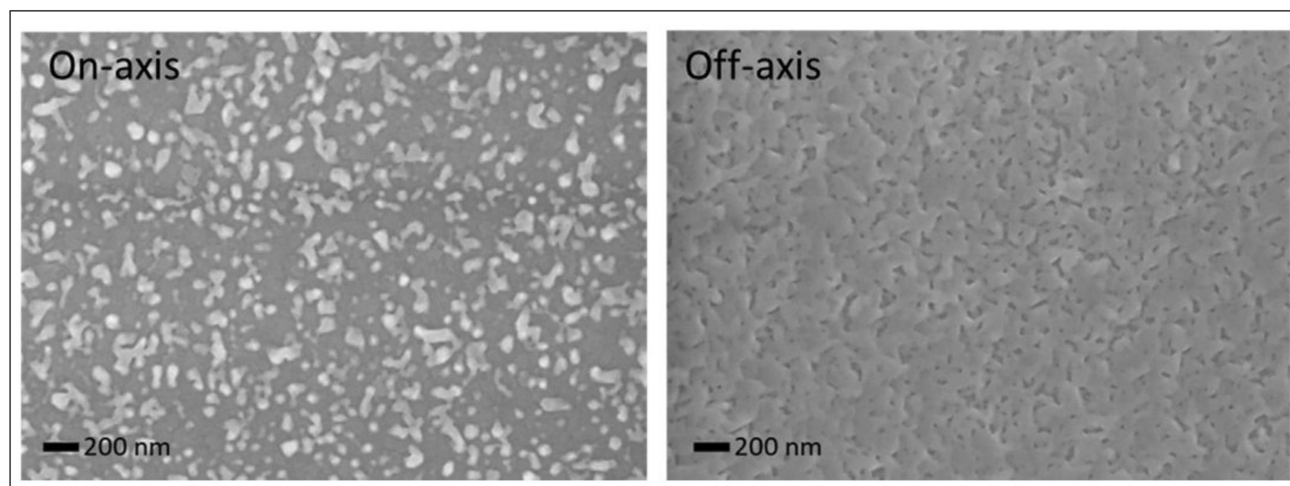


Figure 1. SEM studies of 5-minute ε-Ga_2O_3 MOCVD on (left) on-axis and (right) 4° off-cut GaN on sapphire.

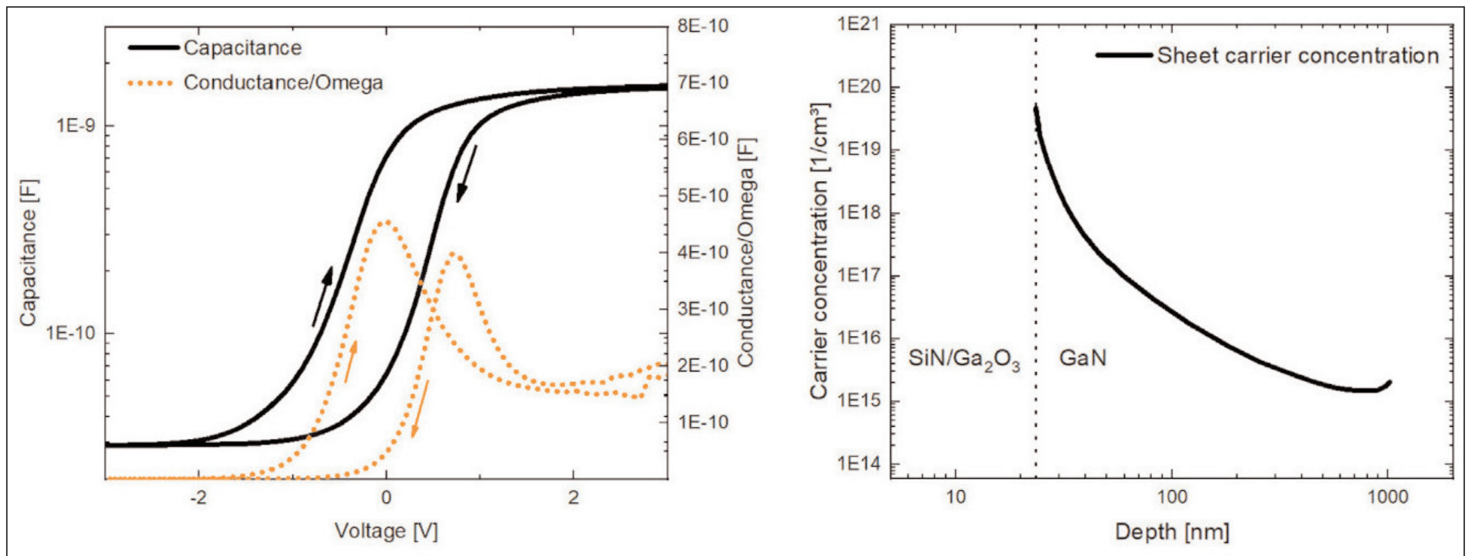


Figure 2. (left) Capacitance versus voltage and conductance/angular frequency (G/ω) versus voltage and (right) CV-derived carrier density versus depth profile.

hexagonal) crystal structure with nominal 8.8% lattice mismatch with GaN. The researchers also investigated depositing the ε-Ga_2O_3 before the GaN — the drawback being that ε-Ga_2O_3 begins a transition to β-Ga_2O_3 at 700°C, which completes at 900°C. Thus, with ε-Ga_2O_3-first deposition the researchers reduced the GaN growth temperature to 690°C. Although the GaN-on-ε-Ga_2O_3 (GaN/ε-Ga_2O_3) surface was smooth, there were several defects visible in microscopic inspection.

Depositing the GaN at high temperature (1050°C) converted the ε material to β. according to x-ray analysis. By contrast, the low-temperature GaN/ε-Ga_2O_3 remained in the ε phase. The crystal quality of the overlying GaN is described as "poor" in both cases, on the basis of large full-width at half-maximum (FWHM) values for various x-ray rocking curve peaks. The low-temperature sample was particularly poor.

Although the growth of ε-Ga_2O_3 on GaN was better, the deposition tended to begin with 3D islands that later began to coalesce. Such behavior could lead to decent quality in thick layers, but the researchers were more interested in creating thin ε-Ga_2O_3 on GaN heterostructures with a view to fabrication of HEMTs.

To encourage 2D layer-by-layer growth of ε-Ga_2O_3 the team tried using 4° off-cut (0001) sapphire substrates, giving the GaN surface a step-and-terrace texture. "The coalescence in this sample seems to be much more effective than in the on-axis samples," the researchers observe from scanning electron microscope (SEM) studies (Figure 1).

Capacitance-voltage (CV) analysis of the materials detected 2DEG behavior only when the sample was capped with SiN passivation. However, there was a high level of hysteresis in the curves, ~0.9V, suggesting the presence of defects or ionized states. A SiN/ε-Ga_2O_3/GaN structure was found to have a carrier density profile consistent with a combined SiN/ε-Ga_2O_3 barrier thickness of 25nm. The SiN passivation was 10nm.

The growth time of the ε-Ga_2O_3 was 17 minutes. Thinner layers with shorter growth times down to 3 minutes were less uniform and consequently performed less well in CV measurements. Difficulties in making Ohmic contacts has inhibited the performance of Hall measurements and hence the assessment of carrier mobility. Sheet resistance values were relatively high: 1300–2200Ω/square and 3300Ω/square for on- and off-axis samples, respectively.

The sheet carrier density was estimated to be $6.4 \times 10^{12}/cm^2$, using the CV data. This value was well short of theoretical expectations of $1.2 \times 10^{14}/cm^2$, using Schrödinger–Poisson modeling. The modeled values for AlN and $Al_{0.25}Ga_{0.75}N$ barriers are $6.5 \times 10^{13}/cm^2$ and $1.1 \times 10^{13}/cm^2$, respectively. The higher expectation for ε-Ga_2O_3 barriers rests on a higher spontaneous charge polarization of the crystal structure and the more ionic character of the chemical bonds.

The suppression of the 2DEG sheet carrier density in the experimental samples relative to theoretical expectations could be due to factors such as non-optimized morphology and high defect densities. Despite this, the team sees their results as being "very promising". One key component in future HEMT development would be the fabrication of low-contact-resistance Ohmic source-drain electrodes without exceeding the 700°C thermal limit imposed by the ε-to-β polytype phase transition of the Ga_2O_3. The team points hopefully to recent work using titanium/gold annealed for three hours at 300°C, which gave low reported contact resistance on ε-Ga_2O_3. ■

https://doi.org/10.1016/j.jcrysgro.2020.125511
www.imem.cnr.it

Author: Mike Cooke

PiTrans project results in AlScN-based SAW resonators for smartphones

Two further Fraunhofer IAF-led AlScN-based projects targeting wide-bandgap current sensors and switchable HEMTs

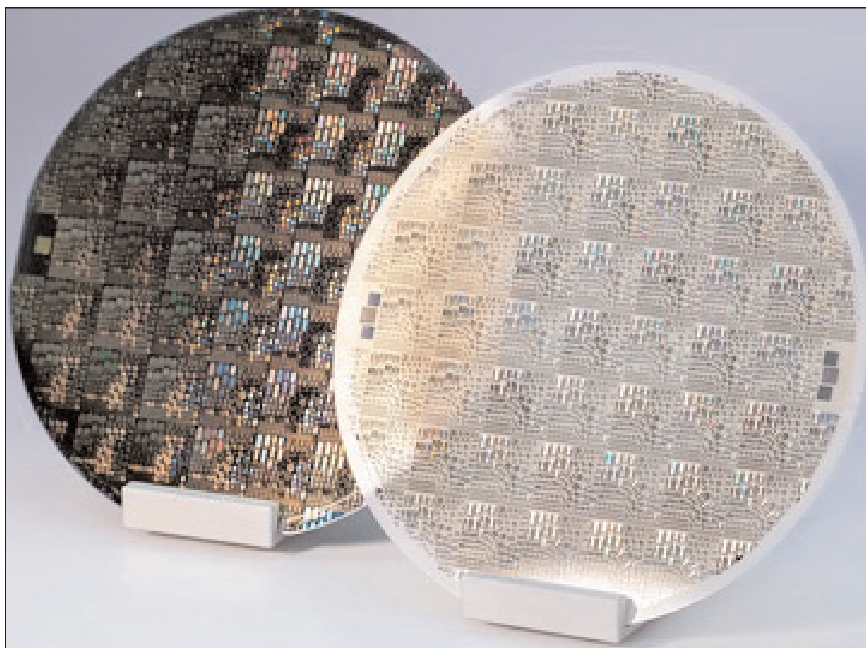
The ever-growing mobile data transfers in the wake of 5G require the use of more and higher frequency ranges, all of which need to be accommodated within a single mobile device. The demands on radio frequency (RF) components are hence constantly increasing. The Fraunhofer Institute for Applied Solid State Physics IAF of Freiburg, Germany has developed novel, compact and energy-efficient high-frequency/high-bandwidth RF filters to meet those needs ('Enhanced electromechanical coupling in SAW resonators based on sputtered non-polar $Al_{0.77}Sc_{0.23}N$ $(11\bar{2}0)11\bar{2}0$ thin films', Appl. Phys. Lett. 116, 101903 (2020)). During the project 'PiTrans — AlScN — Development of novel piezoelectric materials' (running from 2015 to 2020) the researchers managed to grow aluminum scandium nitride (AlScN) with the required industrial specifications and to realize novel electroacoustic devices for smartphones.

The amount of RF components built into a single smartphone has increased significantly over the past years and there is no end in sight. Predicting this trend in 2015, the PiTrans project set out to develop and produce improved RF piezo-transducers with ternary AlN-based nitrides as the piezo-active layer. Within the five years of the project, the researchers succeeded in growing highly crystalline AlScN layers and realizing surface acoustic wave (SAW) resonators that meet the increasing requirements of the industry.

For growth of the material, which is also promising for other power electronic applications, a modern magnetron-sputtering infrastructure was established at Fraunhofer IAF. The project was funded by a 'Fraunhofer Attract' excellence stipend program and was successfully completed in January under the leadership of Dr Agne Zukauskaite.

Potential and challenges of AlScN

AlScN remains the most promising new material to replace conventional aluminum nitride (AlN) in RF filter applications inside mobile phones. By introducing scandium (Sc) into AlN, the electromechanical coupling and piezoelectric coefficient of the material is increased, enabling a more efficient mechanical-to-electric energy conversion. This allows the production of much more efficient RF devices. However, the instability of the piezoelectric AlScN crystal phase has so far been a problem for industrial use of the material, as segregation of wurtzite-type AlN and cubic ScN usually occurs during growth. "Back in 2015, we knew the potential of AlScN, but we needed to find the right conditions to grow it in a stable and scalable process," recalls Zukauskaite.

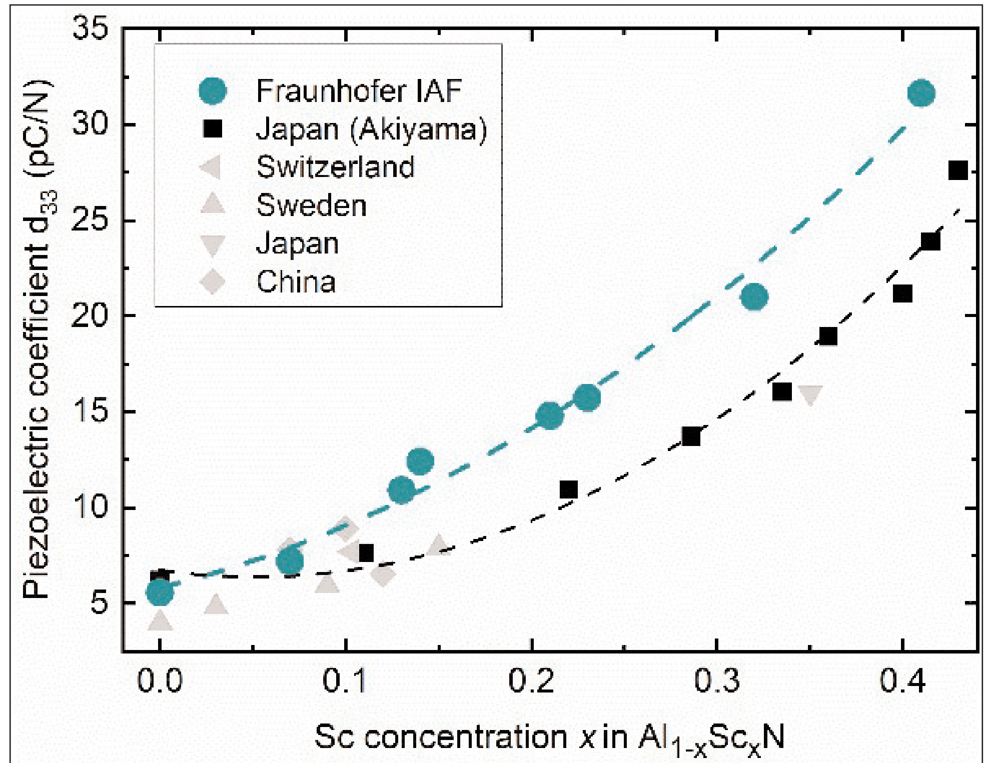


Successful growth and device development

In the course of the project, the researchers at Fraunhofer IAF managed to grow highly crystalline AlScN layers with a wide range of compositions up to a Sc content of 41%. Good homogeneity of the layers was achieved across the entire silicon wafer up to 200mm in diameter, which meets the requirements of industrial productions. Besides these industry-relevant results,

the project team also succeeded in realizing epitaxial growth on lattice-matched sapphire (Al_2O_3) substrates through a special magnetron sputter epitaxy (MSE) method of deposition, which will be useful for future material research.

In addition to the material development, the researchers produced three generations of test structures to demonstrate the performance of the AlScN thin films. The implementation of MSE to produce AlScN/Al_2O_3-based resonators yielded an electromechanical coupling increase of up to 10% at 2GHz frequency. In a collaboration with the companies Evatec and Qualcomm, a non-polar AlScN thin film was also developed that further improves the electromechanical coupling of SAW resonators. This technology is currently being further researched, and first results have recently been published in a scientific paper.



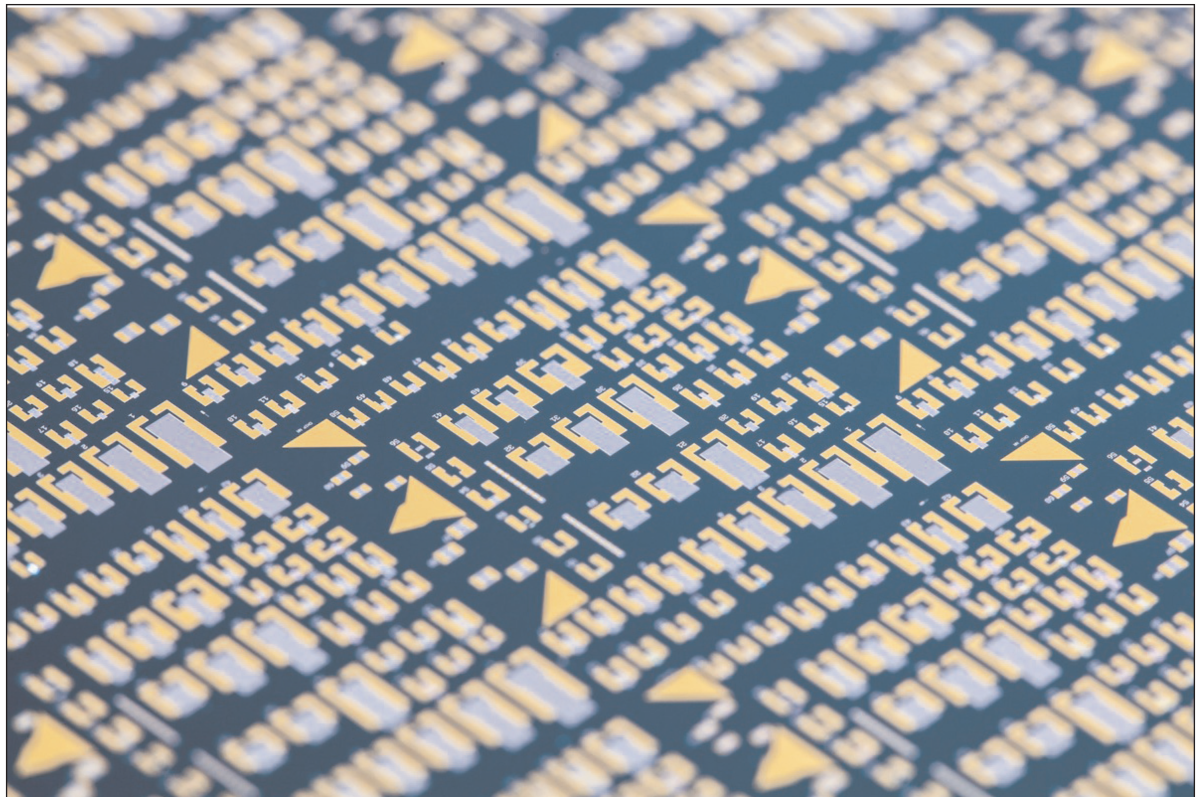
Piezoelectric properties of AlScN layers produced at IAF compared with results of other research institutes. © Fraunhofer IAF

AlScN for other applications

"We see AlScN as a very promising candidate for enabling future applications that capitalize on the piezoelectric effect, such as sensor technologies and high-electron-mobility transistors [HEMTs]," says Zukauskaite. The success of the PiTrans project led to the acquisition of two further projects involving AlScN technology at Fraunhofer IAF. In the project mAgnes, wide-bandgap current sensors (such as those used in e-cars) are being researched; and in the project SALSA the research team is developing new types of switchable HEMTs. Both projects benefit from the developed expertise in AlScN growth and AlScN-based device development as well as the necessary infrastructure established at Fraunhofer IAF. ■

https://doi.org/10.1063/1.5129329

www.iaf.fraunhofer.de/en/researchers/electronic-circuits/high-frequency-electronics/pitrans.html



Silicon wafer with AlScN-based SAW resonator structures fabricated at Fraunhofer IAF.

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

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

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

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

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

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

9 Materials & metals

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

Goodfellow supplies small quantities of metals and materials for research, development, prototyping and specialised manufacturing operations.

10 Gas and liquid handling equipment

Air Products and Chemicals Inc
(see section 7 for full contact details)

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

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

SAES Pure Gas Inc
4175 Santa Fe Road,
San Luis Obispo,
CA 93401,
USA
Tel: +1 805 541 9299
Fax: +1 805 541 9399
www.saesgetters.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
E-mail: conax@conaxtechnologies.com

www.conaxtechnologies.com
Conax Technologies is a designer and manufacturer of standard and custom-engineered temperature sensors, compression seal fittings and feedthroughs, probes, wires, electrodes and fiber-optic cables. The company is headquartered in Buffalo, New York, with locations on the US West Coast, Canada, Europe and Asia.

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 AXS GmbH
Oestliche Rheinbrueckenstrasse 49,
Karlsruhe, 76187,
Germany
Tel: +49 (0)721 595 2888
Fax: +49 (0)721 595 4587
www.bruker-axs.de

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

Keithley Instruments Inc
28775 Aurora Road,
Cleveland, OH 44139, USA
Tel: +1 440.248.0400
Fax: +1 440.248.6168
www.keithley.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

Ismeca Europe Semiconductor SA
Helvetie 283, La Chaux-de-Fonds,
2301, Switzerland
Tel: +41 329257111
Fax: +41 329257115
www.ismeca.com

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

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

Compound Semiconductor Technologies Ltd
Block 7, Kelvin Campus,
West of Scotland, Glasgow,
Scotland G20 0TH,
UK
Tel: +44 141 579 3000
Fax: +44 141 579 3040
www.compoundsemi.co.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

MEI, LLC
3474 18th Avenue SE,
Albany, OR 97322-7014,
USA
Tel: +1 541 917 3626
Fax: +1 541 917 3623
www.marlerenterprises.net

20 Facility consumables

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

Ansoft Corp
4 Station Square,
Suite 200,
Pittsburgh, PA 15219,
USA
Tel: +1 412 261 3200
Fax: +1 412 471 9427
www.ansoft.com

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

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

Henry Butcher International
Brownlow House, 50–51
High Holborn, London WC1V 6EG,
UK

Tel: +44 (0)20 7405 8411
Fax: +44 (0)20 7405 9772
www.henrybutcher.com

M+W Zander Holding AG
Lotterbergstrasse 30,
Stuttgart, Germany
Tel: +49 711 8804 1141
Fax: +49 711 8804 1950
www.mw-zander.com

24 Consulting

Fishbone Consulting SARL
8 Rue de la Grange aux Moines,
78460 Choisel,
France
Tel: + 33 (0)1 30 47 29 03
E-mail: jean-luc.ledys@neuf.fr

25 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
3081 Zanker Road,
San Jose,
CA 95134,
USA
Tel: +1 408 943 6900
Fax: +1 408 428 9600
www.semi.org

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

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15–17 April 2020 — POSTPONED
EPIC Annual General Meeting 2020
Radisson Blu Hotel Lietuva, Vilnius, Lithuania
E-mail: neringa.norbutaite@epic-assoc.com
www.epic-assoc.com/epic-annual-general-meeting-2020

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

26–29 April 2020 — POSTPONED
2nd International Conference on UV LED Technologies & Applications (ICULTA 2020)
MELIÃ Hotel, Berlin, Germany
E-mail: contact@iculta.com
www.ICULTA.com

28 April – 30 May 2020
(postponed from 29 March – 2 April 2020)
2020 IEEE International Reliability Physics Symposium (IRPS)
Now online (rather than Hilton DFW Lakes Executive Conference Center, Dallas, TX, USA)
E-mail: IRPSreg@ieee.org
www.irps.org

4–6 May 2020
16th International Conference on Concentrator Photovoltaic Systems (CPV-16) — CANCELLED (to be held online)
Golden, near Denver, CO, USA
E-mail: info@cpv-16.org
www.cpv-16.org

7–8 May 2020 — POSTPONED
EPIC Meeting on Nanophotonics for Communication, Sensing and Data Processing at Nanoscribe
Karlsruhe, Germany
E-mail: neringa.norbutaite@epic-assoc.com
www.epic-assoc.com/epic-events

10–15 May 2020
2020 Conference on Lasers & Electro-Optics (CLEO)
San Jose Convention Center, San Jose, CA, USA
E-mail: CLEO@compusystems.com
www.cleoconference.org

11–14 May 2020 — CANCELLED
CS MANTECH:
2020 International Conference on Compound Semiconductor Manufacturing Technology
JW Marriott Starr Pass, Tucson, AZ, USA
E-mail: registration@csmantech.org
www.csmantech.org

17–21 May 2020 — POSTPONED
32nd International Symposium on Power Semiconductor Devices and ICs (ISPSD 2020)
Hofburg Palace, Vienna, Austria
E-mail: ispsd2020@guarant.cz
www.ispsd2020.com

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

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21–26 June 2020
Microwave Week, including:
IEEE MTT-S International Microwave Symposium (IMS 2020)
Radio Frequency Integrated Circuits Symposium (RFIC 2020)
Automatic Radio-Frequency Techniques Group Conference (ARFTG)
Los Angeles, CA, USA
E-mail: e.niehenke@ieee.org
www.ims-ieee.org

21–23 July 2020
SEMICON West 2020
Moscone Center, San Francisco, CA, USA
E-mail: semiconwest@semi.org
www.semiconwest.org

22–25 July 2020
International Congress on Advanced Materials Sciences & Engineering (AMSE-2020)
Vienna, Austria
E-mail: eve@istci.org
www.istci.org/amse2020

28–30 July 2020 (postponed from 5–7 May)
PCIM Europe 2020 (Power Conversion and Intelligent Motion)
Nuremberg Exhibition Centre (Messe Nürnberg), Germany
E-mail: pcim@mesago.com
https://pcim.mesago.com/nuernberg/en.html

23–27 August 2020
SPIE Optics + Photonics 2020
San Diego Convention Center, San Diego, CA, USA
E-mail: customerservice@spie.org
https://spie.org/Optics_Photonics

23–28 August 2020
International Workshop on Nitride Semiconductors (IWN 2020)
Maritim Hotel Berlin, Germany
E-mail: iwn2020@conventus.de
www.iwn2020.org

23–28 August 2020
9th International Conference on Optical, Optoelectronic and Photonic Materials and Applications (ICOOPMA)
University of Pardubice, Czech Republic
E-mail: info@icoopma.com
www.icoopma.com

7–11 September 2020
22nd European Conference on Power Electronics and Applications (EPE 2020 ECCE Europe)
Lyon, France
E-mail: info@epe2020.com
www.epe2020.com

9–11 September 2020
22nd China International Optoelectronic Exposition (CIOE 2020)
Shenzhen World Exhibition & Convention Center, Shenzhen, China
E-mail: cioe@cioe.cn
www.cioe.cn/en

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

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

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

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

14–16 December 2020
IEEE International Electron Devices Meeting (IEDM 2020)
Hilton San Francisco and Towers, San Francisco, CA, USA
E-mail: info@ieee-iedm.org
www.ieee.org/conference/iedm

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

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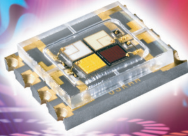

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