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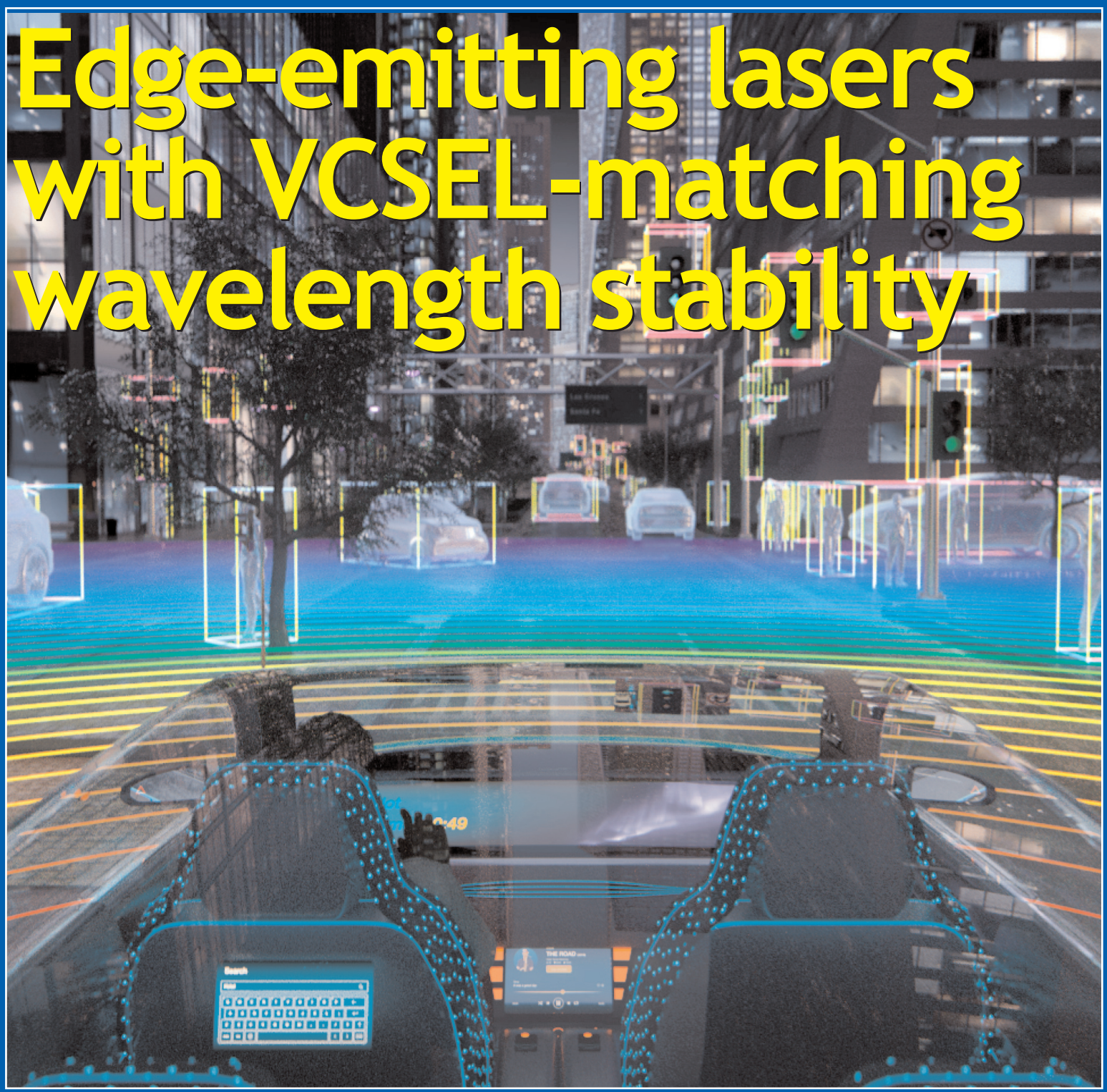
Edge-emitting lasers with VCSEL-matching wavelength stability



Cree to become Wolfspeed • Osram acquires stake in Bolb
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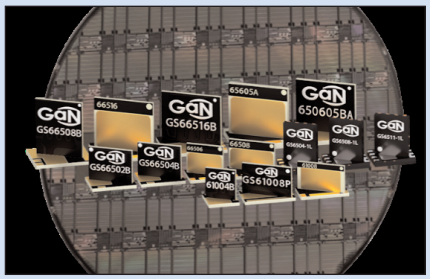
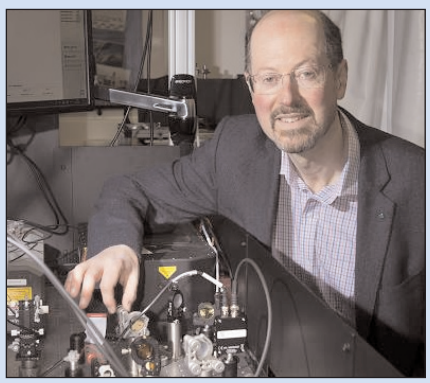
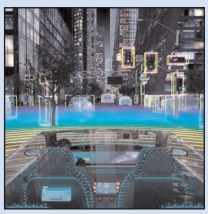


p20 GaN Systems has shipped its 20 millionth GaN transistor. Its factory partners are due to complete a 40-fold capacity expansion in 2021.

p34 OIPT is to move to a new manufacturing facility in summer 2022.



p43 Martin Dawson, director of research at Strathclyde's Institute of Photonics and head of the Fraunhofer Centre for Applied Photonics, has won the 2021 OSA Nick Holonyak Jr Award.



Cover: Osram's new edge-emitting laser chip design can match and even exceed the wavelength stability of vertical-cavity surface-emitting lasers (VCSELs) at up to 125°C typical for automotive applications. A smaller wavelength filter on the detector boosts the signal-to-noise ratio for LiDAR in autonomous vehicles. **p47**

editorial

Supply chains and IP in contention

The coronavirus crisis over the last year led to a reduction in automobile production and hence demand for chips that go into them. Meanwhile, the trend to remote home-based work/entertainment has led to booming demand for optical and wireless communications equipment (infrastructure and consumer electronics) and hence the associated chips.

So, there has been disruption and realignment of supply chains (from one application to another), especially because so many firms outsource wafer processing to a limited number of foundries, particularly Taiwan's TSMC.

Now, despite a rebound in auto demand, over the last month the strain on the supply of silicon chips has led to many major automobile as well as consumer electronics manufacturers worldwide having to idle their plants.

This has coincided with Intel resorting increasingly to outsourcing to TSMC for the latest, most challenging chip technology generation, especially after delays with its own in-house manufacturing technology development.

The US government is hence concerned about vulnerability in growing dependence on imported ICs, leading to the new Biden administration's 'CHIPS for America Act', aiming to fund (via last year's National Defense Authorization Act) a reversal in the 50% decline in the USA's share of global semiconductor manufacturing capacity over the last 20 years.

TSMC is also the manufacturing partner for US-based Navitas, which was founded in 2014 and recently shipped its 13 millionth gallium nitride on silicon (GaN-on-Si) power IC (see page 22). Meanwhile, GaN Systems (founded in 2008) has shipped its 20 millionth GaN transistor, while foundry partner TSMC prepares to complete a 40-fold capacity expansion in 2021 (page 20). GaN-on-Si power ICs are comparatively insulated from the supply & demand issues of commodity silicon ICs. However, as GaN technology is rapidly being adopted (e.g. in 5G wireless base-stations and fast chargers for consumer electronics), similar supply vulnerabilities may arise.

The USA, in particular, is sensitive to the strategic importance of GaN in defense electronics (a reason for blocking Germany-headquartered and also US-based GaN MOCVD system maker Aixtron's sale to China's Grand Chip Investment in 2016). However, UK-based Compound Semiconductor Centre (CSC, a joint venture involving epiwafer foundry IQE) and fellow Wales-based Newport Wafer Fab have received UK government funding to develop a GaN-on-Si high-electron-mobility transistor (HEMT) foundry process on 200mm wafers (see page 25), initially targeting automotive applications in inverters in electric vehicles (EVs), then fast chargers and solar inverters etc.

More immediately, power electronics is migrating rapidly from silicon to silicon carbide (SiC) technology. The SiC-based power electronics & inverter market is forecasted to rise at a compound annual growth rate (CAGR) of 32.5% from just $542.2m in 2020 to $3888.2m in 2027 (page 6).

Correspondingly, investments in SiC manufacturing are accelerating. Cree — which, after divesting its remaining LED business, is soon to assume the name of its Wolfspeed RF & power electronics business — is to start up its Mohawk Valley SiC fab equipped for 200mm-diameter substrates, skipping 150mm (page 16).

However, while the USA and Europe are strong in the technology, SiC could become more contentious internationally — the US Justice Department has just charged a Chinese semiconductor start-up's VP of sales with conspiring with an engineer at General Electric to steal that firm's SiC MOSFET IP.

Mark Telford, Editor

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Editor
Mark Telford
Tel: +44 (0)1869 811 577
Cell: +44 (0)7944 455 602
Fax:+44 (0)1242 291 482
E-mail: mark@semiconductor-today.com

Commercial Director/Assistant Editor
Darren Cummings
Tel: +44 (0)121 288 0779
Cell:+44 (0)7990 623 395
Fax:+44 (0)1242 291 482
E-mail: darren@semiconductor-today.com

Advertisement Sales
Darren Cummings
Tel: +44 (0)121 288 0779
Cell:+44 (0)7990 623 395
Fax:+44 (0)1242 291 482
E-mail: darren@semiconductor-today.com

Original design Paul Johnson
www.higgs-boson.com

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

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- feature articles (technology, markets, regional profiles);
- conference reports;
- event calendar and event previews;
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SiC-based power electronics & inverter market to reach $3888.2m by 2027

CAGR of 21.5% to $542.2m in 2020, despite COVID

The global silicon carbide (SiC)-based power electronics & inverter market is projected to reach $3888.2m by 2027, rising at a compound annual growth rate (CAGR) of 32.5% during the forecast period, estimates Fortune Business Insights in its report 'SiC Based Power Electronics & Inverter Market, 2020–2027'. The market was just $446.3m in 2019.

Growing presence of startups to transform market landscape

Silicon carbide and gallium nitride based semiconductors are rapidly being adopted in the power electronics industry due to their superior properties, such as the ability to withstand high voltages. Recognizing the potential of these materials, innovative startups have emerged. For example, UK-based Anvil Semiconductors develops SiC-based power systems that have wide applicability across industries, including traction systems in the rail industry. Similarly, Belgium-based EpiGan manufactures GaN-on-silicon epiwafers for power switching applications, especially for 5G networks. As these startups continue to innovate, SiC-based power electronics & inverter products should therefore see escalating demand in the near future, reckons the report.

COVID-19 impact

The sudden eruption of the COVID-19 pandemic in March 2020 ushered in a period of massive supply chain disruptions in the electronics industry. With strict lockdowns and social distancing measures in place, manufacturing and production activities in the industry have taken a severe blow. However, these events have not had serious ramifications for the SiC-based power electronics & inverter market growth. In fact, the market registered a healthy CAGR of 21.5% and reached $542.2m in 2020. This can be attributed to the strong demand for consumer electronics and the increasing adoption of connected devices amid the pandemic.

Market segments

Based on type, the market has been bifurcated into power electronics and inverters.

On the basis of end-use industry, the market has been segregated into automotive, consumer electronics, IT & telecoms, aerospace & defense, and others. By applications segment, automotive led the market with a share of 47.8% in 2019. By geographic region, China led with a share of 49.2%.

Driving factor — creation of SiC electronics to boost market

Leading companies in the automotive electronics domain have been innovating next-generation SiC-based power electronics & inverter solutions to meet the evolving energy demands of consumers. For example, in June 2018 Bosch announced plans to building a SiC semiconductor manufacturing facility. According to Bosch, using SiC-rather than silicon-based devices can reduce energy lost as heat by 50%. Another example is the 2019 partnership between Delphi and Cree, in which Cree's SiC MOSFETs were combined with Delphi's inverters to reduce the power module's overall temperature while facilitating higher output. Such innovations in the automotive electronics domain are rapidly raising the potential of this market.

Competition in this market is set to intensify as key players are actively entering contractual partnerships with fellow participants. These partnerships aim to expand market footprint in a mutually coordinated manner while augmenting each other's R&D capacities as well as production capabilities for SiC-based power electronics & inverter devices

Regional insights — rapid growth of ASEAN manufacturing sector to drive Asia-Pacific market

The Asia-Pacific region is expected to dominate the SiC-based power electronics & inverter market during the forecast period due to the phenomenal progress displayed over the past decade by the manufacturing sector in the ASEAN countries, which have a strong electronics manufacturing base and have excelled in semiconductor development. In 2019, the Asia-Pacific market stood at $188.7m.

In Europe, the robust presence and high-tech investments by the region's auto giants will stimulate the regional market for SiC-based power electronics & inverter, forecasts the report. In North America, the widespread adoption of consumer electronics will foster long-term growth of the market, it adds.

Competition in this market is set to intensify as key players are actively entering contractual partnerships with fellow participants. These partnerships aim to expand market footprint in a mutually coordinated manner while augmenting each other's R&D capacities as well as production capabilities for SiC-based power electronics & inverter devices.

www.fortunebusinessinsights.com/sic-based-power-electronics-and-inverter-market-104880

RF GaN market growing at 30.58% to $3057.4m by 2026

The RF gallium nitride (GaN) market was $665.81m in 2020, and is rising at a compound annual growth rate (CAGR) of 30.58% to a projected $3057.397m in 2026, according to the report 'RF GaN (Radio-frequency Gallium Nitride) Market – Growth, Trends, COVID-19 Impact, and Forecasts (2021 – 2026)' by Mordor Intelligence LLP.

One of the major factors driving demand is the increasing adoption of RF GaN in electric vehicles (EVs). Silicon carbide devices are already in use in the onboard battery chargers of electric buses, taxis, lorries, and passenger cars. In addition, increasing government regulations in favor of the EV market globally are further stimulating RF GaN market demand. For example, in India, the NITI Aayog Action Plan for Clean Transportation (released in 2018) recommended eliminating all permit requirements for EVs, in order to encourage electric mobility. Moreover, according to the International Energy Agency, almost 1.5 million battery electric vehicles (BEVs) were sold worldwide in 2018. These factors indicate that the growth of electric vehicles is expected to boost the adoption of RF GaN over the forecast period.

Artificial intelligence, augmented reality and other sensing technologies require low latency for various applications like mission-critical end-use applications. This should further drive demand for RF GaN devices.

Through strategic partnerships, R&D and mergers & acquisitions, some of the prominent players in the industry have been able to further the technology, fueling market growth over the forecast period. For example, in February 2019, MACOM Technology Solutions and STMicroelectronics announced an expansion of the 150mm GaN-on-Si production capacity in ST's fabs, as well as 200mm, as per demand. The expansion is designed to service the worldwide 5G telecom infrastructure buildout.

The increasing implementation of Internet of Things (IoT) devices is expected to lead to signal congestion and will demand the use of GaN technology that can amplify power, capacity and the bandwidth required for communicating with all interconnected devices, says the report. 5G technology is expected to unleash a massive IoT ecosystem that will increase the user-base manifold and increase demand for these semiconductors as network operators have to serve billions of connected devices.

Key market trends

The report notes that there is strong demand from the telecom infrastructure segment, driven by advancements in 5G implementation.

Due to the ability to provide higher-frequency data bandwidth connections, GaN RF technology is becoming the ideal choice for network service providers. These devices help to ensure that the device generates maximum frequency at the necessary band and also prevents any interference from other frequency bands.

The deployment of GaN RF power devices will enable advanced mobile devices to offer speeds that will allow consumers to upload and download high-quality content (such as music and photographs) and also play online games and watch online TV shows on maximum frequency bands, which is expected to lead to a rise in their adoption rates.

Moreover, firms are investing in the development of 5G core services and architecture. For example, in January 2019 ZTE Corp completed the IMT-2020 third phase of 5G test for core network performance stability and security function, thoroughly verifying the maturity of ZTE's 5G core network.

Most carriers were expected to roll out 5G in second-half 2019, and most deployments should take place in urban areas. According to the Ericsson Mobility report November 2019, VoLTE subscriptions numbered 2.1 billion, and will reach 6.4 billion in 2025, accounting for over 85% of combined LTE and 5G subscriptions.

In June 2019, China granted commercial licenses to four state-owned telecom giants (China Telecom, China Mobile, China Unicom, and China Radio and Television) to start rolling out 5G services, indicating Beijing's determination to be the global leader in setting up superfast wireless networks amid tensions with the USA over technology and trade.

APAC to see significant growth

The Asia-Pacific region's discrete semiconductor industry is driven by China, Japan, Taiwan and South Korea, which together constitute about 65% of the global discrete semiconductor market, while others (like Vietnam, Thailand, Malaysia and Singapore) also contribute significantly to the region's dominance in the market.

According to the Indian Electronics and Semiconductor Association, the country's semiconductor component market is expected to hit $32.35bn by 2025, registering a CAGR of 10.1% over 2018–2025. The country is a lucrative destination for global R&D centers. The Indian government's ongoing Make In India initiative is hence expected to result in huge investments in the semiconductor market.

Over the last few years, the RF industry has received a boost from the implementation of GaN technology. GaN is the main driver in telecom and defense applications. South Korean fabless RF GaN firm WAVEPIA offers cutting-edge GaN systems for RF energy, along with GaN transistors that support growing telecom and defense markets.

The increasing focus on investments to develop infrastructure, in order to support 5G technology, is expected to lead to a surge in demand for RF semiconductors across the APAC region. For example, according to the GSM Association, mobile operators in the Asia-Pacific region are expected to invest over $400bn in their networks between 2020 and 2025, of which $331bn will be spent on 5G deployments.

www.mordorintelligence.com/

Qorvo revenue grows a more-than-expected 11% in December quarter

Mobile growth driven by 5G, while Wi-Fi 6 aids 25% year-on-year growth in Infrastructure & Defense

For fiscal third-quarter 2021 (ended 2 January), Qorvo Inc of Greensboro, NC, USA (which provides core technologies and RF solutions for mobile, infrastructure and defense applications) has reported more-than-expected revenue of $1094.8bn (as much as $34.8m over the $1060m midpoint of guidance). This is up 11% on $1060.3m last quarter (after adjusting that for what was a 14–week quarter, since fiscal 2021 is a 53-week year) and up 26% on $869.1m a year ago.

The sequential growth was driven by Mobile Products revenue of $826m (75.4% of total revenue), up 9.5% on $754m (71.1% of total revenue) last quarter (due to seasonal demand effects plus the ramp of higher-content 5G smartphones) and up 24.8% on $662m a year ago.

Infrastructure & Defense Products (IDP) revenue was $269m (24.6% of total revenue), down 12% on $306m (28.9% of total revenue) last quarter but up 30% on $207m a year ago due to robust Wi-Fi demand and double-digit growth from defense, programmable power management and Internet of Things (IoT) markets.

Strategic highlights are listed as:

Mobile Products

- expanding shipments of complete main-path solutions (low-band, mid/high- and ultra-high-band modules) across the leading 5G basebands and securing design wins to supply next-generation complete main-path solutions in support of upcoming Android 5G smartphone launches in 2021;
- commencing shipments of Qorvo's first generation of mid/high-band dual-connectivity modules (DCMs) to the leading Android smartphone maker, leveraging Qorvo's high-performance BAW (bulk acoustic wave) filtering in the diversity path for receive & transmit;
- launching a next-generation BAW process, increasing bandwidth and reducing insertion loss in ultra-high-band and Wi-Fi 6E applications;
- beginning production shipments of Wi-Fi 6E solutions to top-tier Android OEMs, supporting increased capacity and lower latency in a range of smartphones and other mobile devices;
- increasing ultra-wideband (UWB) customer engagements in smartphones and a broadening range of consumer applications, including tracker tags, smart speakers, smart TVs and other smart home appliances.

Infrastructure & Defense Products

- in infrastructure, securing design wins with multiple base-station OEMs to support US 5G C-band deployments in the USA (for which the spectrum auctions are in the process and initial deployments are expected later this year) and receiving the Best Comprehensive Performance Award from China's ZTE for supporting their initial roll-out of 5G base stations in 2020;
- in defense business, achieving strong growth, driven by domestic airborne radar & communications applications and GaN products for international radar programs;
- in connectivity, commencing shipments of 5GHz Wi-Fi 6 BAW filters and sampling 6GHz Wi-Fi 6E front-end modules (FEMs) for routers and gateways, maximizing throughput and range for high-bandwidth applications such as video conferencing and online gaming (demand for Wi-Fi 6 solutions has been strong across MSOs and retail segments, and Qorvo is seeing continued strength as Wi-Fi 6 deployments are still in the early phases);
- in the connected car, being selected to supply 5G/LTE, C-V2X and Wi-Fi automotive-qualified products to multiple OEMs, including Audi, BMW and Volvo;
- in low-power wireless, being selected to supply the leading TV manufacturer with low-power multi-protocol SoC and custom software, enabling solar-charging remote controls.

The combination of strong end-market demand and ongoing efforts to improve the portfolio are driving productivity, and carefully managed inventories are yielding record results, says the firm.

On a non-GAAP basis, gross margin has risen further, from 49.3% a year ago and 51.7% last quarter to 54.4%, well above the 52.5% guidance due to better-than-expected volumes, pricing and mix as well as lower-than-expected manufacturing and inventory costs.

Although up on $175.6m a year ago, operating expenditure (OpEx) has been cut from last quarter's $218.6m (20.7% of sales) to just $194.2m (17.7% of sales) — better than the expected $205m — due largely to timing on development programs.

Net income has risen from further, $220.8m ($1.86 per diluted share) a year ago and $282.3m ($2.43 per diluted share) last quarter to $356.7m ($3.08 per diluted share, well above the $2.65 guidance).

Qorvo hence exceeded its fiscal third-quarter guidance on revenue, gross margin and EPS.

Cash flow from operations was $403.7m (up from $281m last quarter). Capital expenditure (CapEx) was $36.1m (down from $43.6m). Free cash flow was hence $367.6m (margin of 33.6% of sales), up from $237.4m last quarter (22.4% margin).

During the quarter, Qorvo repurchased $160m of shares. The firm also retired its 2026 notes. It also called the remaining 2025 notes.

Cash and cash equivalents hence amounted to $1234m. The debt balance has now been reduced to $1.7bn. "Our leverage remains low, and our revolver is untapped," notes chief financial officer Mark Murphy. The weighted average maturity of the firm's debt is late 2029 and it has no material near-term maturities.

"With our financial flexibility, we can focus on developing technology, supporting customers and making prudent organic and inorganic investments that support long-term earnings and free cash flow growth," says Murphy. "To that end, we continue to advance our BAW, SAW, GaN, GaAs, packaging and other core technologies and fund UWB, programmable power management, biotechnologies, MEMS and other promising areas," he adds.

"Qorvo delivered an exceptional quarter, helping our customers keep the world connected through the deployment of 5G, the roll-out of Wi-Fi 6 and 6E, and emerging technologies like precision location ultra-wideband," says president & CEO Bob Bruggeworth. "We are sustaining technology leadership in these markets and innovating in new ones including biotechnologies." In January, Qorvo was selected by the US National Institutes of Health (NIH) for its Rapid Acceleration of Diagnostics initiative (RADx) for its program to add COVID-19 antigen testing capacity, utilizing Qorvo's Omnia test platform (a complete test solution enabled by the firm's high-frequency BAW filters that is currently pending Emergency Use Authorization from the US Food and Drug Administration).

"We expect robust end market demand to continue into the March quarter, driving strong year-over-year revenue growth and operating margin expansion," says Murphy.

For fiscal fourth-quarter 2021 (to end-March), Qorvo expects revenue of $1.025–1.055bn (up about 32% year-on-year, from $787.8m a year ago). "Outlook reflects sustained broad customer demand stemming from multi-year technology upgrade cycles," notes Murphy.

"In Mobile, demand for 5G is adding RF complexity and driving higher content," he adds. "The breadth of our customer base and firm demand signals provide confidence and stability in our outlook." Mobile revenue is expected to be about $770m, down sequentially (showing typical seasonality) but up more than 35% on $556m a year ago.

IDP revenue should be $270m, flat sequentially (as is expected seasonally) but sustaining strong double-digit year-on-year growth (from $232m a year ago), driven by Wi-Fi 6 demand and other markets, even as 5G infrastructure build-outs remain uneven.

Gross margin should be 50.5–51%, up more than 100 basis points year-on-year at the midpoint of guidance but down sequentially. "We're trying to keep inventories low, so that will keep a check on absorption," notes Murphy. "We're ramping some lower-margin products, so currently we're just still working down the cost curve on those. They're important longer term. Some of those products are coming into the March quarter, and then that actually continues on into the June quarter. And there are some other mix dynamics as well, including some less defense in the March quarter."

Base-station deployments will slow during the first half of the calendar year, and then we expect those to start to accelerate in the second half... With the C-band auctions nearly complete in the US, we do expect deployments to start later in the year, and we do expect those to include both massive MIMO antennas and GaN power amplifiers

Operating expenses are projected to rise back up to levels previously guided of about $207m. Operating margin is expected to be over 30.5% for the third consecutive quarter. Diluted earnings per share should be $2.42.

Capital expenditure will increase as Qorvo works to meet near-term demand and support long-term supply agreements with multiple customers. However, CapEx should remain below $200m (less than 5% of sales) for fiscal 2021.

For the full fiscal year, Qorvo is on track to achieve record revenue for base-station business (up about 60% year-on-year), driven "mainly by strength in deployments in Asia and the adoption of massive MIMO antennas where GaN has been selected many, many times over LDMOS," notes IDP Group president James Klein. "We've been able to support many of the major frequency bands that have been rolled out in China."

Qorvo now projects full-year operating margin of 31.5% (exceeding the lower end of the margin model laid out previously), OpEx of about 20% of sales, diluted earnings per share of over $9.40 (up nearly 50% year-on-year), and free cash flow of about $1bn (up from the previous forecast of $900m).

"[Base-station] deployments will slow during the first half of the calendar year, and then we expect those to start to accelerate in the second half. Additionally, with the C-band auctions nearly complete in the US, we do expect deployments to start later in the year, and we do expect those to include both massive MIMO antennas and GaN power amplifiers," says Klein. "And then, obviously, we're in the early stages of 5G deployment, and we expect those deployments to continue both in China and around the world as we go through the next several years," he adds.

"As 5G, Wi-Fi 6 and 6E, ultra-wideband and other connectivity protocols are rolled out globally, Qorvo is well-positioned to expand our technology reach," concludes Bruggeworth.

www.qorvo.com

Skyworks' quarterly revenue grows 58% to record $1.51bn

5G and Wi-Fi 6 driving greater-than-expected growth

For fiscal first-quarter 2021 (to 1 January), Skyworks Solutions Inc of Woburn, MA, USA (which manufactures analog and mixed-signal semiconductors) has reported record revenue of $1510m (more than $455m above the midpoint of the $1040–1070m guidance). This is up 58% (rather than the expected 10%) on $956.8m last quarter and up 69% (rather than the expected 18%) on $896.1m a year ago.

Revenue from Skyworks' largest customer (which has just launched its first 5G phones) was about 70% of total revenue (up from the low-60s a year before). However, "All our other customers, all our other segments, every region [including China] was up double digits sequentially and strong double digits on a year-over-year basis," notes chief financial officer Kris Sennesael. Growth was driven by increasing adoption of Mobile solutions with all smartphone OEMs along with record Broad Market revenue and customer reach.

"Skyworks started the new fiscal year with record results, clearly demonstrating the breadth and depth of our business model, from tier-1 Mobile to thousands of Broad Market customers," says president & CEO Liam Griffin.

For the Mobile business sector (Integrated Mobile Systems and Power Amplifiers), revenue grew 80% both sequentially and year-on-year, driven largely by widespread content increases as 5G phones are ramping with all major smartphone brands worldwide.

For the Broad Markets business sector, revenue grew to $326m, up 10.5% on last quarter's record $295m and up 35% year-on-year, benefiting from a diverse set of use cases supporting "work, play, learn from anywhere, and increasing adoption of technologies such as Wi-Fi 6 and Wi-Fi 6E (extended band) along with the continuous momentum in our audio solutions business".

"We are proud to play an instrumental role in shaping the fast-evolving landscape, collaborating with our partners and customers, leveraging key technologies from TC-SAW [temperature-compensated surface acoustic wave] to high-performance BAW [bulk acoustic wave] filtering, silicon-on-insulator (SOI), gallium arsenide (GaAs), and state-of-the-art packaging technologies," says Griffin. "Our strong results in Q1 demonstrate our execution around these themes," he adds.

Specifically:

- In Mobile, Skyworks accelerated the ramp of its Sky5 portfolio, supporting the next wave of 5G launches at South Korea's Samsung as well as China's Oppo, Vivo and Xiaomi and other tier-1 players. In Internet of Things (IoT), the firm captured design wins across a diversified array of new customers. Specifically, it partnered with ASUS on the launch of the world's first Wi-Fi 6E connected home router. Skyworks shipped Wi-Fi 6 solutions for access points at leading network OEMs including Cisco, NETGEAR, TP-Link and Aruba, and launched Wi-Fi 6 engines for CenturyLink's latest GPON media gateway. The firm also captured new design wins at Google for their latest Fitbit smartwatch. In addition, Skyworks delivered low-latency cognitive audio solutions, powering wireless gaming headsets at multiple tier-1 accounts including Turtle Beach and SteelSeries.
- In Industrial, Skyworks ramped Itron's multi-standard ISM connectivity solutions for smart cities.
- In Infrastructure, it commenced volume shipments of 5G amplifier and receive modules, supporting multiple European base-station OEMs.

We established new quarterly records for revenue, operating margin and earnings per share

- In Automotive, Skyworks accelerated shipments of advanced connectivity solutions supporting the world's premier electric vehicle (EV) manufacturer. It leveraged V2X solutions with Volkswagen and Toyota for their enhanced safety systems, and partnered with MediaTek for emerging 5G reference design, specifically targeted at automotive and other IoT applications.

Despite a very tight supply chain environment, non-GAAP gross margin has risen further, from 50.1% a year ago and 50.4% last quarter to 51.1% (exceeding the expected 50.25–50.75%, and above 51% for the first time in eight quarters).

Operating expenses have increased, from $134m a year ago and $147m last quarter to $149m, albeit falling from 15% to 10% of revenue, "demonstrating strong leverage in our operating model, while continuing our strategic investments in support of future growth," says Sennesael.

Net income has risen further, almost doubling year-on-year from $288.8m ($1.68 per diluted share) a year ago then $312.2m ($1.85 per diluted share) last quarter to $560m (a record $3.36 per diluted share, exceeding the $2.06 guidance by $1.30).

"We established new quarterly records for revenue, operating margin and earnings per share, demonstrating both the power of our financial model and unique opportunity to lead the global transition to more advanced wireless communications," says Griffin.

Operating cash flow was $485.1m (up from $267m last quarter). Capital expenditure (CapEx) was $119m (down from $146m). Skyworks paid $83m in dividends and spent $196m to repurchase 1.4 million shares of common stock at an average price of about $139 per share. Overall, during the quarter, cash, cash equivalents and marketable securities rose from $980m to $1019.3m. Skyworks has no debt.

"We will continue to return most of our free cash flow back to the shareholders," says Sennesael. Skyworks' board of directors has hence declared a cash dividend of $0.50 per share of common stock, payable on 9 March to stockholders of record at the close of business on 16 February. The board has also authorized a new $2bn stock repurchase program (replacing the existing two-year $2bn program approved by the board on 30 January 2019, which had about $783m of repurchase authority remaining on expiry). This "reflects their confidence in our business model driven by sustained above-market growth and strong cash flow generation," comments Sennesael.

"Demand for our proven solutions continues to accelerate across a growing set of customers and end markets, powering the world's most impactful use cases, from 5G mobile platforms to IoT, wireless infrastructure, autonomous transport and machine-to-machine installations," notes Griffin. "Importantly, the multi-year wireless transition is now underway, creating a burgeoning set of new opportunities. With deep customer engagements, underpinned by decades of technology investments and scale, Skyworks is uniquely positioned to lead," Griffin reckons.

"We expect the continued and rapid adoption of multiple wireless protocols and expanding use cases to drive strong year-over-year growth," says Sennesael.

In fiscal second-quarter 2021 (to end-March), Skyworks expects revenue growth to $1.125–1.175bn, up 50% sequentially. This is despite some seasonality with Skyworks' largest customer. "If you look at the revenue in Mobile outside of our large customer, as well as the revenue in growth markets, it will be up double digits sequentially, which is a lot stronger than normal seasonality," notes Sennesael. "It further accelerates our year-over-year revenue growth with all those accounts, the Korean, the Chinese [Oppo, Vivo, Xiaomi], as well as thousands of Broad Market customers."

Fiscal Q2/2021 gross margin should be 50.5–51%. Operating expenses is expected to rise to $150–152m. Diluted earnings per share should grow by 75% to $2.34.

"The demand for always-on connectivity is accelerating and extending into new applications, including telemedicine, high-speed video conferencing, remote learning, autonomous transport, essential services for the infrastructure markets, store-to-door delivery, and touchless commerce. This is a global phenomenon, where upgrades of key technologies are increasingly critical in the face of the ongoing pandemic," says Griffin. "The investments we've made over the last two decades have prepared Skyworks to address these challenges. The mobile and wireless ecosystems will benefit from these dynamics, yet outsized gains will largely accrue to those companies that have invested deeply in core technology and scale. These gains are being driven by both a growing device count and an expanding content per device, in some cases doubling or even tripling for Skyworks," he adds.

"We are seeing the confluence of multiple market developments, a significant rise in device complexity and expansion in wireless spectrum and band count combined with a technology bar that has never been higher. These trends directly translate to increased opportunity for Skyworks with both new and existing customers," continues Griffin. "With essential technologies and scale propelling performance gains across a broad set of applications, our purpose-built solutions address all key network protocols, spanning 5G, Wi-Fi-enhanced UPS and Bluetooth. Additionally, we expect the current C-band auction to be a catalyst, with new spectrum creating significant content opportunities for our Sky5 platform. While smartphones were the first to embrace 5G, the performance gains will power a broad set of use cases, extending into billions of IoT devices," he adds. "Looking ahead, we see 5G as a transformative technology, catalyzing new applications, while acting as the universal connector from the home to the car to the factory floor. Skyworks is solidifying market leadership as connectivity meaningfully alters the way we live, work, play and educate, not just from home, but from anywhere."

Skyworks announces new $2bn stock repurchase program

Skyworks' board of directors has authorized the repurchase of up to $2bn of its common stock from time to time prior to 26 January 2023, on the open market or in privately negotiated transactions, in compliance with applicable securities laws and other legal requirements.

The newly authorized stock repurchase program replaces in its entirety the $2bn stock repurchase program that was approved by the board of directors on 30 January 2019, and had about $783m of repurchase authority remaining.

The timing and amount of any shares that are repurchased under the new program will be determined by the company's management based on its evaluation of market conditions and other factors.

The repurchase program may be suspended or discontinued at any time. Any repurchased shares will be available for use in connection with the company's stock plans and for other corporate purposes.

Skyworks expects to fund the repurchase program using working capital. As of 1 January, it had cash and marketable securities of $1bn.

www.skyworksinc.com

Infineon launches 650V CoolSiC Hybrid IGBT discretes

650V TRENCHSTOP 5 IGBT technology combined with unipolar structure of co-packed CoolSiC Schottkys

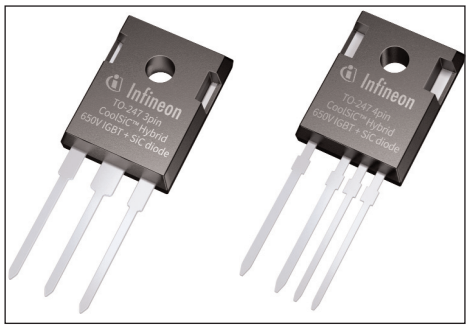
Infineon Technologies AG of Munich, Germany has launched a 650V CoolSiC Hybrid IGBT (insulated-gate bipolar transistor) portfolio in a discrete package with 650V blocking voltage.

The CoolSiC Hybrid product family combines key benefits of the 650V TRENCHSTOP 5 IGBT technology and the unipolar structure of co-packed Schottky barrier CoolSiC diodes.

With what is said to be superior switching frequencies and reduced switching losses, the devices are especially suitable for DC–DC power converters and power factor correction (PFC). These can typically be found in applications such as battery charging infrastructure, energy storage solutions, photovoltaic inverters, uninterruptable power supplies (UPS) as well as server and telecom switched-mode power supplies (SMPS).

Due to a freewheeling silicon carbide (SiC) Schottky barrier diode co-packed with an IGBT, the CoolSiC Hybrid IGBTs perform with significantly reduced switching losses at almost unchanged dv/dt and di/dt values. Compared with a standard silicon diode solution, they offer up to 60% reduction in E_{on} and 30% reduction in E_{off}. Alternatively, the switching frequency can be increased at least by 40% with unchanged output power requirements.

A higher switching frequency can allow a reduction in passive components size and thus lower bill-of-material cost. The Hybrid IGBTs can be used as a drop-in replacement for TRENCHSTOP 5 IGBTs, allowing an improvement in efficiency of 0.1% for each 10kHz switching frequency without redesign efforts.



TO-247-3 pin and TO-247-4 pin packaged 650V CoolSiC Hybrid IGBTs.

The product family creates a bridge between pure silicon solutions and high-performing SiC MOSFET designs. Even more, in comparison to pure silicon designs, Hybrid IGBTs can improve electromagnetic compatibility and system reliability, says Infineon. Because of the unipolar nature of Schottky barrier diodes, the diode can switch quickly without severe oscillations and risk of parasitic turn-on. Customers can choose between a TO-247-3 pin or a TO-247-4 pin Kelvin emitter package. The fourth pin of the Kelvin emitter package allows for an ultra-low-inductance gate-emitter control loop and reduces the total switching losses.

The CoolSiC Hybrid discrete IGBT family follows the path of previously released CoolSiC Hybrid IGBT EasyPACK 1B and 2B modules with both an IGBT chip and CoolSiC Schottky diode.

Available for order now, the discrete portfolio comprises 40A, 50A and 75A 650V TRENCHSTOP 5 ultra-fast H5 IGBTs co-packed with half-rated CoolSiC Gen 6 diodes, or medium-speed S5 IGBTs co-packed with full-rated CoolSiC Gen 6 diodes.

www.infineon.com/coolsic

ROHM's SiC MOSFETs used by MidNite Solar

Power semiconductor maker ROHM Semiconductor says that its silicon carbide (SiC) metal-oxide-semiconductor field-effect transistors (MOSFETs) are being utilized by MidNite Solar Inc of Arlington, WA, USA (a producer of alternative energy products) to drive efficiency and reduce system cost in four products new to the US market: the Hawkes's Bay $600V_{DC}$-to-$48V_{DC}$ 6000W MPPT (maximum power point tracking) solar charge controller, powerful Barcelona dual MPPT charge controller, MNB17 advanced battery-based charger/inverter, and 120/240V Rosie inverter/charger.

"SiC power devices offer vastly improved energy efficiency over the silicon parts they replace, and the cost premium has come down significantly, enabling a wider range of applications to benefit from these devices for better system performance and value," says Ming Su Ph.D., technical marketing manager at ROHM Semiconductor.

"Silicon carbide solves a key challenge," explains MidNite Solar's principal owner & engineering manager Robin Gudgel. "Regular silicon MOSFETs have a very slow body diode. Therefore, trying to make an inverter work as a charger where it must run bidirectionally is very difficult," he adds. "We were looking at an IGBT [insulated-gate bipolar transistor] pair in combination with another diode, but silicon carbide is such a good solution, and ROHM's devices did not require any significant design changes."

MidNite Solar has incorporated ROHM's 60mΩ $R_{DS(on)}$ (on-resistance) SiC devices and newer 30mΩ $R_{DS(on)}$ products in its new solar product ranges. Gudgel expects reliability to be excellent, as the design is running cool. Driving the parts should be simple, as ROHM also supplies the gate drivers.

www.rohm.com/web/global/sic-mosfet

ON Semiconductor launches 650V SiC MOSFETs

Power semiconductor IC supplier ON Semiconductor of Phoenix, AZ, USA has launched a range of 650V silicon carbide (SiC) MOSFET devices for demanding applications where power density, efficiency and reliability are key considerations. By replacing existing silicon switching technologies with the new SiC devices, designers can achieve significantly better performance in applications such as electric vehicles (EV) on-board chargers (OBC), solar inverters, server power supply units (PSU), telecoms and uninterruptible power supplies (UPS), notes the firm.

Since they are based on silicon carbide, the new automotive AECQ101- and industrial-grade-qualified 650V SiC MOSFETs provide superior switching performance and improved thermals compared with silicon, resulting in improved system-level efficiency, enhanced power density, reduced electromagnetic interference (EMI) and reduced system size and weight.

The new generation of SiC MOSFETs employs a novel active cell design combined with advanced thin wafer technology enabling what is claimed to be best-in-class figure of merit R_{sp} (R_{dson}*area) for 650V breakdown voltage. The NVBG015N065SC1, the NTBG015N065SC1, the NVH4L015N065SC1 and the NTH4L015N065SC1 have what is reckoned to be the lowest on-resistance R_{dson} (12mΩ) in the market in D2PAK7L and To247 packages. This technology is also optimized around energy loss figure of merits, optimizing performance in automotive and industrial applications. An internal gate resistor (R_g) allows more flexibility to designers, eliminating the need to slow down devices artificially with external gate resistors. Higher surge, avalanche capability and short-circuit robustness all contribute to enhanced ruggedness that delivers higher reliability and longer device lifetimes, says the firm.

"In modern power applications such as on-board chargers for EV and other applications including renewable energy, enterprise computing and telecoms, efficiency, reliability and power density are constant challenges for designers," says Asif Jakwani, senior VP of the Advanced Power Division. "These new SiC MOSFETs significantly improve performance over the equivalent silicon switching technologies, allowing engineers to meet these challenging design goals," he adds. "The enhanced performance delivers lower losses that enhance efficiency and reduce thermal management needs as well as reducing EMI. The end result of using these new SiC MOSFETs is a smaller, lighter, more efficient and more reliable power solution."

The new devices are all surface-mount and available in industry-standard package types including TO247 and D2PAK.

www.onsemi.com/products/wide-bandgap/silicon-carbide-sic-mosfets

GeneSiC launches third-generation 1200V SiC MOSFETs

On-resistance ranges from 20mΩ to 350mΩ

Silicon carbide (SiC) power semiconductor supplier GeneSiC Semiconductor Inc of Dulles, VA, USA has announced the availability of its third-generation 1200V G3R SiC MOSFETs, with on-resistance ($R_{DS(ON)}$) levels ranging from 20mΩ to 350mΩ. Featuring what are claimed to be industry-leading performance, robustness and quality, system benefits are said to include higher efficiency, faster switching frequency, increased power density, reduced ringing (EMI) and compact system size for automotive and industrial applications.

Offered in optimized low-inductance discrete packages (SMD and through hole), the G3R SiC MOSFETs are highly optimized for power system designs requiring elevated efficiency levels and ultra-fast switching speeds.

"After years of development work towards achieving the lowest on-state resistance and enhanced short-circuit performance, we are excited to release the industry's best-performing 1200V SiC MOSFETs with over 15+ discrete and bare-chip products," says president Dr Ranbir Singh. "If the next-generation power electronics systems are to meet the challenging efficiency, power density and quality goals in applications like automotive, industrial, renewable energy, transportation, IT and telecom, then they require significantly improved device performance and reliability as compared to presently available SiC MOSFETs," he adds.

Applications include electric vehicles (power train and charging); solar inverter and energy storage; industrial motor drives; uninterruptible power supplies (UPS); switched-mode power supplies (SMPS); bi-directional DC–DC converters; smart grid and HVDC; induction heating and welding; and pulsed power applications.

Offered in industry-standard D2PAK, TO-247 and SOT-227 packages, all of GeneSiC's SiC MOSFETs are usable for automotive applications (AEC-Q101) and are PPAP-capable.

The 1200V SiC MOSFET discretes are 100% avalanche (UIL) tested during production.

All devices are available for purchase through the authorized distributors Digi-Key Electronics, Newark Farnell element14, Mouser Electronics, and Arrow Electronics.

www.genesicsemi.com/sic-mosfet

JEDEC WBG Power Semiconductor Committee publishes first guideline for SiC-based devices

Silicon carbide subcommittee provides threshold voltage test methods

The JEDEC Solid State Technology Association (which develops standards for the microelectronics industry) has published 'JEP183: Guidelines for Measuring the Threshold Voltage (V_T) of SiC MOSFETs'. The first publication developed by JEDEC's JC-70.2 silicon carbide subcommittee, JEP183 is available for free download from the JEDEC website.

JEP183 addresses the critical topic of accurately measuring the threshold voltage (V_T) of silicon carbide metal-oxide-semiconductor field-effect transistors, addressing the unique behavior of SiC MOSFETs.

The threshold voltage test methods provided in JEP183 can be used as a common industry guideline for measuring V_T of SiC power devices, focused on N-channel vertical-structure MOSFET technologies, providing a common baseline for the SiC MOSFET market. For flexibility, three test methods are offered that may be applied for datasheet, process control, technology development, final tests and other usage. Threshold voltage is a key parameter in the evaluation of changes in the characteristics of physical stimulus such as voltage and/or temperature stress. Without accurately measuring V_T, it is not possible to monitor how device characteristics are changed by the stress applied to a device. The SiC/SiO_2 interface of a SiC MOSFET is more complex than a Si/SiO_2 interface, requiring careful handling of traps in the device with regard to the change monitoring of characteristics.

"JEP183 recommends approaches for precise and repeatable measurements of SiC MOSFET V_T, which will help ensure successful implementation of SiC devices in automotive and industrial markets," notes JC-70.2 subcommittee chair Dr Jeffrey Casady, Power Die Product Marketing Engineering Manager at Wolfspeed (a Cree Company).

"With this first SiC-related document we are kicking off a series of guidelines addressing the needs of the industry to work on commonly aligned standards," says JC-70.2 subcommittee vice-chair Dr Peter Friedrichs, vice president SiC, at Infineon Technologies.

JEP183 addresses the critical topic of accurately measuring the threshold voltage of silicon carbide MOSFETs

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

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

www.jedec.org

Comtech Xicom awarded $1.6m follow-on order for Ka-band solid-state power amplifiers

GaN-based SSPAs to be used for in-flight connectivity

Comtech Telecommunications Corp of Melville, NY, USA says that 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 — has received a follow-on order worth $1.6m for Ka-band SSPAs that use gallium nitride (GaN) technology for an in-flight connectivity (IFC) application.

"We continue to expand in the SSPA market with new products," says Fred Kornberg, chairman of the board & CEO of Comtech Telecommunications Corp. "Our Bobcat, Puma and Falcon SSPAs utilize the latest GaN technology to deliver RF amplification that enables high-speed satellite communications from ground-based and airborne terminals," he adds.

Comtech's portfolio offers both Ku-band and Ka-band products for IFC applications. Comtech Xicom's product range encompasses 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 applications.

www.xicomtech.com

Fraunhofer ISE develops compact inverter for direct connection to medium-voltage grid

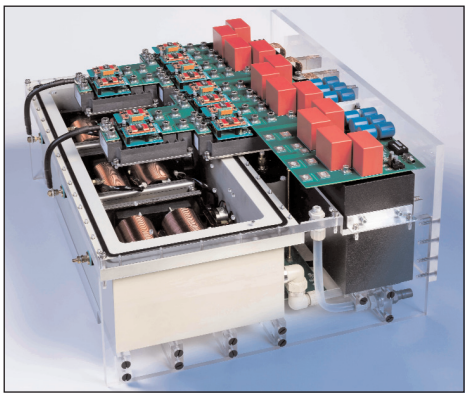
SiC-MSBat yields 250kW inverter stack for feeding into 3kV AC grids

As the energy transition progresses, the expansion of the electricity grids is becoming increasingly important, notes Fraunhofer Institute for Solar Energy Systems ISE of Freiburg, Germany. More and more renewable generation plants as well as electrical storage systems are being connected to the grid. This gives power electronics a decisive role, because it is essential to connect these systems to the grid. However, in addition to the mere feed-in or feed-back of electrical energy, power electronics must also perform other grid-supporting tasks. In the project 'SiC-MSBat — medium-voltage inverters with high-voltage SiC power modules for large-scale storage and system-serving distribution grids', researchers at the Fraunhofer ISE, together with partners, have now developed and commissioned a highly compact inverter for a direct feed into the medium-voltage grid.

Currently, inverters mostly feed into the low-voltage grid. They are then coupled to the medium-voltage grid via large 50Hz transformers. Use of new types of silicon carbide (SiC) transistors with very high blocking voltages now also makes it possible to connect the inverters directly to the medium-voltage grid.

Due to the high control dynamics of SiC inverters, they can take on grid-stabilizing tasks and, for example, act as active power filters to compensate for harmonics in the medium-voltage grid.

Furthermore, SiC inverters can achieve much higher power densities than conventional inverters. This results in a compact design, which is a particular advantage when plants are to be built in inner-city areas or existing old plants are to be retrofitted. In addition to the mere system costs, construction and infrastructure costs also play a very important role, especially in urban areas.



Compact design due to high switching frequency

As part of the SiC-MSBat project, a 250kW inverter stack was developed for feeding into 3kV AC grids.

Here, novel 3.3kV SiC transistors are used. These have significantly lower power losses than comparable silicon transistors. This makes it possible to operate the inverter stack with a switching frequency of 16kHz. With state-of-the-art silicon transistors, only about 10 times lower switching frequencies are possible in this voltage class, says Fraunhofer ISE. The high switching frequency provides savings on the passive components, as these can be dimensioned in a smaller format.

Another special feature of the inverter is its active liquid cooling with a synthetic ester as cooling medium. This medium is pumped through the inverter and cools both the transistors via a liquid heat sink and the filter chokes, which are housed in a closed tank. At the same time, the cooling medium for the filter chokes serves as an electrical insulation medium, allowing the filter chokes to be made even more compact.

The inverter was built and tested in Fraunhofer ISE's laboratories, achieving a very high efficiency rate of 98.4% at rated power. The design of the device allows modular interconnection of multiple inverter stacks to achieve system outputs of several megawatts. Taking into account additional installation space for switchgear and cooling unit, a volume saving of the inverter system of up to 40% can be achieved compared to commercial inverter systems of this voltage class.

The project was funded by the German Federal Ministry for Economic Affairs and Energy (BMWi) as part of the 6th Energy Research Program under the sub-area 'Integration of Renewable Energies and Regenerative Energy Supply Systems'. Project partners were Semikron Elektronik GmbH & Co KG and STS Spezial-Transformatoren Stockach GmbH. Semikron was responsible for the development of the 3.3kV SiC modules in the project, while STS was mainly responsible for the inductive components.

Future power electronics at the medium-voltage level

Fraunhofer ISE sees many potential applications for the use of high-blocking SiC devices in the medium-voltage range. "Especially for large photovoltaic (PV) power plants, the trend is towards higher and higher voltages," says Andreas Hensel, head of team Medium Voltage Power Electronics. "With the 1500V PV technology that has been available for a few years, the low-voltage directive is already being fully exploited. The next step here will be the transition to feed-in at medium-voltage level, which will bring further potential for savings and improvements in the system concept of PV power plants."

In addition to regenerative power plants and large battery storage systems, other areas of application for medium-voltage power electronics include drive systems and rail technology.

For testing such systems, Fraunhofer ISE has the multi-megawatt laboratory, which was inaugurated in mid-2019. This enables the operation of medium-voltage systems with a power of up to 20MVA.

www.ise.fraunhofer.de

Cree's Wolfspeed quarterly revenue grows by 5%

Cree to change name to Wolfspeed; Mohawk Valley SiC fab to skip 150mm substrates and start up at 200mm

For its fiscal second-quarter 2021 (ended 27 December 2020), for continuing operations, Cree Inc of Durham, NC, USA has reported revenue of $127m, up 5% on $120.7m a year ago and up 10% on $115.5m (53% of total revenue) last quarter (and above the $118–124m guidance), fueled by continuing strong demand for silicon carbide solutions.

"The momentum we're seeing in silicon carbide reinforces our competence and our growth strategy as we execute on our long-term plan," says CEO Gregg Lowe.

On 18 October, Cree agreed to sell its LED Products business unit to SMART Global Holdings Inc for up to $300m. The transaction is targeted to close in calendar first-quarter 2021. This follows Cree's sale in May 2019 of its Lighting Products business unit. "By divesting our LED assets, we have established ourselves as a global pure-play semiconductor powerhouse with a sharpened focus on silicon carbide (SiC) and gallium nitride (GaN) solutions," says Lowe.

"Demand for devices and materials continues to improve despite the ongoing uncertainty in the macroeconomic environment," adds chief financial officer Neill Reynolds.

"In power, momentum continues to build as our customers have a demonstrated need for our solutions. In particular, we're pleased with our 650V [SiC] MOSFET platform, which continued to gain strong traction across a number of industry sectors. While our supply levels remain below normal due to COVID-19 safety measures, we made progress in the quarter and expect to continue to improve as we execute our capacity expansion plan," Reynolds says.

"In RF [GaN], our performance was better due to increased 5G activity during the quarter with communications infrastructure providers. Our backlog continues to grow, underscoring the growing opportunity we have as the 5G rolls out across the globe," he adds.

"In materials [SiC substrates], we saw a modest uptick in order flow in the quarter, which we expect to continue throughout the remainder of fiscal 2021," says Reynolds.

On a non-GAAP basis, gross margin has risen further, from 31% a year ago and 34.5% last quarter to 35.4% (despite the impact of $4m of corporate items). In particular, gross margin for the Wolfspeed business (SiC materials and SiC power devices & GaN RF devices) was 38.5%, up from 34.6% a year ago and 36.6% last quarter, driven by yield and cost improvements in device product lines. "Gross margin performance also continues to be dampened by our continued COVID-19 safety measures," notes Reynolds.

Operating expenses were $78m (61.4% of revenue). Net loss was $26.6m ($0.24 per diluted share), up from $21.8m ($0.20 per diluted share) a year ago.

Operating cash flow was –$29m. Capital expenditure (CapEx) was $144.7m. Free cash flow was hence –$173.7m. During the quarter, cash and short-term investments overall fell from $1138.5m to $970m.

"We had a strong and healthy balance sheet with $970m in liquidity to support our growth strategy, zero withdrawn on our line of credit, and convertible debt with a total face value of $1bn," notes Reynolds.

The momentum we're seeing in silicon carbide reinforces our competence and our growth strategy as we execute on our long-term plan

For fiscal third-quarter 2021 (to end-March), for continuing operations Cree targets revenue of $127–133m. Gross margin should to be 34.5–36.5%.

Operating expenses are expected to rise to $80–81m. "The gradual ramp in our operating expenses is fueled by our investments in R&D, including development projects at our Mohawk Valley Fab and supporting 200mm wafer development as well as increased sales & marketing expenses as we pursue new business opportunities," says Reynolds.

Net loss is targeted to be $23–28m ($0.21–0.25 per diluted share).

"Once the divestiture of Cree's LED business is complete, we will have achieved a major milestone in our transformational journey to establish our company as a pure-play global semiconductor powerhouse, well positioned to lead the industry transition from silicon to silicon carbide," believes Lowe.

"To further amplify this transition, we are changing the name of our company to Wolfspeed. This is a natural progression that builds on our strong reputation of developing silicon carbide solutions over the last 30 years, while at the same time capitalizing on the competitive positioning that the Wolfspeed brand has in the market," he adds. "We expect the name change to be complete sometime in the next few quarters."

"While we continue to confront some of the challenges associated with the broader macro-environment, we continue to invest for the future to support several growth opportunities across multiple sectors," says Lowe.

"Customers continue to give us feedback that the interest in and demand for silicon carbide continues to grow. The strength of our device opportunity pipeline, which currently stands at more than $10bn, underscores the demand we're seeing, not only for automotive power, but also in RF, industrial and energy solutions," says Lowe. "The cadence ►

at which our sales team is converting these opportunities continues to be impressive, with approximately $600m of design-ins awarded during the previous quarter. A significant portion of these were for automotive products and the rest spread across industrial, communications, infrastructure, energy and aerospace & defense. Further, our engineering team is constantly innovating to bring new products to market," he adds.

"Earlier this month, we announced the launch of the Wolfspeed Wolfpack family of power modules, which supports a wide range of solutions for power markets, including EV task charging, renewable energy and energy storage and industrial power applications. This 1200V Wolfspeed MOSFET module technology delivers maximum efficiency in packages that allow customers to significantly increase efficiency and performance with smaller, more scalable power systems. Once again, we're working closely with the team at Arrow Electronics to successfully launch this new offering. While the automotive industry continues to anchor our business, merits of silicon carbide are being recognized across other industries, and we are well prepared to serve the different needs and applications of these businesses," notes Lowe.

"On 5G, while China continues to lead the world in infrastructure and mobile rollout, we are encouraged by signs of progress in other regions. Although we're still in the early stages, we expect 5G and GaN-on-SiC to be a multi-year growth opportunity as momentum continues to build."

"In materials, we are pleased to announce that we signed an extension and expansion of an existing long-term wafer supply agreement with a major semiconductor provider during this past quarter. The extended agreement now represents approximately $250m in materials and provides the customer with Wolfspeed's 150mm SiC bare and epitaxial wafers over the next several years. The extension is yet another example of how the industry at large is shifting towards silicon carbide and how we are best positioned to lead this transition," says Lowe.

"Our 200mm team has made solid progress, and in fact has made substantial breakthroughs in 2020. As a result, we have decided to forgo our original plan to initially open up the Mohawk Valley fab at 150mm. Instead, we'll begin ramping Mohawk Valley directly with 200mm silicon carbide substrates in the first half of calendar 2022, establishing the world's first 200mm silicon carbide fab," says Lowe. There is also some incremental CapEx spending associated with building more 200mm crystal growers (Cree builds its own SiC crystal growers for all wafer diameter sizes).

"We are raising our fiscal 2021 CapEx spend to about $550m [from $400m previously], which reflects a greater percentage of completion of Mohawk Valley versus our previous CapEx plan as well as leased investments in 200mm wafer and epi capacity," he adds. "The higher completion rate of the fab construction and fit-out this year and the increased investment in 200mm capacity will give us the ability to ramp the fab solely at 200mm. We believe it is in the best interest of our customers to have the Mohawk Valley Fab and the Durham crystal growth facilities up and running at 200mm, saving a qualification cycle, and allowing for a quicker adoption in the industry. We see this as better positioning the company to address what many are now expecting to be a steepening demand curve for silicon carbide beyond 2024."

"Our current operations are not optimized to support our ambitious long-term growth plans. To achieve the necessary operating scale to support the steepening demand curve in the automotive 5G and other critical industrial sectors out beyond 2024 and meet the needs of our customers, we determined it's better for us to invest now," says Reynolds. "We will now be running 150mm to support our current book of business, while at the same time building out our 200mm assets sooner than we originally planned, which calls for additional 200mm equipment," he adds.

"While we currently have ample liquidity to fuel our investment plans, we will continue to monitor the capital markets and evaluate ways we may continue to maximize our financial flexibility as we expand our leadership position," says Reynolds. "Our CapEx and cash flow during 2021 continue to be subject to variability depending on our Mohawk Valley construction progress as well as reimbursement timing from the state of New York."

www.cree.com

Cree completes $500m at-the-market equity offering

Proceeds to support silicon carbide capacity expansion

Cree has completed an offering of shares of its common stock, pursuant to an at-the-market equity program described in a shelf registration statement filed with the US Securities Exchange Commission on 11 February.

Through the program, the firm sold 4,222,511 additional shares of its common stock for gross proceeds of about $500m.

The equity offering "will further strengthen our balance sheet and liquidity position as we grow the Wolfspeed business," comments CEO Gregg Lowe. "The additional capital will help support our capacity expansion efforts as we continue to invest for long-term growth and drive the industry transition from silicon to silicon carbide."

Cree appoints former GM executive to board

Global manufacturing and automotive experience to aid Cree's focus on silicon carbide

Cree Inc of Durham, NC, USA (which makes LEDs and silicon carbide- and gallium nitride-based RF & power semiconductors) has appointed Marvin A. Riley to its board of directors.

Riley is president & CEO of EnPro (an industrial technology company using materials science in the semiconductor, life sciences, and other technology-enabled sectors), a position has held since July 2019. He was previously executive VP & chief operating officer from July 2017. He has also served in various leadership positions including president of the firm's Fairbanks Morse division; VP of its corporate manufacturing function; and VP of global operations for its GGB division.

Prior to EnPro, Riley was an executive with General Motors Corp, working in the General Motors Vehicle Manufacturing Group where he held multiple positions of increasing responsibility from 1997 to 2007. His experience at GM includes leadership positions in general assembly, body operations, dimensional control, plant maintenance and supporting multiple vehicle launches. He also credits his deep understanding of lean manufacturing to his time at GM.

"Marvin's extensive experience in the global manufacturing and automotive sectors will be a unique asset for the company as we work with the executive team to capitalize on the vast opportunities ahead for Cree's silicon carbide in a variety of high-growth automotive and industrial applications," believes chairman Darren Jackson. "We look forward to his contributions as we continue our long-term plans to lead the global transition from silicon to silicon carbide and expand the company's leadership position."

Cree is focusing on its Wolfspeed silicon carbide materials and silicon carbide (SiC) power device & gallium nitride (GaN) RF device business, whose product families include silicon carbide materials, power-switching devices and RF devices targeted at applications such as electric vehicles (EVs), fast-charging inverters, power supplies, telecom and military and aerospace.

Previously, in May 2019, Cree sold its Lighting Products business unit (Cree Lighting, including the LED lighting fixtures, lamps and corporate lighting solutions business for commercial, industrial and consumer applications) to Ideal Industries Inc of Sycamore, IL, USA. Most recently, in October 2020, Cree agreed the sale of its LED Products business unit (Cree LED) to SMART Global Holdings Inc, for which the transaction is targeted to close in this quarter.

Riley replaces Anne Whitaker, who is leaving the board to focus on her board duties at other life sciences companies. She has served on the board since 2013, helping guide the firm with her extensive executive leadership experience. "

www.cree.com

Nexperia to grow global production and boost R&D spend

Nexperia BV of Nijmegen, The Netherlands (which manufactures discrete and MOSFET components and analog & logic ICs) has confirmed that during 2021 it will be making significant additional global investments in manufacturing capacity and R&D.

The new investments are in line with a growth strategy that last year saw parent company Wingtech Technology Co Ltd commit RMB12bn ($1.85bn) to building a new 300mm (12-inch) power semiconductor wafer fab in Lingang, Shanghai, that should go live in 2022, with an estimated annual output of 400,000 wafers.

Nexperia's plans for this year include improving production efficiency and implementing new 200mm technologies at its European wafer fabs in Hamburg in Germany and Manchester in the UK. In Hamburg there will also be additional investment in new technology for wide-bandgap semiconductor manufacturing.

New product development will be supported with a commitment to increase R&D investment to about 9% of total sales. Nexperia recently opened new global R&D centers in Penang in Malaysia and Shanghai in China and expanded the existing R&D sites in Hong Kong, Hamburg and Manchester. The company will also enhance test & assembly capabilities at Nexperia factories in Guangdong in China, Seremban in Malaysia and Cabuyao in the Philippines, including the implementation of advanced automation and system-in-package (SIP) capabilities.

"Increased vehicle electrification, 5G communications, Industry 4.0 and the mainstream adoption of gallium nitride (GaN)-based designs will all drive increased demand for power semiconductors in 2021 and beyond," says chief operating officer Achim Kempe. "Nexperia is already the largest manufacturer of semiconductors by units shipped — more than 90 billion annually. The additional global investment will ensure that we continue to provide the technology and manufacturing capacity needed to deliver products in volumes that support future demand," he adds.

"Since Wingtech's acquisition of Nexperia in 2019 we have committed to ongoing investment to support ambitious growth plans and capitalize on the synergies between the two businesses," says Xuezheng Zhang (Wing), CEO of Wingtech and Nexperia. "Following last year's announcement of the new 300mm fab and the opening of design centers in Penang and Shanghai, we are continuing with investments that support our growth across the globe, increase our industrial footprint and market share."

www.nexperia.com

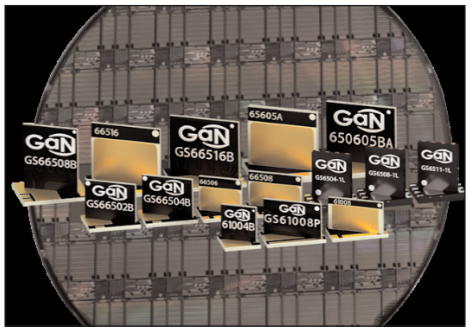
GaN Systems ships 20 millionth GaN transistor

40x capacity expansion to be completed in 2021

GaN Systems Inc of Ottawa, Ontario, Canada (a fabless developer of gallium nitride-based power switching semiconductors for power conversion and control applications) says that it has shipped its 20 millionth GaN transistor and that its factory partners are on schedule to complete a 40-fold capacity expansion in 2021.

The capacity increase is in advance of the next wave of orders for GaN Systems' transistors across many applications. The firm says it has been seeing exceptionally high growth in several key industrial markets. In addition to phone and computer chargers and adapters, its transistors are shipping in audio amplifiers, data-center power supplies, industrial motor drives, laser drivers, medical power supplies, satellite and aerospace systems, and automotive electric vehicle (EV) power electronics.

GaN Systems claims that the proven reliability and demonstrated benefits of its line of 100V and 650V



products (such as higher efficiency and power density while reducing size, weight and costs) contribute to GaN's growing market acceptance versus legacy silicon and new silicon carbide (SiC) transistors.

Additionally, GaN is significantly cheaper than SiC, which requires a more expensive and complex manufacturing process, says the firm. Costs required to increase capacity for SiC are 10x higher than for GaN, it adds. For GaN, low capital expenditure (CapEx) for capacity, combined with very low substrate cost, results in GaN transistors being lower cost than SiC. Also, GaN is half the price that it was just a few years ago, making system costs similar or lower than power systems built with legacy silicon transistors, it is reckoned.

"Our product design expertise, range of product offering, and collaborative customer partnerships have produced a market-leading GaN product line," claims CEO Jim Witham. "This is supported by our tremendous growth and [foundry partner] TSMC's commitment to stay ahead of our demand curve."

GaN Systems says major firms and OEMs are now designing and shipping products with gallium nitride. As forecasted in GaN Systems' '2021 Top Technology Predictions in Power Electronics', the market is seeing increased demand for and adoption of GaN-powered products. The perceived risk factor has shifted from technology adoption risk to the risk of being left behind because you didn't adopt GaN, reckons the firm.

www.gansystems.com

GaN Systems launches first GaN power stage with programmable source current and over-current protection

GaN Systems has released two 650V half-bridge daughter cards (30A and 60A), which provide a versatile platform for evaluating GaN drivers and transistors.

The evaluation cards are available in two power levels of up to 3kW (GS-EVB-HB-66508B-RN) and 6kW (GS-EVB-HB-66516T-RN), and include the Renesas RAA226110 low-side GaN FET driver. The cards are reckoned to be the first to provide programmable over-current protection with adjustable thresholds and programmable source current for adjustable turn-on slew rate.

"GaN transistors have established themselves as a fundamental building block in power electronics," says Paul Wiener, VP of strategic marketing at GaN Systems. "The introduction of Renesas' low-side GaN FET driver with its best-in-class features and performance are a confirmation that GaN transistors have become the preferred tool of choice for power design engineers," he adds.

"Renesas is committed to the development of innovative power products that support GaN transistors," states Philip Chesley, VP of the Industrial and Communications business unit at Renesas. "One example is our new RAA226110 low-side GaN FET driver, which provides all of the features customers are looking for in a high-performance driver."

The power stage designs can be utilized in a wide range of applications, from enterprise 1U power supplies (up to 5kW), high-power density bridgeless totem pole PFCs, PV inverters, energy storage systems, motor drives, and automotive DC/DC converters and onboard chargers.

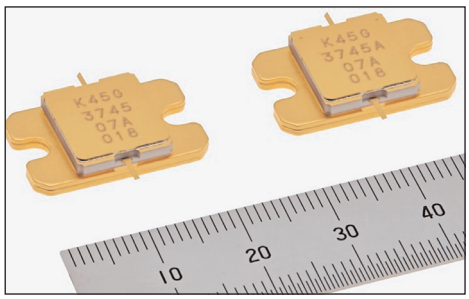
Design flexibility, simplicity and unique features define the evaluation board, which operates with a GaN Systems' motherboard for easy setup and plug-and-play operation. The evaluation card also features integrated V_{GS} regulation at 2MHz f_{SW} and one-of-a-kind functions such as programmable over-current protection with adjustable thresholds of 40mV/80mV/120mV and differential current sensing as well as programmable source current for adjustable turn-on slew rate (0.3A, 0.75A or 2A).

Mitsubishi Electric adds Ku-band GaN HEMTs

For multi- & single-carrier communications, larger data capacity and smaller SATCOM earth stations

Tokyo-based Mitsubishi Electric Corp is adding two new 13.75–14.5GHz (Ku-band) 30W (45.3dBm) output, 9dB-linear-gain gallium nitride high-electron-mobility transistors to its lineup of GaN HEMTs for satellite communication (SATCOM) earth stations. On sales from 15 March, the two products, one for multi-carrier communication and the other for single-carrier communication, will support increased data-transmission capacity and smaller earth stations.

Ku-band satellite systems are increasingly being deployed for emergency communication during natural disasters and for satellite news gathering (SNG) by TV broadcasters in remote areas where cable networks do not exist. Meanwhile, in addition to the growing use of conventional single-carrier communication, multi-carrier communication is increasingly needed for fast, high-volume communication and to support the downsizing of mobile stations for purposes such as SNG.



GaN HEMTs for Ku-band SATCOM earth stations: single-carrier 30W MGFK45G3745 (left) and multi-carrier 30W MGFK45G3745A (right).

So far, Mitsubishi Electric has introduced five GaN HEMTs for multi-carrier and single-carrier SATCOM earth stations. The two new 30W GaN HEMTs can enable more flexible amplifier designs, including for rated power levels and the use of GaN drivers. They can also support the downsizing of earth stations as well as faster, larger-capacity satellite communication.

Specifically, the MGFK45G3745A for multi-carrier communications delivers low third-order intermodulation distortion (IMD3) with wide offset frequencies of up to 400MHz for large-capacity, high-speed SATCOMs. The MGFK45G3745 for single-carrier communications has an offset frequency of up to 5MHz.

The new products are suitable for final-stage applications in 30W-class SATCOM amplifiers and driver-stage applications in 70–100W-class amplifiers.

www.MitsubishiElectric.com

Navitas ships 13 millionth GaNFast Power IC

Navitas Semiconductor Inc of El Segundo, CA, USA says that over 13 million of its gallium nitride (GaN) power ICs have been shipped to date with zero failures, demonstrating GaN's rapid adoption in the fast-charging mobile consumer market and beyond.

GaN ICs are reckoned to run up to 100x faster than silicon chips, with 40% energy savings and up to 3x power density improvements. Navitas claims that its GaNFast power ICs (which integrate power, analog and digital circuits) are the highest-performance, most integrated and lowest-system-cost power GaN devices on the market. They are shipping in mass production to many tier-1 customers including Lenovo, Dell, Xiaomi and OPPO.

Two Navitas customers were announced as Consumer Electronics Show (CES2021) Innovation Awards Honorees. Chargeasap received its award for the high-power 200W Omega 2C+2A charger, and ADG was rewarded for its 100W '9-in-1' power and communications hub. Both designs use GaNFast power ICs to deliver high performance in extremely compact form-factors.

Founded in 2014, Navitas has 120+ patents issued or pending on all aspects of GaN device, packaging, applications and systems. Its proprietary GaN process design kit (PDK) was developed based on the GaN-on-Si platform of foundry TSMC.

"At CES 2021, we were pleased to deliver on our predictions and not only announce that over 100 fast mobile chargers use GaNFast technology but also to thank our trusted foundry partner TSMC," says CEO & co-founder Gene Sheridan. "We are experiencing unprecedented demand and truly appreciate TSMC's support in bringing GaNFast power ICs to the market quickly," he adds.

"TSMC will continue to support our customers with leading GaN manufacturing expertise to deliver great energy efficiency improvement for power conversion applications that are more eco-friendly," says Sajiv Dalal, senior VP business management, TSMC North America.

"We are delighted with our continued partnership in accelerating the development and delivery of GaN power ICs," comments Dan Kinzer, Navitas' chief operating officer/chief technology officer & co-founder. "The delivery and quality results speak for themselves with a run-rate of over 1 million GaNFast power ICs shipping every month, over 13 million shipped in total and zero field failures," he adds. "Navitas is investing aggressively to accelerate development of a new generation of GaN power ICs with even higher levels of integration, speed, energy savings and lower system costs."

www.navitassemi.com

Navitas launches high-power 650V/800V-rated GaNFast power IC

Navitas has launched the NV6128, a high-power 650V/800V-rated GaNFast power IC to address the high-power mobile and consumer power electronics market. The 70mΩ NV6128 represents a 66% increase in current capability, in a small (6mm x 8mm) PQFN package with a proprietary, integrated cooling pad for high-efficiency, high-density power systems.

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

"GaNFast power ICs have been broadly adopted by tier-1 names like Lenovo, Dell, OPPO and Xiaomi for fast-charging mobile adapters up to 200W, with over 13 million shipped and zero failures," notes CEO & co-founder Gene Sheridan. "With the higher-power NV6128, we extended the effective power range to 500W for the consumer market and look beyond that to multi-kW data-center, eMobility and new energy applications."

Unlike competing solutions, it is claimed, the NV6128 is rated at 650V for nominal operation plus a high 800V peak capability for robust operation during transient events. As a true power IC, the GaN gate is fully protected and the whole device is rated at what is claimed to be an industry-leading electrostatic discharge (ESD) specification of 2kV.

"Compared to current tier-1 OEM laptop adapters using old silicon in traditional diode rectification and boost PFC topologies at 50–70kHz, the GaNFast NV6128 enables a modern high-speed totem-pole architecture and complete 300W solutions at over 1.1W/cc," says chief operating officer/chief technology officer & co-founder Dan Kinzer. "That's up to 3x smaller and lighter with existing 200kHz control," he adds. "When you crank up the speed to MHz+, you get another major step-increase in power density."

For power electronics designers, the NV6128 and all the GaNFast power IC family offer easy-to-use, high-speed, high-efficiency solutions for 200-500W applications such as all-in-one PCs, TVs, game consoles, eMobility chargers (eScooters, eBikes) and gaming laptops, the firm says.

Design-support includes detailed datasheets, electrical models (SPICE) and mechanical models (.stp). The NV6128 is in high-volume mass production and immediately available from distribution partners, at a price of $7.85 in 1000-unit quantities.

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Keysight and Transphorm create power supply reference design

Keysight Technologies Inc of Santa Rosa, CA, USA (which supplies electronic design automation software) and Transphorm Inc of Goleta, near Santa Barbara, CA, USA — which designs and makes JEDEC- and AEC-Q101-qualified 650V and 900V gallium nitride (GaN) field-effect transistors (FETs) for high-voltage power conversion applications — have announced the availability of a new power supply reference design that enables engineers to identify and correct design errors before building hardware, thereby lowering product costs and speeding time to market.

Switched-mode power supplies (SMPS) provide greater efficiency, increased power density and lower overall system costs when using GaN devices. However, as a high-switching-speed, high-performance wide-bandgap semiconductor, GaN can produce voltage spikes that result in detrimental radiated electromagnetic interference (EMI). Optimized layout design and placement of components before building hardware is hence critical when using GaN.

Available with Keysight's PathWave Advanced Design System, the new power supply reference design is a virtual prototype based on Transphorm's 4kW high-efficiency single-phase AC–DC conversion evaluation board. It consists of the component and board models needed for engineers to visualize and optimize the time and frequency domains' behavior of voltages, currents and electromagnetic fields.

"The need for switch-mode power supplies is driving rapid adoption of wide-bandgap semiconductors," notes Tom Lillig, general manager of Keysight's PathWave Software Solutions division. "The new reference design of Transphorm's high-voltage GaN solution will speed time to market of this technology, which is changing how the world powers electronic products."

Keysight's PathWave ADS software provides pre-compliance analysis via a virtual prototype that ensures the intended design configuration performs as intended, eliminating the need to build a virtual workspace. Virtual prototypes are complementary to physical prototypes, which are the gold standard for compliance and measured characteristics. However, they can also be expensive and present physical challenges to certain in-house test & measurement protocols. Virtual prototypes are easy to change and can flag device overstress as warning messages during simulation. The voltage, current and fields can be monitored and corrected at every time step in the simulation. All data is available for analysis including inside a semiconductor package.

"Transphorm looks for partnerships that help our customers close skill gaps, increase design simplicity and reduce time to market," says Philip Zuk, Transphorm's VP of worldwide technical marketing & North American sales. "With proper modeling, analysis of any design type prior to physical prototyping is a useful resource. Teaming with Keysight enables us to bring our 4kW AC–DC power conversion board into a virtual design environment that will be advantageous to product designers."

www.keysight.com/find/eesof-power-electronics

Transphorm appoints defense procurement expert to board

Transphorm has added Katharina McFarland to its board of directors.

With over 30 years of government service, McFarland is recognized as a leading subject-matter expert on government acquisition, program management and procurement, says Transphorm. She is currently the president of consulting services firm Blue Oryx Inc. Previously, McFarland served as Assistant Secretary of Defense for Acquisition and Acting Assistant Secretary of the Army for Acquisitions, Logistics & Technology as the Army's Service Acquisition Executive and Chief Science Advisor. Prior to her political appointments, she was president of the Defense Acquisition University and director for acquisition at the US Missile Defense Agency (MDA). She currently serves as a director on the board of Science Applications International Corp, which had acquired Engility Holdings Inc, where she previously served as a director.

McFarland holds a Bachelor of Science degree in engineering from Queen's University, a master's degree in program management from the Program Management Institute, and an honorary doctoral degree in engineering from Cranfield University.

"Katharina is a highly respected expert in her field, and we are pleased to welcome her as a new independent director," comments Transphorm's CEO Mario Rivas. "Her unique and extensive experience in government service and procurement brings a new and informed perspective, which is highly relevant to our current and prospective GaN business with the DoD [US Department of Defense] and other government agencies, while also serving to expand the depth and expertise of our board," he adds. "This appointment also demonstrates our commitment to board diversification in order to further strengthen the breadth, talent and background of our directors."

www.transphormusa.com

Compound Semiconductor Centre & Newport Wafer Fab to develop 200mm GaN HEMT foundry process

Project supported by UKRI's Automotive Transformation Fund

UK Research and Innovation (UKRI) is supporting Compound Semiconductor Centre Ltd (CSC, a joint venture founded in 2015 between Cardiff University and epi-wafer foundry and substrate maker IQE plc of Cardiff, Wales, UK) and Newport Wafer Fab (NWF, the UK's 200mm compound semiconductor wafer foundry) to develop a 200mm-wafer-diameter gallium nitride (GaN) high-electron-mobility transistor (HEMT) foundry process. The project is a co-ordinated effort by CSC and NWF to deliver a foundry-grade 650V GaN-on-silicon HEMT process on a 200mm wafer platform.

The HEMT fabrication process technology will leverage 30 years of silicon-based power device manufacturing heritage at Newport Wafer Fab, developed under an automotive (IATF 16949) quality accredited volume manufacturing environment.

The epitaxial solution will leverage IP developed by CSC in partnership with parent company IQE on a high-volume Aixtron G5 200mm manufacturing platform at its Cardiff facility. CSC recently achieved full ISO9001 accreditation of its internal Quality Management System covering development through to volume scale up. The project is supported by UKRI under the 'Automotive Transformation Fund: moving the UK automotive sector to zero emissions'.

"This is an exciting step towards NWFs vision of becoming a major manufacturer of compound-on-silicon products," says Sam Evans, NWFs director of external affairs. "We see the wide-bandgap power device market as an excellent area to address in our plans to expand our current manufacturing footprint of 8000 wafer starts per week to 14,000, and it's a natural opportunity for us to pursue given our heritage in high-power silicon MOSFET, IGBT and GaN device development manufacturing," he adds.

"The GaN power market is estimated to be $700m by 2025, with massive future growth opportunity for electric vehicle (EV) adoption, and we are collaborating with a global power semiconductor blue-chip to help steer the process roadmap," says Rob Harper, GaN program manager at CSC. "We are initially targeting the EV segment of the market, including traction inverters; as the project progresses we hope to roll out custom foundry offerings that address additional market segments including mobile/laptop fast chargers and energy storage inverters," he adds.

"This is an excellent example of two partners in the South Wales semiconductor ecosystem building on their respective technology and manufacturing strengths to offer advanced, next-generation foundry services to the global semiconductor industry," comments CSC director Wyn Meredith.

www.newportwaferfab.co.uk
www.compoundsemiconductorcentre.com

Cambridge GaN Devices raises $9.5m Series A funding

Staffing to be doubled and GaN power electronics portfolio expanded

Fabless semiconductor company Cambridge GaN Devices (CGD) has raised $9.5m in a Series A round of funding co-led by IQ Capital, Parkwalk Advisors and BGF, and including investment from Foresight Williams, Cambridge Enterprise, Martlet Capital, Cambridge Angels and Cambridge Capital Group.

The new funding will be used by CGD to expand its product portfolio of energy-efficient power devices and to double the size of its team.

CGD was spun out of the University of Cambridge Department of Engineering's Electrical Power and Energy Conversion group in 2016 by CEO Dr Giorgia Longobardi and chief technology officer Florin Udrea (professor in semiconductor engineering and head of the High Voltage Microelectronics and Sensors group) in order to develop power semiconductors using gallium nitride (GaN)-on-silicon substrates. The company's core business is to design, develop and commercialize power transistors and integrated circuits.

CGD is developing a range of GaN transistors that are customized for key applications in market segments such as consumer and industrial switch-mode power supply (SMPS), lighting, data centers and automotive hybrid electric vehicles (HEVs/EVs). The firm says that the higher efficiency of its devices, combined with the unique ease-of-use introduced by its proprietary IP, will allow CGD GaN to replace silicon in those key applications, while enabling more compact power systems and better use of energy resources.

The company is the result of decades of research in power devices and GaN reliability carried out with leading organizations in the field, and through several partnerships and collaborations. CGD is currently leading the $10m European-funded project 'GaNext' with 13 industrial and academic partners across Europe, developing GaN-based modules for low- and high-power applications.

The investors were advised by Mills&Reeve, a law firm specializing in growing tech businesses. CGD was advised by Taylor Vinters, a legal and advisory business for the innovation economy.

"This latest round of investment is a great recognition of our success to date, with new and existing investors confirming the strength of our technology," says Longobardi. "Since 2016, CGD has grown significantly and we are thrilled to be in a position to deliver several products to market, following decades of industry-leading research in reliability of power devices. This investment will allow us to supplement our experienced team with additional experts and expand our markets globally, creating more sustainable electronics worldwide," she adds.

"Our close collaboration with CGD has been an incredibly rewarding win-win experience," comments Eric Stodel, CEO at Neways, an EMS System Innovator and Lifecycle Partner in the GaNext project. "It enables us to develop an extremely compact solar inverter based on the GaN technology," he adds.

"We are proud to support the CGD team as they build on their core technology, from a strong base of academic research and IP, to create the world's best GaN power devices for a wide range of applications," says IQ Capital managing partner Ed Stacey. "This highly experienced team has incredible potential to disrupt the electronics industry with new devices that will unlock commercial and environmental gains for suppliers and customers."

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AXT's Q4 revenue grows 47% year-on-year

For full-year 2020, AXT Inc of Fremont, CA, USA — which makes gallium arsenide (GaAs), indium phosphide (InP) and germanium (Ge) substrates and raw materials — has reported revenue of $95.4m, rebounding by 15% from 2019's $83.3m, driven by growth in every category across the firm's portfolio.

"2020 was a year of solid improvement for AXT, capped off by strong InP growth, particularly in 5G, in Q4, which is typically a seasonally down quarter," says CEO Morris Young.

Fourth-quarter 2020 revenue was $27m, up 5.9% on $25.5m in Q3 and 46.7% on $18.4m a year ago.

Specifically, revenue from the two raw material joint ventures that AXT consolidates (BoYu and JinMei) has grown further, from $3.9m a year ago and $5.2m in Q3 to $5.5m. In 2020, both BoYu and JinMei relocated their factory to AXT's campus in Kazuo. This has enabled both JVs to expand capacity in response to strong market demand. BoYu — which makes high-temperature pyrolytic boron nitride crucibles and pBN-based tools for organic light-emitting diodes (OLEDs) — continued to see healthy growth. High-purity material supplier JinMei is also posting solid results as gallium prices continue to rise, while also supplying InP poly. Relocation and expansion have allowed both JVs to participate in new business opportunities, which is fueling their continued growth. "Their close proximity to our own manufacturing lines allows AXT to expand recycling efforts, while improving manufacturing economics," notes Young.

Substrate revenue was $21.5m, up 5.9% on $20.3m in Q3 and 48.3% on $14.5m a year ago.

Q4/2020 was AXT's second best quarter ever for InP revenue, beaten only by Q2/2019, when AXT received a very large order from a single customer that is building inventory for expected future demand, whereas Q4/2020 revenue was spread across many customers and applications. "The current revenue diversity demonstrates the broad and sustainable nature of our growth opportunities in InP, says Young. As well as its increasing use in passive optical networks (PON) and for silicon photonics in data centers, InP is now also being used in the front-haul link on 5G base stations. "It was in April of 2019 that we first mentioned 5G revenue on our earnings report. A year later, 5G and its closely related power applications are driving significant growth in our InP revenue. Demand had been particularly strong in China and Taiwan. China itself built 600,000 last year, and they're going to just increase... They need indium phosphide to do that linkage," he adds. "We don't see any slowing in 2021, as 5G continues to roll out worldwide."

Of total revenue in Q4/2020, the proportion from the Asia-Pacific region rose further, from 70% last quarter to 71%, while Europe fell further from 17% to 16%. North America remained 13%, while Taiwan was level with it at 13%.

Two customers reached 10% of revenue, and the top five generated about 37% of total revenue.

"In data-center connectivity, the ever-expanding number of users, devices and applications is driving the transition to technology that transports faster, more scalable infrastructures," says Young. "High-capacity connectivity will continue to be essential. In fact, many believe that the evolution from 100G to 400G will happen faster than the move to 100G. We are seeing this growth in silicon photonics reflected in our steady, strong demand in data-center-related revenue. Moreover, we are pleased with the highly productive customer relationships we are developing in this area of our business, and we are applying the tier-one processes we have developed to benefit customer experiences across our portfolio."

For GaAs substrates, revenue from semiconducting GaAs for LED applications continued to rebound, driven by high-end applications, including automotive. "Wireless GaAs revenue was down seasonally in Q4, but Internet of Things (IoT) applications seem to be providing a lift in ongoing demand for semi-insulating GaAs substrates," says Young.

Germanium substrate revenue grew by more than 20% in 2020, after a significant slowdown in 2019. "The primary driver is the satellite solar cell market, which appears to have entered a period of recovery," notes Young. "We expect to see further improvement in 2021."

Gross margin was 33.9%, down from 34.6% last quarter but up greatly from 21% a year ago, attributed to favorable product mix as well as "the leverage we get from higher revenue [absorbs more of the fixed cost over more units]," notes chief financial officer Gary Fischer. Full-year gross margin rose from 29.8% in 2019 to 31.7% in 2020.

Operating expenses are up from $6.7m a year ago and $6.6m last quarter to $7.2m (driving full-year OpEx up from 2019's $25.1m to $26.3m for 2020). This is due to (1) investment in R&D rising by $125,000 to $2.16m (making "good progress on R&D programs") and (2) selling, general & administrative (SG&A) expenses rising by $460,000, driven mostly by year-end staff bonuses totaling about $350,000 (half for BoYu and JinMei) after "a good year with a strong finish", plus a $50,000 charge for bad debt, plus charges related to the firm's private equity round and preparing for the initial public offering (IPO) in China. Also, staff travel to China saw an increase.

Operating income was $1.9m, down from $2.2m last quarter but still an improvement on an operating loss of $2.8m a year ago. Full-year operating income was $3.9m, versus an operating loss in 2019 of $0.3m.

After turning profitable last quarter (yielding $45,000), unconsolidated partially owned joint ventures in AXT's supply chain grew their net profit to $354,000. "Many are benefiting from the increase in commodity

pricing being driven by a healthy demand environment," notes Young.

Q4 results included about $400,000 in tariffs as a result of the 25% tariff charged on importing wafers into the USA from China.

Net income has more than doubled from $1m ($0.02 per share) last quarter to $2.06m ($0.05 per share), an improvement on a net loss of $2.05m ($0.05 per share) a year ago. Full-year net income was $3.2m ($0.07 per share) for 2020, compared with a net loss of $2.6m ($0.07 per share) in 2019.

During the quarter, depreciation and amortization rose to $1.37m. Capital expenditure (CapEx) fell back slightly to $5.3m.

Cash, cash equivalents, and investments would have hence remained level with last quarter's $29.8m. However, they instead rose by $48.8m, to $78.6m, due to the IPO process of partnering with private equity firms in China.

On 16 November, AXT announced a strategic plan to access China's capital markets and progress to an IPO by its China-based wafer manufacturing company Beijing Tongmei Xtal Technology Co Ltd, on the Shanghai Stock Exchange's Sci-Tech innovAtion boaRd (the STAR Market). The first step is engaging reputable private equity firms in China to invest funds in Tongmei. "This went smoothly, was met with enthusiasm, and closed faster than we expected," comments Fischer. In January, the final instalment of $1.5m in private equity investment funding brought the total raised to about $49m in exchange for a stake in Tongmei of about 7.28%. Going public on the STAR Market includes several periods of review. "We hope to file the application with the China Securities Regulatory Commission by the end of June," says Fischer. Tongmei expects to complete the process in mid-2022.

"Simultaneously, we have been working on some reorganization plans, which will make Tongmei have broader product lines, more consolidated revenue, more customers and, in general, strengthen this company and support the high valuations awarded by that investment community," says Fischer. "One example is that we are moving our two consolidated raw material companies BoYu and Jin Mei into the Tongmei family," he adds.

During Q4, AXT's net inventory rose by $3.2m to $51.5m, consisting of 48% in raw materials, 47% for work in progress (WiP) and only 5% in finished goods. The largest rise was in raw materials, which was deliberate. "The market for raw materials has tightened up [with prices rising]," comments Fischer. "We think this will hold in 2021."

"We're continuing to see strong market demand, maybe not so strong for the GaAs wireless [which is still going to hold flat], but every other substrate category is looking good," notes Fischer.

For first-quarter 2021, AXT expects revenue to grow (which is untypical), to $28.5–29.5m. This is despite February being a short month, and the factory being shut down for about a week due to Chinese New Year. Net income should be $0.05–0.07 per share. "We can still achieve higher than the recent two quarters in terms of gross margin," believes Fischer. "Initially, we're trying to just get it back to 35%, but there are still some gains to be made in yields and manufacturing efficiencies, as the manufacturing teams settle into the new locations," he adds. It also depends how much more business AXT can do on InP, as well as some high-end GaAs business, Young adds.

"Capacity in our industry remains very tight," notes Young. "We have and will continue to run capacity at our Beijing facility to keep pace with customer demand. Scaling quickly and cost effectively is something AXT is uniquely able to do, and we expect to gain market share because we have the shortest lead time among our primary competitors," he adds.

"In 2021, we expect to see the meaningful emergence of additional new applications for InP in such areas as healthcare monitoring and consumer devices," says Young. "Many are being innovatively driven by tier-one players and showcase the unique properties of InP. These applications have the potential to represent an entirely new growth area, for which we are well positioned and engaged," he reckons.

In GaAs, new applications — both emerging today and on the horizon — include world-facing cameras, augmented & virtual reality (AR/VR), automotive sensors and biosensors, notes Young. "Micro-LED may follow as the next major volume driver of GaAs chips. Micro-LEDs are expected to consume less power, provide sharper contrast, and produce brilliant lighting and colors. Their applications are set to scale from wearable devices and handheld devices to very large screens, like high-end televisions of the future," he adds. "We're seeing reports that the micro-LED market for small consumer devices like wearables and phones may eventually reach an annual demand of 2 million 6" GaAs substrates for the red LED portion alone. It will be larger than the entire current market for semiconducting GaAs substrates. This is an exciting space that could add significant new values to the LED market in 2024 and beyond. Tier-one players are already driving the development, and we believe that our wafers are being used for early-stage activities," continues Young.

"We completed the relocation of our GaAs manufacturing, elevated our business and manufacturing processes to meet tier-1 standards, and expanded capacity in response to increasing demand. Now, with the gathering momentum of 5G and its related technologies, the technology progression in data-center connectivity, and new applications emerging in healthcare and consumer devices, we believe AXT is in a strong position to lead our industry and enable many of the defining trends of the coming decade," says Young. "In 2021, we expect to bring 8" GaAs and 6" InP to market. We expect to exceed that elusive $30m revenue quarter-per-quarter mark," he concludes.

www.axt.com

IQE's IQepiMo delivers improved BAW filter performance for 5G

Early data indicates k^2 rises by up to 40% at 6GHz

In what it describes as a significant milestone in the development of its proprietary IQepiMo template technology for high-performance bulk acoustic wave (BAW) RF filters, epiwafer foundry and substrate maker IQE plc of Cardiff, Wales, UK says that customer device data shows that filters fabricated using IQE templates demonstrate improved performance compared with incumbent technology.

Announced in November, IQE has since trialed its IQepiMo product with potential customers and partners. Recent data indicates that IQepiMo enables them to achieve better electro-mechanical coupling (as measured by k^2), a key measure of filter performance, compared with conventional technology.

Initial data indicates that k^2 increases by as much as 40% at a frequency of 6GHz, which is at the top end of the frequency range used in existing 5G applications.

At present, industry is finding it difficult to achieve high levels of performance using conventional BAW filter technology at these higher frequencies. The data confirms that the superior material quality achievable using IQepiMo is linked to significant performance improvement in electro-mechanical device performance in this challenging frequency range, says IQE.

IQE and its partners remain engaged in additional trials and testing to further refine the technology for high-end BAW filters. It is expected that IQE's templates will provide significant benefit to high-scandium-content ScAlN BAW designs that will form a key component of high-performance filters at the higher 5G frequencies. As scandium content increases in BAW filters, maintaining high acoustic material quality and hence performance becomes ever more challenging. IQepiMo offers users a route to overcoming these inherent challenges while still using their existing infrastructure and processes.

Built on its cREO (crystalline rare-earth oxide) technology platform (acquired by IQE in March 2018), the IQepiMo templates are available in diameters of up to 200mm.

"IQE's strategy of investing in unique leading-edge materials technologies for the broad semiconductor industry means that we are now at the forefront of providing our customers with improved 5G device performance and solutions," says chief technology officer Dr Rodney Pelzel. "This key milestone for our IQepMo template technology shows its potential for providing customers with the necessary means to enable their current infrastructure and processes to deliver the demanding performance required for 5G filters, especially at higher frequencies."

www.iqep.com

IQE settles intellectual property legal dispute

Epiwafer foundry and substrate maker IQE plc of Cardiff, Wales, UK has provided an update regarding an ongoing, multi-faceted intellectual property legal dispute (referenced in IQE's 2018 and 2019 Annual Reports, where the associated legal costs were listed as exceptional costs).

An arbitration hearing was held in September 2019 and the tribunal's final award was delivered in January 2020. The award was entirely in IQE's favour. Since then, the parties have been engaged in litigation in US federal court regarding the effect of the tribunal's decision on cases that had been brought against both IQE and IQE employees in that court.

The parties have settled the claims out of court and IQE has now received a full and final settlement payment of $2.5m.

"IQE has developed unparalleled materials expertise to meet global demand for advanced semiconductor wafer products, and this is underpinned by our comprehensive intellectual property portfolio which we are prepared to rigorously defend," comments CEO Dr Drew Nelson OBE.

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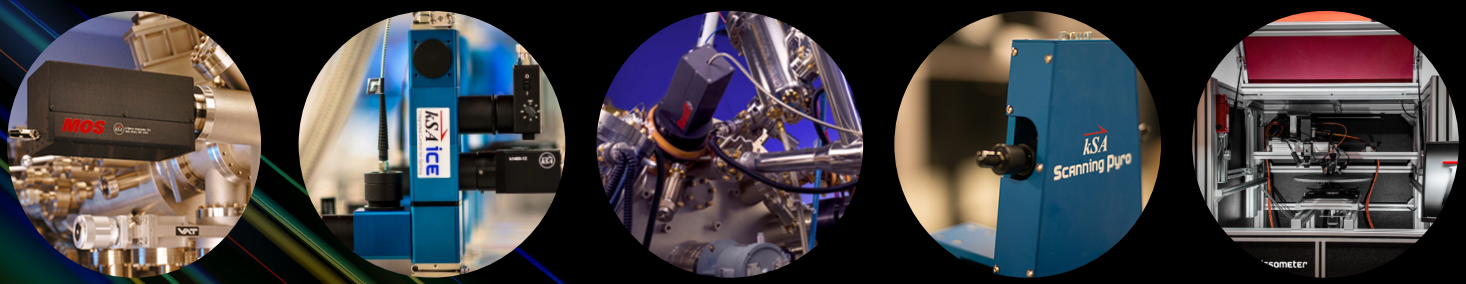

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Veeco's revenue grows 24% in Q4, driven by advanced-node semiconductor and 5G RF compound semi markets

Re-focusing drives return to full-year profit

Epitaxial deposition and process equipment maker Veeco Instruments Inc of Plainview, NY, USA says that its full-year revenue has risen by 8.3% from $419.3m in 2019 to $454.2m in 2020.

"Reflecting on 2020, we completed our organizational restructuring and began to reshape our product portfolio," says CEO Bill Miller. For example, in Veeco's metal-organic chemical vapor deposition (MOCVD) system business, it has pivoted away from the commodity LED market and towards providing high-value solutions. "These include applications in photonics such as indium phosphide (InP) lasers and vertical-cavity surface-emitting lasers (VCSELs), as well as micro-LED with our Lumina MOCVD arsenide-phosphide platform and our Propel gallium nitride (GaN) MOCVD system used for power electronics, RF devices and micro-LED applications," he adds.

To align with its evolving strategy, Veeco has modified the way it reports revenue by end market, from (1) Front-End Semiconductor; (2) LED Lighting, Display & Compound Semiconductor; (3) Advanced Packaging, MEMS & RF Filters; and (4) Scientific & Industrial (including Data Storage) to:

- Semiconductor (Front-End and Back-End, as well as EUV Mask Blank systems and Advanced Packaging) contributed $166m (36% of total revenue), down 6% on 2019's $176m.
- Compound Semiconductor (Power Electronics, RF Filter & Device applications, and Photonics including specialty, mini- and micro-LEDs, VCSELs, Laser Diodes) contributed $108m (24% of total revenue), up 26% on 2019's $86m, driven by photonics and RF applications.
- Data Storage (equipment for thin-film magnetic head manufacturing) contributed $123m (27% of total revenue), up 47% on 2019's $84m, as hard disk drive customers added capacity for thin-film magnetic head manufacturing.
- Scientific & Other (research institutions and other applications) contributed $57m (13% of revenue), down 23% on 2019's $74m.

By region, the Asia–Pacific (excluding China) comprised 39% of revenue, the USA 32%, Europe, Middle-East & Africa (EMEA) 16%, China 13%, and the rest of the world less than 1%.

"Our year-over-year financial performance dramatically improved in 2020 and we are proud to conclude this remarkable year of transformation by delivering solid fourth quarter results," comments Miller Ph.D.

Q4/2020 revenue was $138.9m (exceeding guidance of $120–136m), up 23.9% on $112.1m last quarter and 22.7% on $113.2m a year ago.

"These fourth quarter results were driven primarily by system sales in support of semiconductor advanced-node manufacturing, as well as compound semiconductor system sales for 5G RF applications," Miller says.

The Semiconductor market contributed $57m (41% of revenue), up 68% on $34m in Q3, driven by multiple laser annealing systems and an EUV ion-beam system shipment.

The Compound Semiconductor market contributed $45m (33% of revenue), up 67% on $27m in Q3, driven by multiple system shipments for 5G RF applications and shipments to photonic customers. Also, the sale of commodity LED [MOCVD] systems enabled Veeco to monetize slow-moving inventory (generating about $10m of revenue).

The Data Storage market contributed $19m (14% of revenue), down 49% on $37m in Q3.

The Scientific & Other market contributed $17m (12% of revenue), up 6.7% on $15m in Q3, with systems shipped for a variety of research applications.

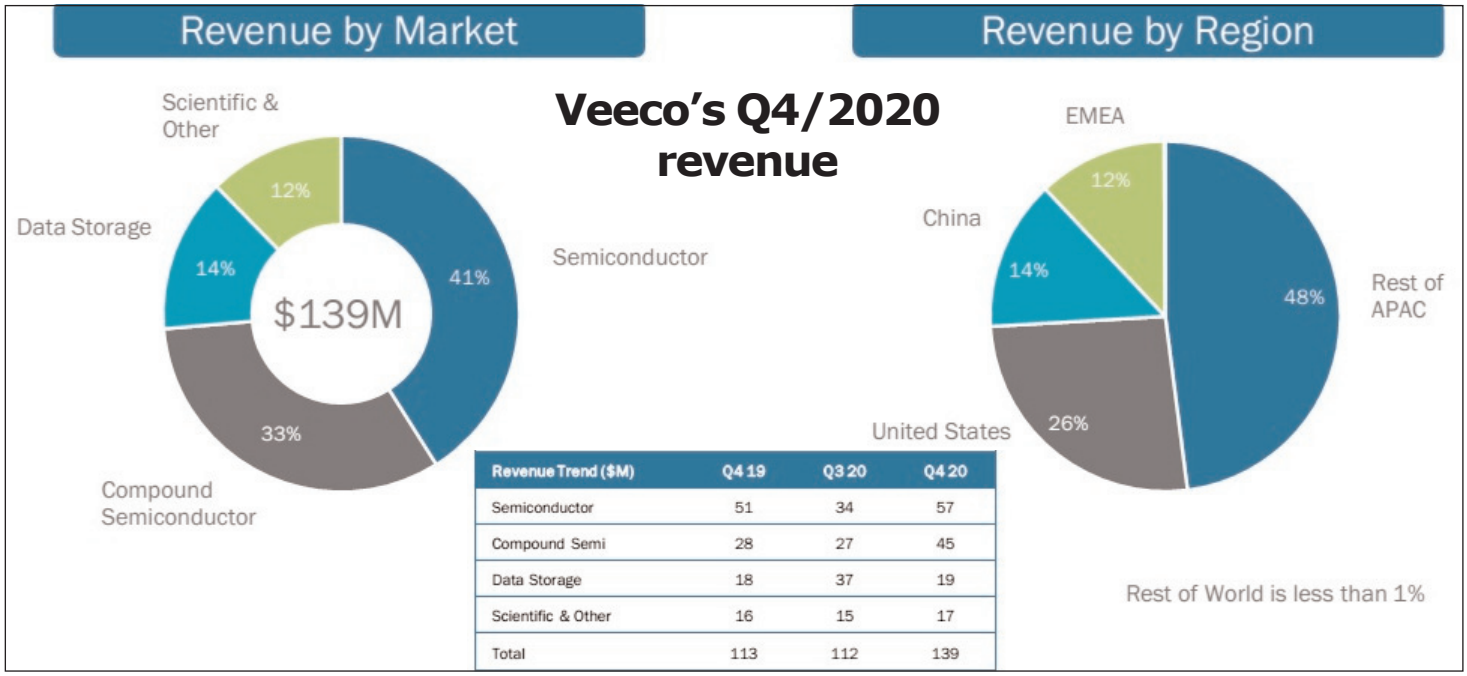
By region, the Asia-Pacific region (excluding China) comprised 48% of revenue, the USA 26%, China 14%, EMEA 12%, and the rest of the world less than 1%.

Due to monetizing slow-moving LED inventory, as well as service costs related to both 5G installations and future semiconductor growth, non-GAAP gross margin was 41.3%, below the 42–44% guidance and down from 44.5% last quarter. Nevertheless, this is still up from 40.2% a year ago. Full-year gross margin has grown from 38.5% for 2019 to 43.3% for 2000. "These improvements reflect the impact of our transformation effort," says chief financial officer John Kiernan.

Operating expenditure (OpEx) was $39.7m, up from $35.7m last quarter and $38m a year ago (and exceeding the targeted $36–38m, although falling from 32% of revenue in Q3 to 29% in Q4/2020). "We incurred higher variable expenses associated with the increase in revenue and order intake," notes Kiernan. "Additionally, we strategically increased R&D expenses as planned in support of our growth initiatives." Despite this, full-year OpEx has still been cut from $156.5m in 2019 to $144m for 2020, as a result of the firm's reorganization and expense management.

Operating income has risen further, from $7.4m a year ago and $14.1m last quarter to $17.6m, boosting full-year operating income from $5.1m in 2019 to $52.5m in 2020.

Quarterly net income has risen further, from $5.4m ($0.11 per diluted share) a year ago and $11m ($0.22 per diluted share) to $15m ($0.30 per diluted share). This has taken full-year net earnings from a



Revenue Trend ($M)	Q4 19	Q3 20	Q4 20
Semiconductor	51	34	57
Compound Semi	28	27	45
Data Storage	18	37	19
Scientific & Other	16	15	17
Total	113	112	139

loss of $1.3m ($0.03 per diluted share) in 2019 to a profit of $42.3m ($0.86 per diluted share) in 2020.

Quarterly cash flow from operations has risen from $10m in Q3 to $15m in Q4 (making $43m for full-year 2020). CapEx was $3.5m (making $6.8m for the year). During Q4, cash and short-term investments hence rose by $10m, from $310m to $320m (up on just $245m a year ago).

"We improved gross margins, reduced operating expenses and improved profitability. We restructured our debt and strengthened our balance sheet," summarizes Miller.

Long-term debt on the balance sheet is $321m, representing the carrying value of $389m in convertible notes. "Over the course of 2020, we went from a single $345m tranche of debt due in January 2023 to a more manageable debt structure with three maturities roughly evenly staggered over the next six years [$132m due in January 2023, $133m due in January 2025, and $125m due in January 2027]," says Kiernan. Total cash interest expense should be $12.9m. "With this debt structure and strong balance sheet, we have the flexibility and capital to focus on driving long-term organic growth across our business," he adds.

From a working capital perspective, accounts receivable remained flat at $80m on increased revenue. Days sales outstanding (DSOs) were reduced from 64 to 52 days. Accounts payable also remained flat at about $34m.

Inventory rose by about $3m, from $143m to $146m, resulting from investments that Veeco is making to ship evaluation systems in 2021 in support of its growth strategy in the Semiconductor and Compound Semiconductor markets.

As a result of a strong year of order intake, Veeco ended 2020 with $366m in order backlog (mostly Data Storage, followed by Semiconductor, Compound Semiconductor and Scientific & Other). A significant portion of the increased Data Storage backlog should be delivered in the second and third quarters of 2021.

"We enter 2021 with healthy backlog, strong customer engagements and overall positive momentum. We look forward to executing our near-term growth strategy, driven in large part by our laser annealing, 5G RF and data storage applications."

For first-quarter 2021, Veeco expects revenue to fall to $115–135m (including just $5m of low-margin slow-moving inventory of LED MOCVD systems). Gross margin should hence be roughly flat at 40–42%, reflecting the anticipated product mix, as well as service costs related to both evaluation systems for Semiconductors and customers' 5G RF ramps.

"We see a tremendous pull for our technology and are planning for success. Typically, we would have one to two evals in the field at a time. In 2021, we expect the evals to reach about 10 in the field [about half in LSA (including some advanced platforms that won't be out until the end of 2021) and some MOCVD tools for power electronics as well as micro-LEDs, plus a wet-processing tool going out shortly] and many of these evals would have a period lasting more than one year or so," notes Kiernan. "As a result, there will be limited amount of benefits that we get to 2021 revenue from these increased evals. So we are supporting these evals ahead of revenue and we are planning for growth in 2022 and beyond," he adds. "We currently view the Q1 gross margins in the 40–42% range as the low point for 2021 and view quarterly gross margins in the range of 40–44% in the quarters as we move forward."

Operating expenses should be cut to $37–39m in Q1/2021, due mainly to a reduction in sales, general & administrative (SG&A) expenses. The firm expects operating income of $10–19m and net income of $6–15m

($0.12–0.30 per diluted share).

Based on its current visibility and backlog, Veeco is increasing its full-year 2021 outlook to revenue of $520–540m (17% annual growth) with EPS of $1–1.20. "We expect Semiconductor market revenue to grow in 2021 on strength in laser annealing systems," says Kiernan. "We expect growth in 2021 in our Data Storage market based upon our order backlog going into the year," he adds.

"As we look out beyond 2021, Semiconductor demand is growing and, as such, we evaluated options that increase production capacity for our laser annealing systems," notes Miller. "We decided investing in a new facility offers the best solution," he adds "We are currently in the final stages of lease negotiations for San Jose property of approximately the same size as our current facility, but with a better footprint allowing us to increase the size and efficiency of our production space," notes Kiernan. CapEx associated with this project should be $30–40m over the next two years. "Additionally, there will be a period of duplicate expenses until the transition to the new facility is completed," he adds.

"With the first phase of our transformation behind us, we will continue to focus on the second phase of our transformation, growing the company organically in the Semiconductor and Compound Semiconductor markets," says Miller. "We think of this growth in two phases, near-term 2021 growth and longer-term 2022 and beyond. Our near-term growth outlook is supported by recent Semiconductor orders from our advanced-node logic customers, demand for 5G RF-related capacity, and market demand and backlog in Data Storage. Looking beyond 2021, we have been investing in our core technologies, which will drive the next phase of Veeco's growth that enable game-changing applications like artificial intelligence (AI), virtual and augmented reality (VR/AR) and electric vehicles (EVs)," he concludes.

www.veeco.com

OIPT to relocate to new manufacturing facility

Move to purpose-built facility driven by growing demand

Plasma etch and deposition processing system maker Oxford Instruments Plasma Technology (OIPT) of Yatton, Bristol, UK plans to move to a new manufacturing facility in Bristol in summer 2022. The relocation is driven by the growing demand from customers (which include leading semiconductor device manufacturers and materials research institutions worldwide, the firm says).

"The continued and accelerating demand for our production and research solutions has meant it's time to create a new facility," says Matt Kelly, managing director of Plasma Technology. "Our new site will be a leading-edge laboratory, manufacturing and office environment for our colleagues, customers and collaboration partners; an inspiring environment that supports team working, innovation, training and provides greater flexibility. Our customers will have even more opportunity to see our solutions and train at our facility. Our building will also be an excellent base to welcome community groups, such as schools and universities promoting STEM subjects," he adds.

"The new premises is just 20 minutes away from our current site and is a purpose-built facility in Bristol," Kelly continues. "We took the decision to keep our manufacturing and R&D facilities in the Bristol area, for several reasons," he adds. "Our employees are of utmost importance to us, and limited disruption to their current work/home life balance was key. We are also passionate about our involvement in and support of the local economy and want to maintain our contribution here. As we grow further, we will continue to provide additional employment opportunities in the Bristol/West-Country tech cluster."

The new facility will include ISO 5 & 6-class application laboratories spanning 1000m^2 equipped with a complete suite of wafer processing solutions and characterization/metrology technologies; many of these being supplied by Oxford Instruments businesses. This is intended to not only enable development of next-generation processes for all customers but also allow continuous improvement, and intense reliability testing of the firm's high-volume manufacturing (HVM) application processes, combining silicon semiconductor standards with compound semiconductor solutions.

The design of the new site incorporates a range of energy-saving technologies to reduce environmental impact, with the goal of eliminating the use of fossil fuels. This includes the option to generate significant amounts of energy from photovoltaic panels, reusing heat from the building's cooling and heating systems, and harvesting rainwater.

https://plasma.oxinst.com

Crystal IS joins LightingEurope

Crystal IS Inc of Green Island, NY, USA (a subsidiary of Japan's Asahi Kasei Group) has joined the industry association LightingEurope, which is based in Brussels, Belgium and represents 30 companies and national associations. Together, these members comprise over 1000 European companies (mostly small- or medium-sized) with a total European workforce of over 100,000 people and annual turnover exceeding €20bn. LightingEurope advocates a positive business and regulatory environment to foster fair competition and growth for the European lighting industry.

Based on its proprietary aluminium nitride (AlN) material, Crystal IS manufactures Klaran ultraviolet light-emitting diodes (UV-C LEDs, emitting at germicidal wavelengths of 260–270nm) and systems for disinfection applications, as well as deep-UV LEDs (emitting at wavelengths of 230–280nm) for sensors in absorption and fluorescence spectroscopy.

"The Covid19 pandemic highlights the need for innovative disinfection products to combat the spread of harmful viruses, whether airborne or on everyday high-contact surfaces," says Crystal IS' CEO Larry Felton. "It's also evident that we need guidelines to ensure that these products provide real disinfection and end-user benefits," he adds. "LightingEurope's mandate to educate institutions and policy makers on the benefits, safety and opportunities brought by innovations in the European lighting market fits our mission to create UVC solutions for healthy living around the world. We look forward to working with LightingEurope and the general lighting industry to advance the use of safe UVC disinfection for infection prevention."

"Interest in UV-C disinfection technologies has boomed over the past months, and LightingEurope offers a unique collaboration platform for manufacturers to ensure safe quality UV-C products are being made available," says LightingEurope's secretary general Ourania Georgoutsakou. "As a LED UV-C specialist, Crystal IS will substantively contribute to our mission on behalf of Europe's lighting industry to accelerate the uptake of good lighting and UV-C disinfection technologies in the new framework of the EU Green Deal and the Renovation Wave Initiative," he adds.

www.cisuvc.com/products/klaran
www.lightingeurope.org

Kubos demos commercially compatible cubic GaN LEDs

Cambridge spin-off aims to license technology to LED makers

Spun out of the University of Cambridge in 2017 — with an exclusive license to its proprietary cubic gallium nitride (GaN) intellectual property to deliver efficient green and amber LEDs — Kubos Semiconductors Ltd of Cambridge, UK says that it has demonstrated the first commercially compatible LEDs based on the cubic crystal phase of GaN, representing a step towards more efficient solid-state lighting.

"This is a culmination of several years of research and development by Kubos and the Cambridge Centre for Gallium Nitride," notes technical director professor David Wallis. "Using the cubic crystal phase of GaN overcomes the limitations of conventional GaN LEDs [through the removal of internal electric fields and a narrower bandgap], allowing us to ultimately deliver significantly higher-efficiency green and amber devices. These devices underline the material's potential and demonstrate another big step towards achieving full commercialization."

Having efficient green and amber LEDs should enable the next stage in the development of solid-state lighting (SSL) solutions, allowing greater control of the lit environment, further energy savings and carbon impact reduction, says the firm. Additionally, by translating the performance benefits of cubic GaN in the lighting sector to smaller devices, the technology could also be a game-changer for micro-LEDs for full-color displays, it adds.

"Previously, cubic GaN has been developed as part of small-reach activities," says CEO Caroline O'Brien. "The process that Kubos is developing is fully compatible with large-scale, volume manufacturing, and Kubos holds the unique IP that makes this ground-breaking technological development possible," she adds.

"As Kubos opens its next round of funding and broadens customer engagements, these devices further strengthen the arguments for cubic GaN to be used in devices across the visible spectrum and its potential to address both the green gap in LEDs and the current limitations in red micro-LEDs."

Kubos claims that its technology can enable production of commercial high-end, low-cost, highly efficient LEDs by fundamentally solving the long-standing green-gap problem in solid-state lighting. The technology is applicable to a wide range of applications including general lighting, micro-LED displays, automotive, street lighting and digital signage.

Kubos plans to license the technology to major LED makers.

The 2020 Cambridge Independent Science and Technology awards has shortlisted Kubos as a finalist in the start-up of the year category.

Low Carbon Innovation Funds (LCIF) 1 & 2, both managed by specialist low-carbon investor Turquoise International, have backed Kubos. LCIF2 invests in early- and late-stage ventures that make measurable reductions to greenhouse-gas emissions, with the creation of financial return and sustainability as the primary goals.

www.kubos-semi.com

Nitride continues enforcement against infringement of UV-LED patent

On 18 February, Japan's Nitride Semiconductors Co Ltd (which was spun off from Tokushima University in 2000 and claims to have developed the first highly efficient ultraviolet light-emitting diode) filed a complaint against global electrical components distributor Digi-Key Corp in the US District Court for the District of Minnesota, asserting that UV-LED products being supplied by various LED companies — such as American Opto Plus LED Corp, Crystal IS Inc, Kingbright Electronic Co Ltd and QT-Brightek Corp — have been infringing its UV-LED patent. In an earlier-filed patent litigation against Digikey, Nitride has already accused patent infringement against UV-LED products of Luminus Device Inc and Lite-On Semiconductor Corp.

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

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

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

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

www.nitride.co.jp

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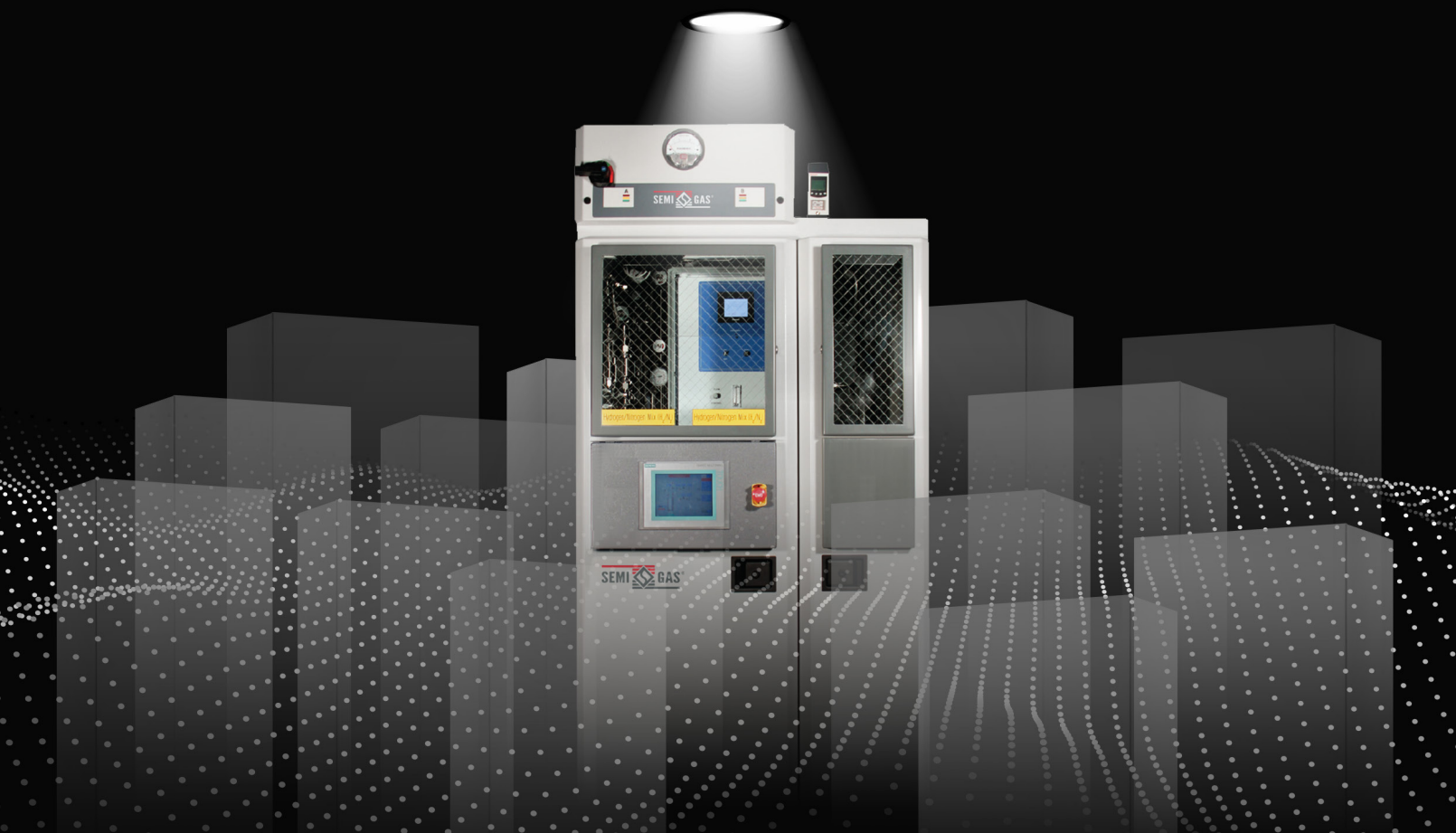

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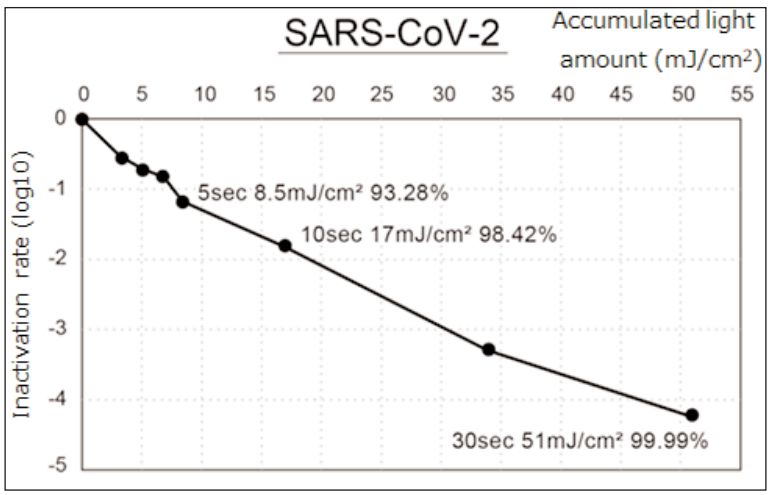
Nichia's new 280nm deep-UV LEDs eliminates up to 99.99% of SARS-CoV-2

Virucidal power of 280nm LED about 1.3 times that of 265nm LEDs

Nichia Corp of Anan City, Tokushima, Japan has launched the NCSU334B deep-UV LED which, at a peak wavelength of 280nm, is claimed to outperform other commercially available UV-C LEDs (regardless of wavelength) in output, efficiency and lifetime. Meanwhile, independent research has confirmed that they are also best-in-class for disinfection performance against the SARS-CoV-2 novel coronavirus.

Nichia says that its UV-C LED technology was extensively tested at Tokushima University to demonstrate its bacteria and virus disinfection efficiencies. Experiments conducted by the Graduate School of Biomedical Sciences confirmed that irradiating SARS-CoV-2 with the NCSU334B for 30s at a fluence (UV dose) of 51mJ/cm^2 yielded 99.99% inactivation (see Figure 1). The experiment was also conducted on the basis of the NCSU334B's binned input power and for 1.7mJ/cm^2 and 5cm distance. There remains adequate room to reduce the time or increase the dosage, depending on the conditions or the designated working distance, the number of LEDs or the input power. For example, at half the working distance, the performance increases fourfold.

Reflecting its commitment to serve global markets, Nichia has scaled up its investment in R&D and manufacturing capacity for its UV LED products. Now in mass production, the NCSU334B, at a wavelength of 280nm, achieves what is claimed to be industry-leading output, efficiency and lifetime. It delivers a typical irradiance of 70mW with a wall-plug efficiency (radiance efficiency) of 3.6% (an improvement of 27% on its predecessor). Due to its hermetic seal, it also provides long lifetime performance, especially at peak temperatures and humidity levels.



SARS-CoV-2/Hu/DP/Kng/19-020 (GenBank: LC528232), provided by Kanagawa Prefectural Institute of Public Health.

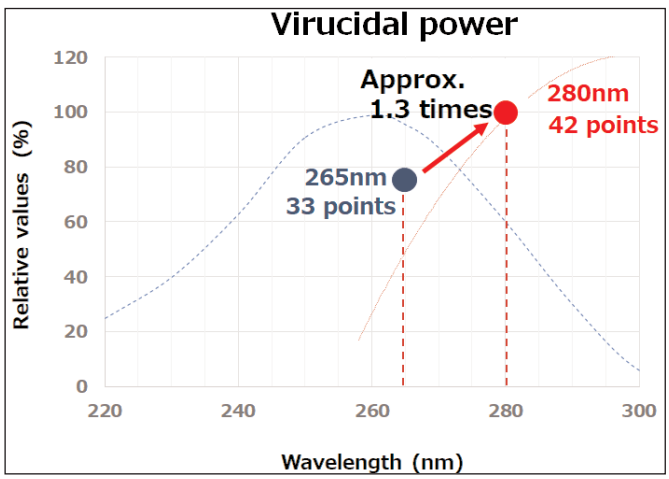
While traditional UV-C technologies, such as low-pressure mercury vapor lamps, were limited to a 254nm peak, the most efficient wavelength to disinfect bacteria and viruses is known to be 260nm due to the peak absorption spectrum of the DNA/RNA. However, Nichia has demonstrated that 280nm delivers the highest virucidal power as it has a very strong irradiance, wall-plug efficiency and lifetime, all at practical operating conditions versus what are described as many other unreasonable claims in the market. Indeed, data highlights that the virucidal power of the 280nm LED is about 1.3 times (127%) that of 265nm LEDs. The 280nm LED also delivers a lifetime ten times longer than a 265nm LED.

Generally, the advantageous compact size of LED-based UV-C solutions means that they can be directly integrated within disinfection applications in restricted spaces including industrial applications, water purifiers, air conditioning systems etc.

UV-C light is making a significant contribution to combatting viruses and bacteria, simplifying traditional methods. For example, to obtain a high viricidal effect (i.e. 4-log) when using an alcohol solution for disinfection (containing 77–81% ethanol), surfaces need to be sufficiently wetted with the substance or require significant effort and time (often times beyond 30s). Used in conjunction with such measures, Nichia's 280nm deep UV LED can provide a highly viricidal effect while saving time and effort.

Nichia says that, after succeeding in 1997 in developing and mass-producing deep UV LEDs, it aims continuously to improve its products. So, after many years of accumulated research into the technology of crystal growth and package structures with efficient heat dissipation, the firm plans to announce further expansion of its UV-C portfolio soon.

www.nichia.co.jp



Osram acquires 20% stake in UV-C LED firm Bolb

Strategic investment to strengthen disinfection technology

Osram GmbH of Munich, Germany is further expanding its expertise in disinfection applications using UV-C ultraviolet light by investing in the UV-C LED specialist Bolb Inc of Livermore, CA, USA, acquiring a stake of about 20% in the firm.

Future cooperation between the two companies in research is aimed at accelerating the industrialization of highly efficient and high-performance UV-C LEDs. Unlike previous solutions, LED-based disinfection systems require very little space and can be installed directly at the point of use — such as in water taps, washing machines or ventilation systems. Space-saving disinfection solutions can make an important contribution to combating the coronavirus, reckons Osram. The market for UV disinfection solutions is currently worth about €1bn and will quadruple by 2027, forecasts Allied Market Research.

Market researchers also expect the share of UV-C LED solutions to grow steadily.

Similar to the many advantages that LEDs provide for conventional lighting applications versus traditional lighting technologies, UV-C LEDs promise a variety of benefits for manufacturers of disinfection solutions. These include lower energy consumption, long lifetime and significantly simplified system design due to the compact size of the light sources.

"Osram already has various UV-C light solutions for disinfection, including LED and traditional technologies," says Olaf Berlien, CEO of OSRAM Licht. "The strategic investment in Bolb strengthens our know-how in the UV-C LED field

"Osram already has various UV-C light solutions for disinfection, including LED and traditional technologies," says Olaf Berlien, CEO of OSRAM Licht AG. "The strategic investment in Bolb strengthens our know-how in the UV-C LED field," he reckons.

Due to a unique technical building block for UV-C LEDs, Bolb has already achieved efficiency values ahead of other products available on the market, it is claimed. "With Osram's decades of experience in the development and manufacturing of semiconductor-based products, this partnership sets the course for Osram and Bolb to lead the market for UV-C LEDs," expects Ulrich Eisele, head of Fluxunit, Osram's venture capital unit.

www.bolb.co
www.osram.com
www.fluxunit.de

NewEnergy launches linear module using Luminus LEDs

Human-centric lighting with 3000K, 4000K and 5000K CCTs targets high melanopic ratios

Luminus Inc of Sunnyvale, CA, USA — which designs and makes LEDs and solid-state technology (SST) light sources for illumination markets — and North Carolina-based NewEnergy LLC have introduced new linear modules built with Salud MP3030 LEDs.

Salud LEDs are engineered to achieve specific melanopic/photopic ratios in addition to providing light that is both comfortable and renders true colors. NewEnergy's Salud linears deliver light that aims to keep people healthy, alert and productive and are available in correlated color temperatures (CCTs) of 3000K, 4000K and 5000K. The linear modules are suitable for indoor applications including offices, schools, nursing homes, retail locations, hospitals and medical facilities — places where comfortable lighting and smart design can promote productivity and wellness.

The standards of the International WELL Building Institute (IWBI) have paved the way for the design, creation and implementation of spaces that promote human health and wellness, as well as daily productivity. The Salud linears can aid the design and creation of space that is both welcoming and healthy. The high melanopic ratios of the 3000K, 4000K and 5000K linear boards can enable lighting designers to meet the equivalent melanopic lux (EML) requirement of the WELL Building standard without having to use cool CCTs like 6500K and without having to over-light the environment.

Features of the linear modules include the following:

- an engineered spectrum with enhanced cyan for melatonin suppression;
- full-spectrum emission (no cyan gap);
- color rendering Ra>90;
- enriched 660nm emission for natural skin tones and excellent red rendering;
- configurable with off-the-shelf optics; and
- 4000K Salud suitable for luminaires requiring compliance with the Cyanosis Observation Index (COI).

The modules are available through NewEnergy's distribution channels including Digi-Key Corp and Mouser.

www.new-energyllc.com

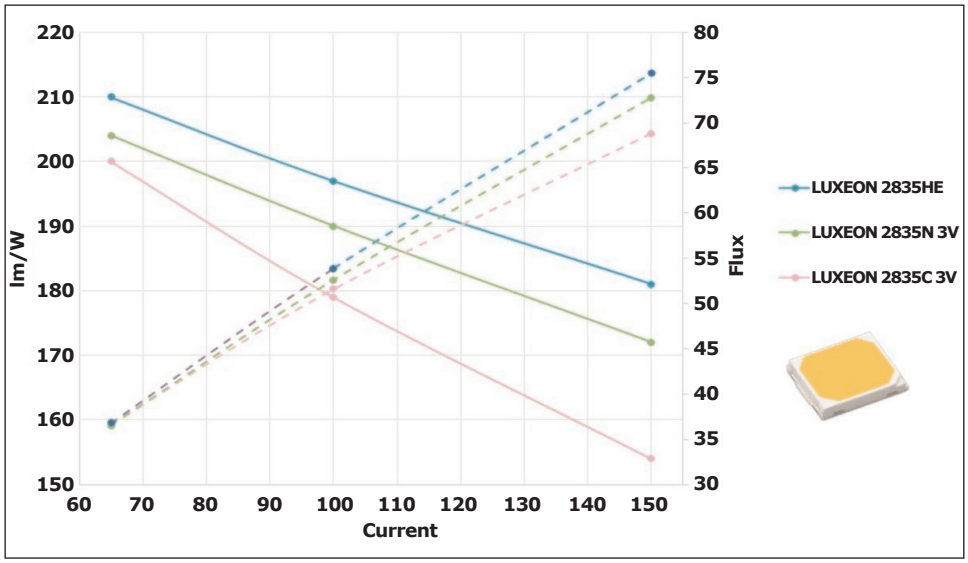
Lumileds fills 2835 mid-power LED performance gap

LUXEON 2835N slots in between 2835C and 2835 HE

LED maker Lumileds LLC of San Jose, CA, USA has launched the LUXEON 2835N, which fills in the performance gap between the LUXEON 2835C and the 2835 HE.

The three variants are relatively close in performance at a drive current of 65mA — LUXEON 2835N delivers 204 lumens per Watt — but, as current increases, real differences in both light output and efficacy become clear. With its 300mA current capability and thermal characteristics, the LUXEON 2835N is reckoned to be an optimal 3V choice.

"The value of LUXEON 2835N really starts to show itself as luminaire manufacturers take advantage of its current and thermal capabilities," says product manager Ryan Dong. "At 100mA, we're delivering 190lm/W and at 150mA LUXEON 2835N is producing 72.8 lumens with an efficacy of 172lm/W."



LUXEON 2835N is available in a complete CCT/CRI portfolio. Both 80 and 90 CRI (color rendering index) are supported at CCTs (correlated color temperatures) from 1800K to 6500K. The reliable package has been proven with more than 12,000 hours of data for the LM80 report. 4-quadrant micro color bins and 0.1Vf bins complete an offering for luminaire manufacturers that gives them access to the exact parts needed.

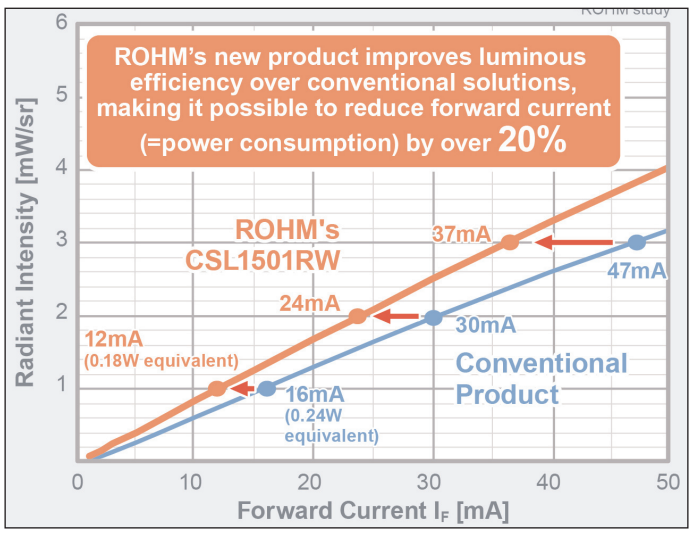
www.lumileds.com/2835N

ROHM expands PICOLED range with side-emitting infrared LED for virtual/mixed/augmented reality

ROHM has expanded its PICOLED range of ultra-compact chip LEDs for compact mobile devices and wearables by launching the CSL1501RW side-emitting (side view) infrared LED, suitable for head-mounted displays, industrial headsets, and VR/MR/AR (xR, virtual/mixed/augmented reality) gaming systems.

In recent years, VR/MR/AR technology, which has emerged following the continuing advancement of the Internet of Things (IoT), is being increasingly adopted in headsets and head-mounted displays within a variety of gaming systems. The ability to simulate 3D space and project data in the real world has expanded the market for VR/MR/AR applications in the industrial sector as well.

In parallel, increasing application functionality has led to the use of IR LEDs for eye tracking together with accelerometers commonly installed for detecting body movement.



In response, ROHM is now offering a new ultra-miniature infrared LED with a side-firing design, optimized for the versatility required as a light source for eye-tracking in VR/MR/AR applications.

The CSL1501RW delivers a peak wavelength of 860nm in what is said to be the industry's smallest (1.0mmx0.55mm, t=0.5mm) side-view design that emits light parallel to the mounting surface, providing exceptional design flexibility. Also, ROHM says it has leveraged its strengths in LED chip manufacturing to improve luminous efficiency and reduce power consumption by over 20% (from 0.24W to 0.18W at 1mW/sr). The device can hence serve as a light source for eye tracking in VR/MR/AR applications that require greater performance.

After samples were made available in November (at $0.36 per unit, excluding tax), mass production will begin in March.

www.rohm.com

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LED lighting development wins 2021 QEPrize

Isamu Akasaki, Shuji Nakamura, Nick Holonyak Jr, M. George Craford and Russell Dupuis awarded engineering accolade

The 2021 QEPrize (comprising a total cash prize of £1m) has been awarded to Isamu Akasaki, Shuji Nakamura, Nick Holonyak Jr, M. George Craford and Russell Dupuis for the creation and development of LED lighting, recognizing not only the global impact of LED and solid-state lighting but also the contribution that the technology has made, and will continue to make, to reducing energy consumption and addressing climate change.

First awarded in 2013 in the name of the UK's Queen Elizabeth II, the 2021 QEPrize was open to up to five living individuals (of any nationality) personally responsible for a ground-breaking innovation in engineering that has been of global benefit to humanity.

The 2021 winners were announced by Lord Browne of Madingley, chairman of the Queen Elizabeth Prize for Engineering Foundation.

Visible LEDs now comprise a global industry predicted to be worth over $108bn by 2025 through low-cost, high-efficiency lighting. LED lighting is 75% more energy efficient than traditional incandescent and compact fluorescent bulbs, and is playing a crucial role in reducing carbon dioxide emissions. LED bulbs last 25 times longer than incandescent bulbs and their large-scale use reduces the energy demand required to cool buildings.

"This is a team prize. I was able to do what I did in the 1980s, because of what had come before," comments professor Nakamura. "When I was modifying reactors every morning and every afternoon continuously for a year and a half, I never thought it would be so successful," he adds.

"The QEPrize is so prestigious and it is spectacular to receive recognition from The Royal Family," says Craford. "I am proud to part of something that has made such a big impact on the world," he adds.

"All five of us each played an important role," notes professor Dupuis. "In those early days, when it was long days and nights hand-building reactors, Nick Holonyak mentored us. He really drew us in and inspired us to be part of the adventure that is engineering."

"This year's prize winners have not only helped humanity to achieve a greater degree of mastery over the environment, they have enabled us to do so in a sustainable way. They have created a product which we now take for granted, but which will play a major role in ensuring that humanity can live in harmony with nature for many more centuries to come," comments Lord Browne of Madingley, chairman, Queen Elizabeth Prize for Engineering Foundation, which administers the QEPrize.

The impact of the innovation "makes lighting a lot cheaper and more accessible for emerging economies," notes professor Sir Christopher Snowden, chair of the QEPrize Judging Panel. "For example, LEDs are being used on fishing boats where previously the only option would have been paraffin lamps. They are much cheaper and safer. It is not only an extreme engineering achievement, but a societal impact that has a significant impact on the environment."

The winners will be formally honoured at a ceremony later this year; they will receive the £1m prize and a trophy designed by the 2021 Create the Trophy winner Hannah Goldsmith, a 20-year-old design student from the UK.

The QEPrize is funded by support from the following corporate donors: BAE Systems plc, BP plc, GlaxoSmithKline, Hitachi Ltd, Jaguar Land Rover, National Grid plc, Nissan Motor Corp, Shell UK Ltd, Siemens UK, Sony, Tata Steel Europe, Tata Consultancy Services, and Toshiba.

www.qeprize.org

Strathclyde's Martin Dawson wins OSA's Nick Holonyak Jr Award

Recognition for contribution to development and application of III–V optoelectronic devices

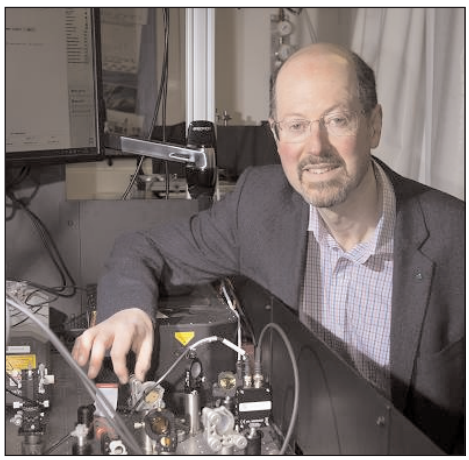
Professor Martin Dawson, director of research at Strathclyde's Institute of Photonics and also head of the Strathclyde-hosted Fraunhofer Centre for Applied Photonics, has been named as the 2021 recipient of The Optical Society's (OSA) Nick Holonyak Jr Award.

The award is presented annually for significant contributions to optics based on semiconductor devices and materials. Dawson is the first UK-based recipient of the award since it was established in 1997.

"It coincides with the 25th anniversary of the founding of the Institute of Photonics, so the timing couldn't have been better, and it is a credit to the scientific adventurousness and close collaboration and teamwork which have been features of the Institute since the outset," says Dawson.

"Martin Dawson's pioneering work on III-V semiconductor devices perfectly represents the spirit of the Nick Holonyak Jr Award," comments 2021 OSA president Connie Chang-Hasnain, Whinnery Chair Professor Emerita of EECS at University of California, Berkeley, USA.

Dawson's career has focused on applied research in academia and industry in the UK and USA and he has been involved in the formation and technical development of a number of spinout businesses. His work involves semiconductor materials, microfabrication, optoelectronic device development and laser technology, with applications in optical wireless communications, displays, biomedical instrumentation and the heterogeneous integration of separately manufactured components into single devices.



Professor Martin Dawson (photo by Fraunhofer UK.)

He is receiving the award for "wide-ranging contributions to the development and application of III–V semiconductor devices, especially including gallium nitride micro-LEDs and optically pumped semiconductor lasers".

"The two areas highlighted in the citation have deep roots at Strathclyde and both are of industrial as well as basic research significance," says Dawson. "Micro-LED technology is now taking off worldwide for new types of high-performance displays, with stunning prototypes and initial commercial products appearing rapidly, so it is particularly gratifying to see our role in the founding and development of the field recognized in this way," he adds.

"When we established the Institute of Photonics, we took a distinctive approach in focusing on applications-driven work of industrial relevance, but of course no-one can predict exactly how markets for new technology will emerge," Dawson continues. "The display industry is incredibly competitive and it will be fascinating to see how micro-LED technology fits into the broader commercial landscape in the years ahead."

Dawson was previously awarded the 2016 Gabor Medal and Prize by the UK's Institute of Physics (IOP) and the 2016 Aron Kressel Award by the IEEE Photonics Society.

www.osa.org
www.strath.ac.uk/science/physics/instituteofphotonics
www.cap.fraunhofer.co.uk

Rockley raises additional $65m to accelerate growth

Funding to speed development of integrated optical sensors products

Rockley Photonics of Oxford, UK and Pasadena, CA, USA has closed an additional $65m round of growth capital from both new private funds and follow-on existing investor Morningside Ventures. To date, Rockley has raised over $290m of financing to develop its unique silicon photonics platform from recent investors such as Credit Suisse backed SIG-I Capital and Applied Ventures LLC (the venture capital arm of Applied Materials Inc).

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

"There is tremendous need for technologies that can enable effective digital health and wellness, driven by the associated benefit provided to population health," says Rickman. "This funding provides the resources for Rockley to dramatically accelerate its product offerings, particularly our integrated optical sensors products. We are committed to our tier-1 customers and our ability to help expand their product offerings and the innovative data-driven business models these products will enable," he adds.

"We are very pleased to support Rockley at this juncture of the company's development and contribute to the commercial success of their integrated optical chipsets and related products in multiple markets," comments Morningside Group investment manager Mick Sawka. "Silicon photonics is at a tipping point, and the technical attributes of Rockley's platform, coupled with the strong product roadmap and established high-volume production ecosystem, uniquely positions the company for growth in exciting verticals of interest including healthcare and communications," he believes.

Rockley was recently named as an early constituent in the Lazard T100 Venture Growth Index, a developing collection of selected firms demonstrating the potential to disrupt multi-billion-dollar sectors and shaping the European venture growth ecosystem.

www.rockleyphotonics.com

II–VI launches 1060nm seed laser for fiber lasers in materials processing

3-pin package allows sharing manufacturing line with telecom pump lasers

Engineered materials and optoelectronic component maker II–VI Inc of Saxonburg, PA, USA, has launched a 1060nm seed laser in a 3-pin miniature package for pulsed fiber lasers in materials processing.

The intensifying competition in the industrial laser market is driving demand for components that are more compact and lower cost to differentiate next-generation laser systems, notes the firm. Its new seed laser, which emits a broadband spectrum of more than 10nm at 1060nm, is now available in a 3-pin miniature package.

The new product benefits from sharing the manufacturing line with II–VI's telecom pump lasers in the same package, which are already being manufactured at scale.

"The success of our gallium arsenide (GaAs) technology platform is the result of decades of investment in the design, manufacturing, and modeling of our lasers and our ability to scale to a vertically integrated 6-inch platform over the last few years," says Dr Karlheinz Gulden, senior VP, Laser Devices and Systems business unit. "We have led the market in component miniaturization for telecom applications," he claims, "and we are now leveraging these innovations for fiber lasers. Our 3-pin package was the first of its kind for telecom pump lasers, and now it is the first of its kind for seed sources for pulsed fiber lasers."

II–VI Inc's broad portfolio of components for fiber-laser systems includes seed lasers, pump lasers, acousto-optic modulators, fiber Bragg gratings, kilowatt pump and signal combiners, matched chirped mirror pairs, dispersion-compensation prism pairs, diffractive gratings, polarization-mode combiners, ion beam sputtering (IBS) coated laser optics, and micro-optics for high-power isolators.

II–VI is showcasing its product line of optics and lasers at the 2021 SPIE Photonics West Digital Forum (6–11 March).

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

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II–VI launches double-junction 940nm VCSEL arrays for 3D sensing

Output doubled and power conversion efficiency boosted to 56%

Engineered materials and optoelectronic component maker II–VI Inc of Saxonburg, PA, USA has announced its double-junction vertical-cavity surface-emitting laser (VCSEL) arrays, the first of its multi-junction VCSEL array platforms for next-generation world-facing 3D sensing applications.

The growing adoption of 3D sensing in several markets (including in consumer electronics, automotive and industrial) is driving demand for depth sensors with longer and wider range, lower power consumption, smaller size and lower cost. II–VI's new VCSEL arrays are based on a double-junction technology that doubles the power output per VCSEL emitter and improves the power conversion efficiency to 56%, compared with 46% in existing single-junction technology. This can be leveraged for a number of benefits, including higher output power to sense further and wider, reduced battery power consumption, and smaller size to achieve lower cost and to enable more inconspicuous designs, says the firm.

"We have developed over the years strong partnerships with our customers, closely collaborating on the development of long-term technology and product roadmaps aimed at providing breakthrough solutions and continuously elevating user experience in 3D sensing," says Dr Julie Eng, senior VP, Optoelectronic & RF Devices business unit. "A few years ago, we successfully scaled our vertically integrated GaAs optoelectronics technology platform from 3-inch to 6-inch, which enabled us to shorten our development cycles and introduce new products to meet aggressive market windows," he adds. "We are now once again evolving the platform, this time with a leap to double-junction technology that we believe will unlock exciting new use cases, such as farther depth of sensing in world-facing applications and seamless integration into consumer products for AR [augmented reality] and VR [virtual reality] applications."

II–VI's double-junction VCSEL arrays emit at 940nm, and their steep slope efficiencies enable very short pulses of very high peak powers. The VCSEL arrays are designed for low-cost non-hermetic packaging and, like the single-junction arrays, can be reliably and cost-effectively scaled in total power by increasing the number of emitters per chip, says the firm. They can also be produced in high volume on II–VI's vertically integrated 6-inch platform.

II–VI's portfolio of products for 3D sensing includes diffractive optical elements (DOEs) and thin-film filters that are produced at wafer-scale for high-volume applications. DOE flat lenses and lenslet arrays collimate, focus or transform beams from VCSEL arrays. DOE diffusers homogenize the output of VCSEL arrays and produce a uniform field of illumination. DOE splitters separate an input beam into multiple output beams. Filters are used to improve the signal-to-noise ratio of the image sensor array. II–VI VCSEL arrays are available as chips or integrated with DOEs in surface-mount technology packages.

II–VI is showcasing its product line of lasers and optics for 3D sensing at the 2021 SPIE Photonics West Digital Forum (6–11 March).

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

II–VI Inc wins Fujitsu Supply Chain Excellence Award

II–VI Inc of Saxonburg, PA, USA, which makes optical transceivers, has received the Supply Chain Excellence Award 2020 from Fujitsu Network Communications Inc (a provider of business, information technology and communications solutions) at its virtual Supplier Appreciation Day held on 14 January. II–VI was honored by Fujitsu in recognition of its excellent overall performance, including achievement of 100% on-time delivery.

"II–VI is proud to receive this recognition from Fujitsu and would like to thank our operations teams for their dedication to excellence that made it possible," says Dr Lee Xu, senior VP, Transceivers business unit. "The award is a strong demonstration of our ability to leverage our vertical integration and global supply chain management to deliver advanced transceivers at scale to a world-class equipment manufacturer that demands superior quality."

II–VI offers a broad portfolio of transceivers that are fully compliant with all the most widely deployed standards, including Ethernet, Fibre Channel, InfiniBand, SONET/SDH/OTN, CPRI and PON. The firm's transceivers operate at data rates from 100Mbps to 800Gbps and perform over extended voltage and temperature ranges while minimizing jitter, electromagnetic interference (EMI), and power dissipation. They range from very short to very long reaches, encompassing data-center, campus, access, metro, wireless and long-haul applications.

www.fujitsu.com/global/services/infrastructure/network
www.ii-vi.com

Osram's new edge-emitting laser chip design matches wavelength stability of VCSELs

Enabling smaller wavelength filter on detector boosts signal-to-noise ratio for LiDAR in autonomous vehicles

Light detection & ranging (LiDAR), which uses infrared light to create a precise, three-dimensional map of the environment, is a key technology in the development of autonomous vehicles (AVs). In combination with radar and camera systems, it acts as the vision of the car, capturing its surroundings. The better the visual information provided by LiDAR, the easier it is for the downstream systems to use it, notes Germany's Osram.

Up to now, the infrared lasers used for this purpose have had deviations in wavelength stability of up to 40nm as temperature rises in the component. As a result, the LiDAR system's 'vision' was a bit blurred. Osram says that it has produced a novel chip design that now reduces the wavelength shift to just 10nm, enabling much clearer and sharper images of the surroundings.

Due to the newly developed chip design, edge-emitting lasers can match and even exceed the wavelength stability of vertical-cavity surface-emitting lasers (VCSELs) at operating temperatures of up to 125°C typical for automotive applications, reckons Osram. This milestone in the development of infrared lasers allows the use of a much smaller wavelength filter on the detector, significantly improving the signal-to-noise ratio, claims the firm.

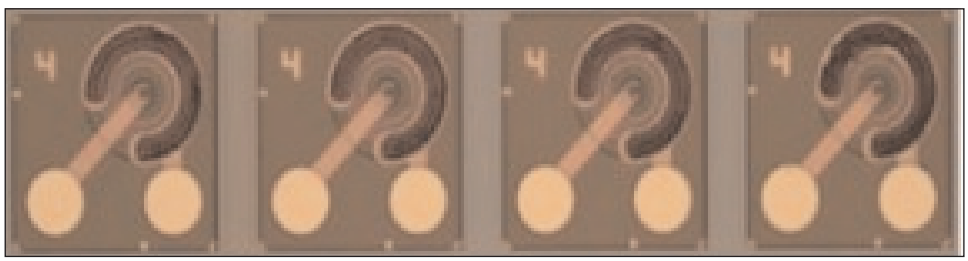
The technical advance has been demonstrated in components with triple-junctions (three light-emitting surfaces stacked one on top of the other). In the future, the new design will be used in all Osram infrared lasers, offering enormous advantages to LiDAR system manufacturers, reckons the firm.

www.osram.com

Seoul Viosys begins production of 25G VCSELs for 5G

Production for sensor applications starting in Q1/2021

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



As a light-based communication technology, VCSELs can achieve ultra-high-speed data communication in 5G environments. They are also necessary for augmented reality (AR)/virtual reality (VR), 3D sensing and the camera-applied ToF (time of flight) for smartphones, as well as automotive light detection & ranging (LiDAR). Seoul Viosys' VCSELs for sensor applications have already received customers' approval and will be mass-produced in first-quarter 2021, and the LiDAR technology is also undergoing the approval process to be supplied to an automotive system provider. According to the market research firm Yole Développement, the VCSEL market is expected to grow 18.4% annually from $1.1bn in 2020 to $2.7bn in 2025.

The 25Gbps VCSEL market has seen three large US-based firms — II–VI, Lumentum and Broadcom — involved in a power struggle for these high-value-added products (which have a selling price more than 10 times larger than that of an LED). Seoul Viosys' VCSEL can be implemented in single-channel or four-channel configurations, depending on the intended use, with the four-channel implementation providing 100Gbps (4x) data reception and transmission. Although VCSEL technology involves a high degree of difficulty in implementation, it is expected to span a wide range of applications in the future, as it is price competitive compared with horizontal-type laser diodes that emit light from the sides.

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

www.seoulviosys.com

Emcore's quarterly Broadband revenue up 68% year-on-year

CATV manufacturing maintained in Beijing till end-2021 to hedge COVID-19 risks

For fiscal first-quarter 2021 (to end-December 2020), Emcore Corp of Alhambra, CA, USA — which provides mixed-signal products for the aerospace & defense and broadband communications markets — has reported revenue of $33.4m, level with $33.5m last quarter (the largest quarterly revenue since December 2014) and up 31% on $25.5m a year ago.

Broadband segment revenue was $19.8m (59.3% of total revenue), up 4% on $19m last quarter and up 68% on $11.8m a year ago, driven by the continued surge in demand for cable TV optical transmitters and components, as MSOs continued to invest in their networks to break bottlenecks caused by bandwidth demand from work-at-home initiatives.

Aerospace & Defense (A&D) segment revenue was $13.6m (40.7% of total revenue), roughly level with $13.7m a year ago but down 6% on $14.5m last quarter, due primarily to the program timing for quartz micro-electro-mechanical system (QMEMS) Navigation products (for which revenue was down 8%), since contract delivery dates tend to mirror the government's fiscal year (which ends in September). Revenue for Defense Optoelectronics product lines was essentially flat, although the new millimeter-wave Q- and V-band products continue to gain customer interest in the market across military and commercial applications.

"From an operational perspective, the supply chain and operations team continued to meet the challenges of COVID-19 driven shortages," notes president & CEO Jeff Rittichier. "The biggest difficulties were delays caused by air freight and customs, especially at the end of the quarter [impacting revenue by almost $0.5m]. While we foresaw these problems, they were a bit worse than we expected."

On a non-GAAP basis, gross margin was 38%, level with last quarter but up from just 30% a year ago. Broadband's gross margin saw a further rise, from 26% a year ago and 42% last quarter to 43%, driven primarily by the segment's higher revenue. Conversely, A&D's gross margin fell slightly further, from 33% a year ago and 32% last quarter to 31%.

Operating expenses (OpEx) improved again to $9.3m (28% of revenue), cut from $9.7m (29% of revenue) last quarter (having been 36.9% of revenue a year ago), due primarily to reduced project-related R&D expenses (with A&D R&D expenses falling from $4m to $3.56m, and Broadband R&D expenses falling from $0.62m to $0.53m).

As a result of another strong quarterly performance for revenue and gross margin, combined with the lower OpEx, net income was $3.4m ($0.11 per diluted share), a further improvement from $2.9m ($0.10 per diluted share) last quarter and a net loss of $1.8m ($0.06 per diluted share) a year ago.

From an operational perspective, the supply chain and operations team continued to meet the challenges of COVID-19 driven shortages. The biggest difficulties were delays caused by air freight and customs, especially at the end of the quarter. While we foresaw these problems, they were a bit worse than we expected

"The Emcore team executed well in Q1/2021, combining revenue and gross margin consistency with lower operating expenses to drive strong sequential-quarter earnings growth," comments Rittichier. "We continued to overcome COVID-19-related challenges in our supply chain and operations, and made good progress on product qualification and new programs capture despite the COVID headwinds."

Cash generated from operations was $1.6m (level with last quarter). Capital expenditure (CapEx) was $900,000 (down from $1.1m). During the quarter, cash (net of a $6.5m loan payable) therefore rose by $0.7m, from $24m to $24.7m.

The transition of cable TV manufacturing operations from Emcore Asia (EA) in Beijing, China to Shenzhen-based electronics manufacturing services (EMS) provider Hytera Communications' facility in Bangkok, Thailand made "significant progress against its operational milestones: transmitter yields in Bangkok remain on target and laser module yields continue to improve," notes Rittichier. "Strong demand from our customers and the rash of COVID-19 outbreaks in both the Hebei province in China as well as Thailand dictate that our best strategy is to hedge the geographic risk of COVID-19 outbreak by continuing to operate Beijing and Bangkok in parallel until the end of the calendar year. In addition, our customers simply cannot afford the temporary loss of production capacity associated with the final move to Bangkok. We responded rapidly to challenges to keep production on plan, but these incidents demanded additional measures to deal with the problem. Going forward, we will also ship lasers for our sensing customers

out of Alhambra to further hedge risk and increase production volumes," he adds.

Due to the customs delays as well as the receipt of materials across three factories that are now producing laser modules, inventory levels increased quarter-over-quarter in fiscal Q1/2021. However, inventory should start to come down in the March quarter.

For fiscal second-quarter 2021 (to end-March), Emcore expects revenue to grow to $34–36m, driven by stronger-than-normal performance from CATV and QMEMS product lines.

"Our biggest note of caution remains tied to COVID-19 impact on our personnel and supply chains in the US, China and Thailand," says Rittichier.

"The Thai government started to allow foreign workers back into the country right at the end of the December quarter. They have since tightened entry requirements to only admit Thai citizens," notes Rittichier. "While our Thai manufacturing teams continue to improve their effectiveness, adding the highly experienced EA engineers into the mix would have a positive impact," he adds.

"The strong demand for cable TV products more than justifies parallel operations at both facilities [Beijing and Bangkok] until the end of the calendar year and enables us to better hedge the COVID-19 risks," continues Rittichier. "Our customers expect certainty in their ship date and multi-facility operations helps to provide that."

"We remain excited and confident about the growth prospects across our Aerospace & Defense product portfolio. On the Broadband side, we have a strong order book for our cable TV products through the September 2021 quarter, with MSOs favoring proven linear optics to provide the network bandwidth that customers need," says Rittichier.

"Charter and Comcast recently announced earnings and their capital plans for the year. Comcast reported increases in scalable infrastructure balanced against reductions in CPE, while Charter highlighted the larger amount of nodes splitting that they're doing to meet bandwidth demands. These statements are consistent with our strong order book through the September quarter. The trend should continue through at least the December quarter. Although the cyclical nature of the cable TV business gives us pause regarding the ultimate duration of this upgrade cycle, we remain confident that we can complete our move to variable cost manufacturing, while orders are strong," says Rittichier.

The strong demand for cable TV products more than justifies parallel operations at both facilities [Beijing and Bangkok] until the end of the calendar year and enables us to better hedge the COVID-19 risks," continues Rittichier. "Our customers expect certainty in their ship date and multi-facility operations helps to provide that."

"Looking beyond the very near-term in CATV, we believe that MSOs will continue to invest in linear optics technology to meet their needs. DAA or remote PHY keeps pushing further out to the right, while our development work on linear remote PHY shelf products continues to gain traction," he adds.

"The broadband business unit also generated some important successes outside of cable television.

Most importantly, we're seeing growing traction with our LiDAR and sensing components. On the LiDAR front, our chip design has already been qualified for the major design wins we announced with the tier-1 manufacturer. Beyond that we're about to start sampling a second-generation package designed to at least three more tier-1 automotive subsystem manufacturers. Although volume shipments won't really occur until sometime in fiscal year 2022, we're excited with the response that we're getting from these customers," continues Rittichier. "Our China rail design wins grew strong demand in the quarter, which should continue for the foreseeable future."

"Outside of sensing, we continue to rack up design wins in highly differentiated chip products, and expect to see growth materialize toward the end of calendar year 2021. Taken together, the broadband business has many important growth opportunities outside of cable television," Rittichier concludes.

www.emcore.com

Emcore closes $35.9m public offering

Underwriters exercise their option in full

Emcore has closed its underwritten public offering (announced on 10 February) of 6,655,093 shares of its common stock, which includes the full exercise of the underwriters' option to purchase 868,056 additional shares, at a price of $5.40 per share. All of the shares in the offering were sold by Emcore.

The gross proceeds to Emcore from the offering (before deducting the underwriting discounts and commissions and other offering expenses) were about $35.9m.

Cowen acted as book-running manager and Craig-Hallum as co-manager for the offering.

First Solar to sell US development platform to Leeward

Leeward to also buy 1.8GW$_{DC}$ of First Solar PV modules

Leeward Renewable Energy Development LLC of Dallas, TX, USA has entered into a purchase and sale agreement to acquire a utility-scale solar project platform of about 10GW$_{AC}$ from First Solar Inc of Tempe, AZ, USA, which makes thin-film photovoltaic (PV) modules based on cadmium telluride (CdTe). The transaction is expected to close in first-quarter 2021, after obtaining regulatory approvals and satisfying customary closing conditions.

Leeward is a portfolio company of OMERS Infrastructure, an investment arm of OMERS, one of Canada's largest defined benefit pension plans (with CDN$109bn in net assets, as at end-December 2019). Upon closing of the transaction, Leeward will acquire the US project platform, which includes the Rabbitbrush, Madison, Oak Trail, Horizon and Ridgely projects (which are expected to commence construction in the next two years) as well as the 30MW$_{AC}$ Barilla Solar project (which is operational). First Solar will retain 1.1GW$_{AC}$ of projects in the USA that are expected to be sold separately. Key members of the First Solar project development team are also expected to join Leeward.

Subject to closing of the acquisition, Leeward will purchase 650MW$_{DC}$ of First Solar's Series 6 PV modules for its additional development opportunities. The firm's acquisition of the project platform also includes purchase orders for 888MW$_{DC}$ of Series 6 modules for the five development projects. Additionally, Leeward's acquisition of the project platform will include 242MW$_{DC}$ of Series 4 modules safe-harbored under the solar Investment Tax Credit (ITC) program, 148MW$_{DC}$ of which has previously been booked. In total, the acquisition will comprise the acquisition of projects with module purchase orders, together with the entry into additional purchase orders, of about 1.8GW$_{DC}$ of First Solar PV modules, of which 744MW$_{DC}$ represent new bookings as of closing.

"This acquisition will support our aggressive growth strategy as a leading independent power producer and elevate Leeward's prominent position in today's energy market," says Leeward Renewable Energy's CEO Jason Allen. "The public recognizes that renewable energy is a key driver in combating the global issue of climate change. Solar and renewable technologies continue to advance and now provide economically viable solutions in virtually every market in the US," he adds.

"The sale of the platform is a result of the strategic review we announced in 2020," notes First Solar's CEO Mark Widmar. "Enabled by our Series 6 module's seamless compatibility with industry systems and processes, the sale is part of a transition that allows us to focus on doing what we do best, which is scaling, developing and selling our world-class module technology."

The completion of the transaction is subject to a number of closing conditions, including the receipt of regulatory approval from the US Federal Energy Regulatory Commission (FERC), the expiration of the waiting period under the Hart–Scott–Rodino (HSR) Antitrust Improvements Act of 1976, and review by the Committee on Foreign Investment in the United States (CFIUS).

www.firstsolar.com
www.leewardenergy.com

Midsummer ships first DUO system to Russia

First machine delivered under Rusnano agreement

Midsummer AB of Järfälla, near Stockholm, Sweden — a provider of turnkey production lines as well as flexible, lightweight copper indium gallium diselenide (CIGS) thin-film solar panels for building-integrated photovoltaics (BIPV) — says that, in the first week of February, it shipped the first DUO machine for the Russian market. This is the first flexible CIGS solar cell manufacturing system delivered under the Midsummer–Rusnano framework agreement, signed in September 2019.

Under the agreement, the Moscow-based Russian government-owned technology firm Rusnano Group aims to use Midsummer's technology to promote and develop the manufacturing of lightweight flexible CIGS PV cells and modules to set up production and end-user product development in Russia and in other countries of the Eurasian

Economic Union (Russia, Armenia, Belarus, Kazakhstan and Kyrgyzstan). Midsummer will also source panels for worldwide distribution of panels manufactured in Russia and the region.

"The corona pandemic has made it impossible to travel to Sweden from the countries and regions where our machine customers are located," says Midsummer's CEO Sven Lindström. "This has caused difficulties for us to make acceptance tests and install our already sold DUO machines," he adds. "Thanks to a new procedure that makes it possible to make final approvals through video link instead of on location in Järfälla, we have now been able to perform the acceptance test and ship the machine to Russia."

The DUO machine will be installed in a factory in Saransk (about 630km east of Moscow), to be run by the Nanotechnology and Nanomaterials Center of the Republic of Mordovia and their partner Solartek, which promotes solutions for integrated solar roofs.

www.midsummer.se

Midsummer signs another cooperation agreement in Spanish market

Midsummer and Hiansa Panel of Villafranca de Córdoba, Spain (which manufactures pre-painted steel panels for roofs and facades) have signed a letter of intent to offer customers in the Spanish industrial and agricultural sector a sandwich panel integrated with Midsummer SLIM solar panels, making the roof produce energy. This is Midsummer's third major cooperation agreement signed on the Iberian Peninsula in a short period of time.

The cooperation between Midsummer and Hiansa Panel will offer the Spanish industrial and agricultural market a sandwich panel with an integrated solar panel. As the Midsummer SLIM solar panel only adds 3kg/m^2, the solution is suitable for roofs with weight limitations or where extra wind load can be dangerous for the building — factors that often prevent the installation of conventional solar panels. The solar panel can be integrated into the sandwich panel directly in the factory, but it can also be mounted afterwards.

"Midsummer SLIM, which is usually sold integrated in standing seam metal roofs, is our most popular product in Sweden. It is very exciting to expand its area of use and integrate it into a sandwich panel for the industrial and agricultural sector. It feels particularly promising to do this in Spain, which has the strongest growth in solar energy in Europe, from 288MW/year 2018 to a full 4680MW/year 2019 [according to the 'EU Market Outlook For Solar Power/2019-2023']," says Midsummer's CEO Sven Lindstöm.

Hiansa Panel is a manufacturer in pre-painted steel panels for roofs and facades and offers sandwich panel products. The firm is active in Spain, Portugal, Africa and Latin America and is part of Grupo Hiemesa, a Spanish group of companies in the steel sector.

"As the solar energy market in Spain today is booming, we are proud to offer a smart solution with Midsummer's thin and flexible solar panel integrated into our sandwich panel already from the factory," says Hiansa Panel's CEO José Ramón Piqué. "The combination of our sandwich panels and Midsummer's solar panels means a smooth and fast installation for the customers, making it easy to produce their own electricity on the roof."

www.hiansa.com

www.solarpowereurope.org

InP quantum dots on silicon with high PL intensity

A high dot density reduces the impact of threading dislocations on output.

University of Illinois at Urbana-Champaign in the USA has realized monolithic indium phosphide (InP) quantum dots (QDs) on silicon with only slight photoluminescence (PL) intensity reduction relative to comparison structures grown on gallium arsenide (GaAs) [Pankul Dhingra et al, Appl. Phys. Lett., vol117, p181102, 2020].

Some of the emitted light was in the visible red wavelength range (625–750nm, full visible range 380–750nm), raising the hope for efficient emitters on silicon over a wider wavelength range than previously achieved in research focused on infrared devices for 1.24–1.55μm optical communications. The team sees InP QDs as "promising for micro-scale light-emitting diodes (micro-LEDs) and lasers". Further prospects include integrated optogenetics, biophotonic sensing, and quantum optics.

The maintenance of PL intensity on silicon was attributed to a high dot density relative to the threading dislocation density. The growth process also avoided misfit dislocations, which are commonly seen in InAs QD structures aimed at optical communications. The researchers believe that the ability to lattice match the InGaP quantum well that capped the QDs to the underlying GaAs allowed misfits to be avoided.

The team comments: "The lack of misfit dislocations around the active region may prove beneficial for improving the performance and reliability of InP QD-based emitters, as the climb of misfit dislocations in InAs QD lasers on silicon during device operation significantly increases non-radiative recombination and operating current."

The researchers used solid-source molecular beam epitaxy (MBE) to produce their QD samples (Figure 1). The substrate was supplied by Germany-based NaAsPIII-V GmbH, on which the Urbana-Champaign researchers grew GaAs. The commercial substrate consisted of GaP/Si with a 4.3μm $GaAs_yP_{1-y}$ step-graded buffer, resulting in a relaxed GaAs cap layer at room temperature. The GaAs/Si material was cleaved into smaller pieces for the QD growth.

The GaAs/Si was loaded into the MBE equipment alongside comparison pure GaAs pieces. The dot layer was produced at 480°C with a V/III ratio range of 10^{-30}. A surface dot layer was also grown to provide easy access for atomic force microscopy (AFM).

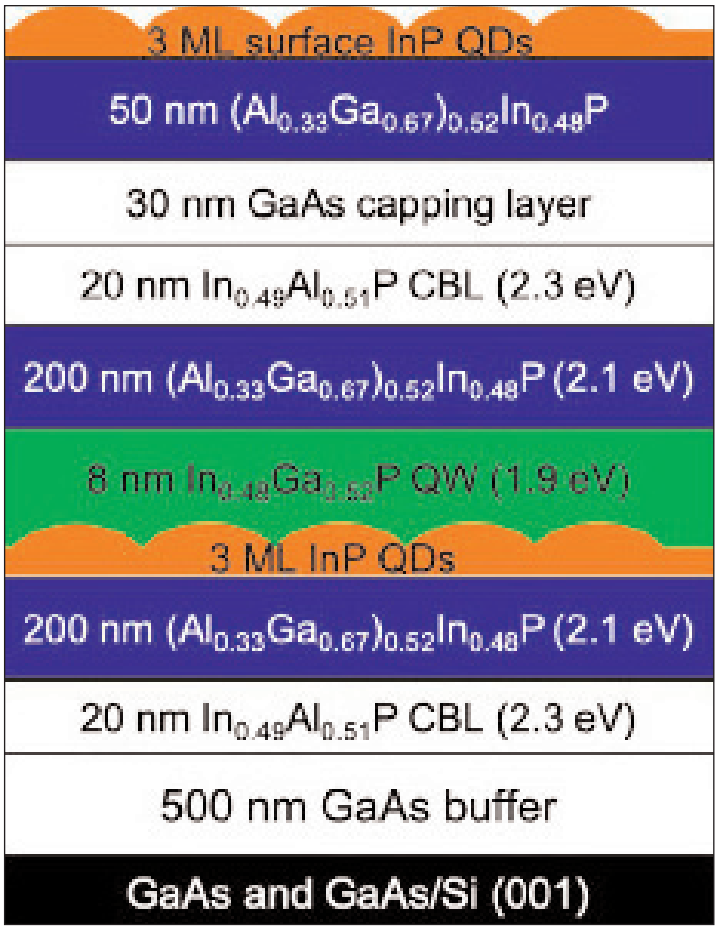


Figure 1. InP QDs co-grown on GaAs and GaAs/Si.

The intervening compounds used for the AlGaInP barrier, InGaP carrier-blocking layer (CBL), and InGaP quantum well (QW) layers were designed to be lattice matched to GaAs, as determined by high-resolution x-ray and PL analysis. The barriers and CBLs prevented carriers from reaching the surface, where non-radiative recombination can take place, sapping the PL intensity. The QDs were found to have ~3.7% compressive strain. This strain is the residue of the mismatch that drives the Stranski-Krastanov self-assembly into dots.

The QD samples were prepared for PL analysis by removal of the surface InP QDs and 50nm AlGaInP before rapid thermal annealing (RTA) at 700–1000°C for between 1 second to 5 minutes. Just before PL, the 30nm GaAs capping layer, protecting the underlying aluminium (Al)-containing layers from oxidation, was also removed. The best RTA conditions for InP QD PL

intensity were found to be 750°C for 5 minutes. Some InGaP QWs grown without QDs were found to perform best when subjected to 1000°C for 1 second. RTA drives out point defects from the structure, increasing PL intensity.

The PL emission (Figure 2) from the InP QDs was found to be 0.4eV blue-shifted relative to bulk InP. The higher energy bandgap is a result of the carrier quantum confinement and compressive strain in the dots. InGaP QW structures suffered a 9x degradation in PL intensity when grown on GaAs/Si, compared with pure GaAs substrates. By contrast, the InP QDs suffered relatively little impact from growth on GaAs/Si. "Strong non-radiative recombination at threading dislocations" was blamed for the reduction in InGaP QWs.

The researchers comment: "The integrated emission intensity of InP QDs on silicon was 8x higher than that of InGaP QWs on silicon, demonstrating the viability of dislocation-tolerant, visible, phosphide-based light emitters on silicon." They add: "A reduced diffusion length of carriers due to lateral carrier confinement also makes InP QD active regions insensitive to dislocations compared to InGaP QW structures, where carriers freely diffuse to dislocations. Finally, differences in the energy level and capture cross section for dislocation-related traps in InP and InGaP could also partially account for the observed discrepancies in dislocation tolerance."

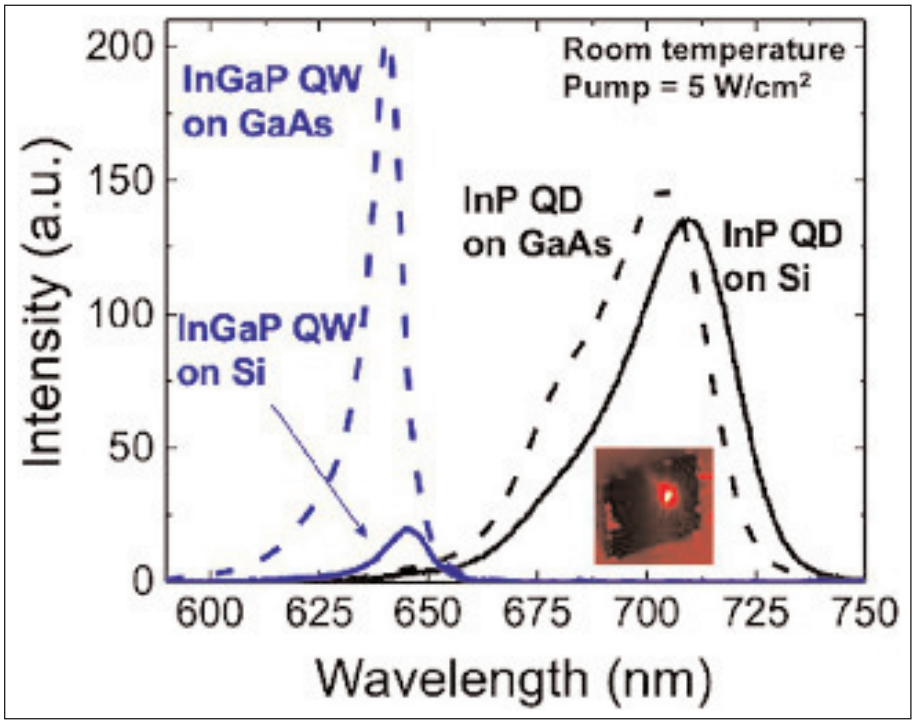


Figure 2. Room-temperature PL spectra of InGaP QW (blue) and InP QDs (black) grown on GaAs (dashed) and GaAs/Si (solid). Inset: visible emission observed from InP QDs grown on GaAs/Si.

The PL emission spectra showed ground-state emissions of 649nm wavelength (1.91eV) and 713nm (1.74eV) for InGaP QWs and InP QDs on GaAs, respectively. The corresponding full-widths at half-maximum (FWHMs) were 24meV and 65meV. The InGaAs QW spectra also showed a shoulder around 621nm from the first excited state. The shoulder on the InP QD spectrum was attributed to a bimodal QD size distribution. The researchers comment: "The comparatively higher FWHM of InP QDs can be attributed to inhomogeneous broadening due to the distribution in QD size."

The high dot density is seen as being essential for efficient luminescence and defect-tolerance of visible QD-based emitters on silicon. The typical InAs QD density is around $5x10^{10}/cm^2$. Cathodoluminescence suggested a threading dislocation density of $3.3x10^7/cm^2$, around four orders of magnitude lower than the InP dot density

The PL from samples on GaAs/Si were slightly red-shifted relative to pure GaAs, an effect attributed to tensile strain arising from thermal expansion mismatch between the GaAs and silicon.

Transmission electron microscope (TEM) analysis showed "misfit dislocations around the active region, an issue commonly observed with InAs DWELLs grown on silicon," according to the team. The dot density was estimated at ~$10^{11}/cm^2$. In the mean, the height and diameter of individual dots were 2.4nm and 20nm, respectively, similar to InAs dots capped with InGaAs.

AFM showed the dot density to be $1.3x10^{11}/cm^2$, consistent with the TEM results. The density was higher than previous reports, due to "nucleation on an Al-rich surface at a relatively low growth temperature", the researchers say. InP QDs are often grown using metal-organic vapor phase epitaxy at ~650°C. The surface QDs were around 2–3x higher than the capped dots, due to the absence of mass-transport effects into the cap layer. The surface QDs showed bimodal grouping around heights of 4nm and 7nm.

The high dot density is seen as being "essential for efficient luminescence and defect-tolerance of visible QD-based emitters on silicon". The typical InAs QD density is around $5x10^{10}/cm^2$. Cathodoluminescence suggested a threading dislocation density of $3.3x10^7/cm^2$, around four orders of magnitude lower than the InP dot density. ■

https://doi.org/10.1063/5.0030102
https://nasp.de

Author: Mike Cooke

Continuous electrical pumping in 1580nm-wavelength diodes

Researchers in Hong Kong have achieved the first continuous-wave C-band quantum dash lasers fabricated on planar silicon.

Hong Kong University of Science and Technology (HKUST) in China claims the first continuous wave (CW) C-band (~1580nm wavelength) quantum dash (QDash) laser diodes on planar silicon with threshold current densities as low as 1.55kA/cm^2 [Wei Luo et al, Photonics Research, vol8, p1888, 2020].

The researchers see "great potential as critical components in high-volume, low-cost integrated silicon photonics circuits". The team also suggest that the QDash format could be used in semiconductor optical amplifiers, modulators and photodetectors. Apart from high-speed/high-capacity data transmission, such devices could be deployed as light detection & ranging (LiDAR) components.

The use of low-cost silicon in the orientation favored for CMOS (001) could open up wider deployment, particularly with a monolithic growth process that can avoid the potential for defects from a relatively high 8% lattice mismatch between silicon and indium phosphide (InP). The use of quantum dots or dashes mitigates this to some extent, but further defect reduction is needed for effective laser or other light-emitting and -detecting structures.

The growth was through metal-organic chemical vapor deposition (MOCVD) on nominal (001) Si. In-house measurement determined the offcut angle at 0.5° along the [110] direction. A number of growth steps were implemented to counteract the various defect formation mechanisms.

First the silicon substrate was subjected to a 800°C anneal in hydrogen. According to the team, this helps to avoid anti-phase boundary formation through desorbing oxides and rearranging the surface atoms.

The first buffer layer was 1μm of gallium arsenide (GaAs), grown as an intermediate layer between the planar silicon and InP lattices in three temperature steps: 400°C, 500°C and finally 600°C. The defect density in this buffer was reduced by using a five-stage thermal anneal cycling between 330°C and 780°C, reducing the x-ray diffraction (XRD) rocking curve

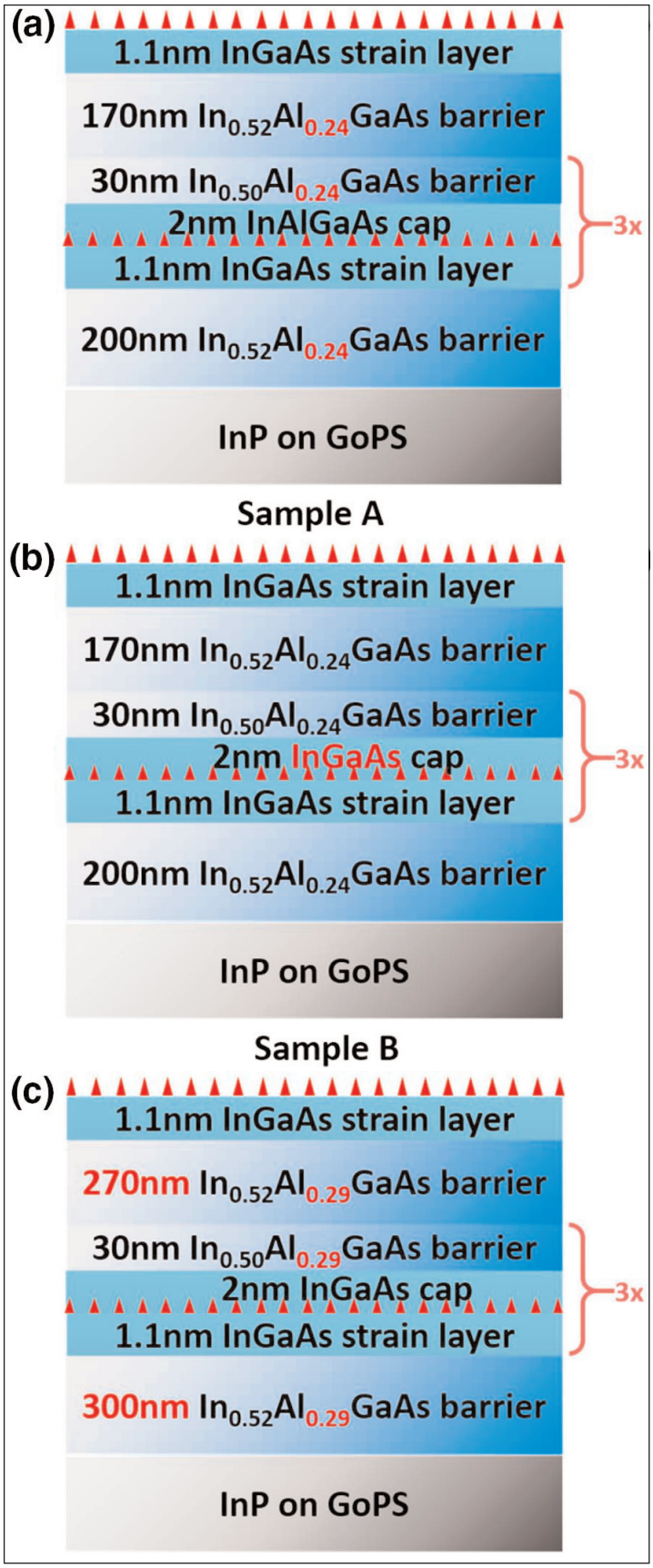


Figure 1. Schematic sample variations of QDash structures grown on InP/GoPS with different structures: Samples A, B and C.

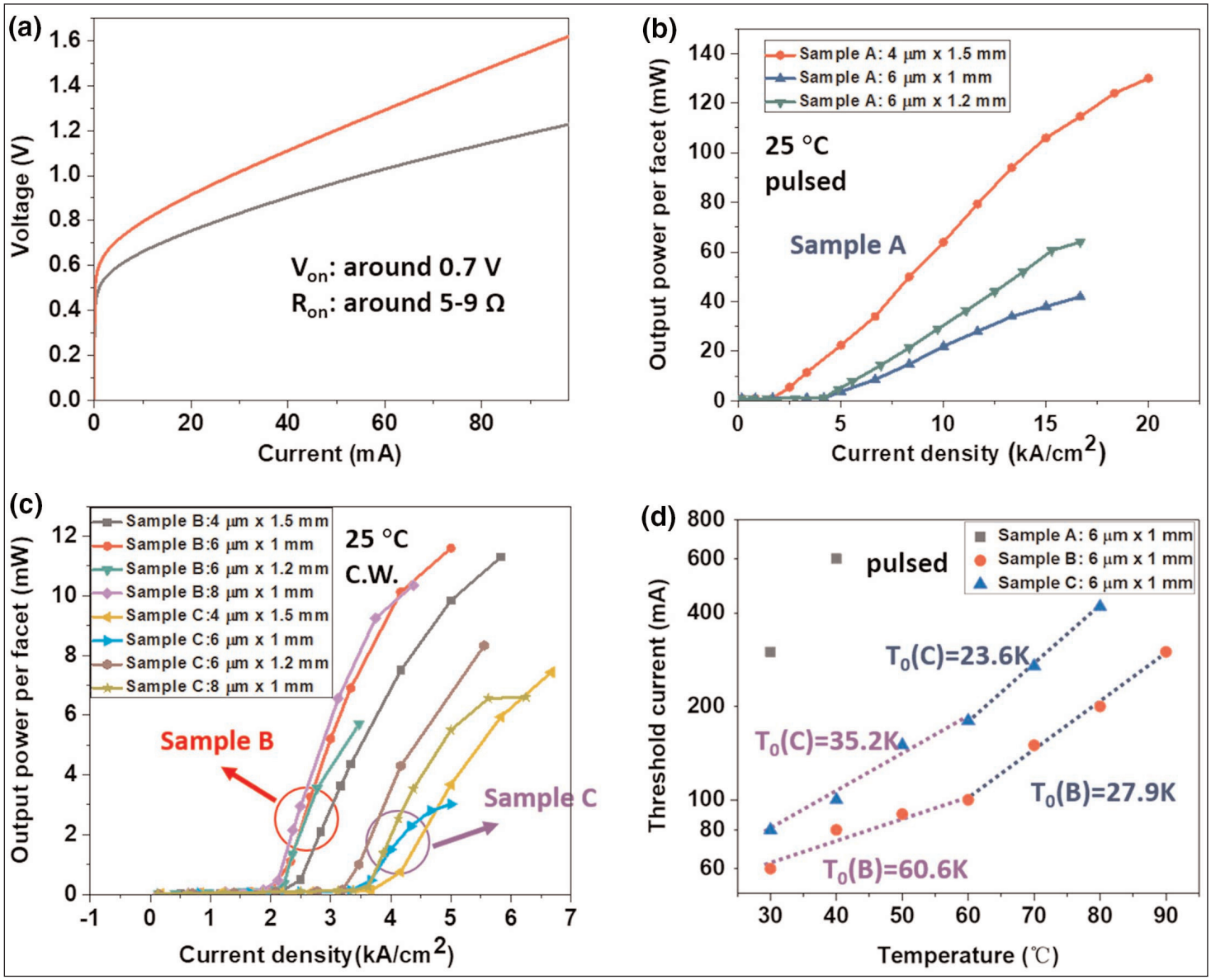


Figure 2. (a) Representative current-voltage curves of fabricated devices. (b) Room-temperature pulsed lasing light output power-current density (L–I) curves of different size FP lasers on Sample A. (c) Room-temperature CW lasing L–I curves on Samples B and C. (d) Pulsed lasing threshold currents of 6μmx1mm lasers on Samples A, B and C at different temperatures.

full-width at half-maximum (FWHM) from 580arcsec to 380arcsec. The root mean square (RMS) surface roughness of the GaAs on planar Si (GoPS) was 1.1nm in atomic force microscopic analysis of a 10μmx10μm field.

The 3.1μm InP buffer was grown in three steps also: 445°C, 555°C and 630°C. The InP grown at the highest temperature included three 10-period 11.5nm/31nm $In_{0.63}Ga_{0.37}As$/InP superlattice structures designed to filter out threading dislocations. The InP spacers between the superlattices were 250nm thick. The 2.8nm RMS surface roughness was somewhat larger than for the GaAs surface. Transmission electron microscope (TEM) analysis of the surface gave an estimate for the defect density at $3.6x10^8/cm^2$ with $0.4x10^8/cm^2$ standard deviation.

Various QDash structures (Figure 1) were grown on this material. The QDashes themselves were assembled from an InAs layer on strained InGaAs. A series of 'dot-in-well' (DWELL) QDash layers were grown using InGaAs and/or InAlGaAs capping in low- and high-temperature steps.

The QDash DWELLs were sandwiched between separate-confinement heterostructures: InAlGaAs cladding lattice-matched to the InP template. The 30nm InAlGaAs spacer layer was slightly strained, compensating for the accumulated strain from the QDashes. A final QDash layer was grown on the surface to enable easy material analysis.

Three different samples were produced in an effort to determine the optimum optical confinement from the cladding, varying the refractive index contrast and layer thickness. The QDashes were found to be elongated along the $[1\bar{1}0]$ direction. The dot density was $3.5x10^{10}/cm^2$. The highest photoluminescence

intensity was from sample B, which used an InGaAs cap, reducing the energy gap between the well and QDashes.

The researchers comment: "The elimination of aluminium in the cap layer helps to reduce the impurities, which accounts for the increased PL intensity in Sample B. In addition, by changing the low-temperature cap layer with little composition difference, the local strain of QDashes is also modified, which influences the morphology and emitting wavelength of QDashes".

The lower aluminium content of the InAlGaAs barriers in sample B also reduced the bandgap and increased the refractive index relative to sample C. This should lead to improved optical confinement, but the reduced bandgap could risk reduced carrier confinement in the DWELL layers.

For electrically pumped lasers the growth sequence was 600nm n-InP contact, 630nm n-InP cladding, three-stack QDash active region, 1500nm p-InP cladding and 140nm p-InGaAs contact.

The three types of QDash structure were used in ridge-waveguide laser diodes with a first mesa terminating just above the active region and a second at the n-InP contact layer. The samples were thinned to 100μm before cleaving into laser bars. The facets were not coated.

The turn-on voltage in pulsed testing was around 0.7V for all the devices. Laser diodes based on sample A would not lase in continuous wave (CW) operation. Again, sample B gave the best performance in terms of low threshold current, and in terms of operation to the highest temperature of 90°C. The characteristic temperature (T_0), reflecting slower variation in threshold, was also higher in sample B laser diodes under pulsed conditions.

The researchers comment: "Compared to the characteristic temperature T_0 of QD laser on native InP substrate, the smaller T_0 value here may be caused by the imperfect InP-on-Si buffer quality, which introduces the non-radiative recombination centers in the active region."

A variation of the laser diode structure with the ridge created in one step down to the n-InP contact enabled a reduction of the threshold current density to 1.55kA/cm^2 in CW operation in a 8μmx1.5mm device. The single-facet output power was as high as 14mW. The emission spectrum consisted of multiple peaks, centered on 1580nm, due to the large size of the cavity, supporting a number of Fabry–Perot modes. The laser continued lasing up to 95°C under pulsed operation. ■

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Author: Mike Cooke

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UV LEDs and coronavirus: how effective are the latest sanitizer systems?

The UV-C LED market will grow from $308m in 2020 to $2.5bn by 2025, reckon PISEO and Yole Développement.

Earlier this year, the UV LED businesses Sensor Electronics Technology Inc of the USA and South Korean Seoul Viosys released a Violeds UV-C LED system that is reported to kill 99.437% of the SARS-CoV-2 virus in a second. Tests were conducted by South Korea-based KR Biotech with SETI and Seoul Viosys stating that the sanitizer device could be an effective method to disinfect airborne viruses as well as water systems and rooms housing Covid-19 patients. But how effective is the technology?

Photonics innovation services provider PISEO, which recently published a UV-C LED technical analysis report 'UV-C LEDs at the time of Covid-19' and has a heritage of system design and realization, believes that more public detail is required before industry players can truly know.

PISEO is a partner of market research & strategy consulting company Yole Développement. The firms have joined force to deliver an overview of the UV LED industry. With an analysis of the market trends and technology evolution, Yole's analysts offer a complementary vision of the UV LED industry via the dedicated report 'UV LEDs – Market and Technology Trends'.

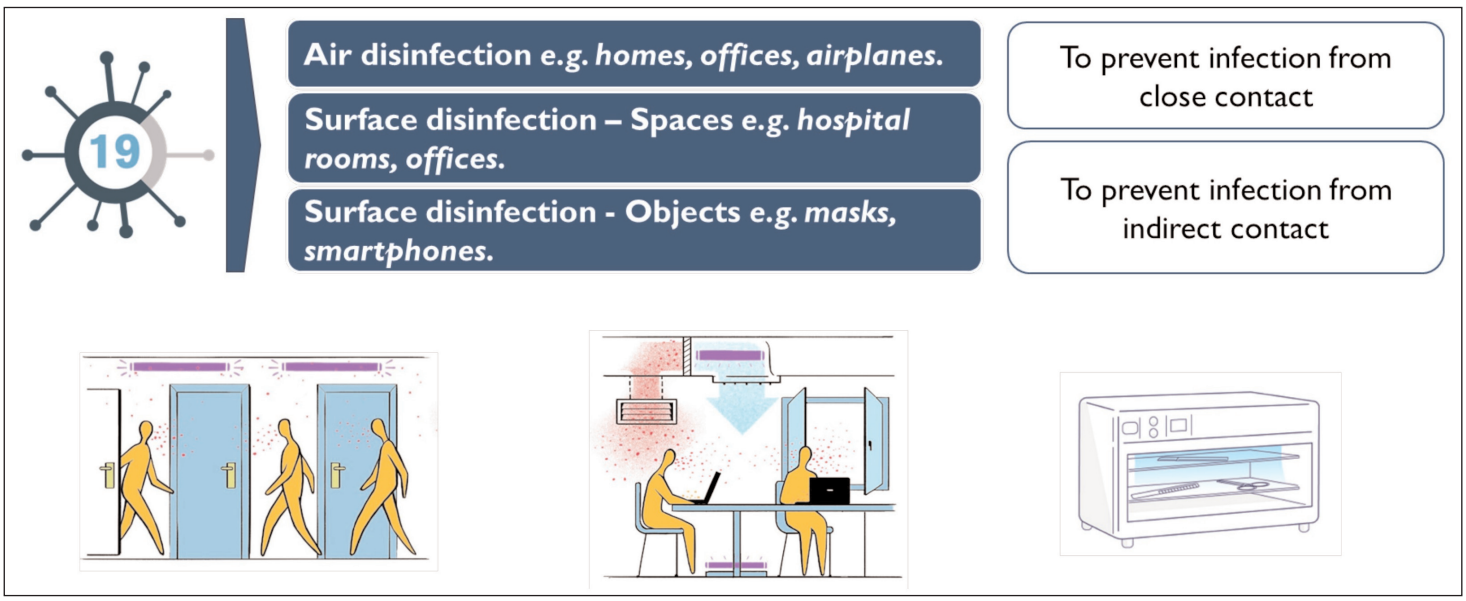
Remarkable growth

The Violeds device comes at a time when the UV-C LED market is seeing unprecedented growth. The pandemic has triggered huge demand for disinfection systems, boosting momentum in UV-C LEDs. According to Yole's UV LED report, the market is expected to more than double, from $144m in 2019 to $308m in 2020, before mushrooming to $2.5bn by 2025.

The rapid growth follows more than a decade of relatively slow market activity. Back in 2008, UV LEDs were beginning to emerge, with only 10 industry players largely focusing on UV-A LEDs for UV curing applications.

Over time, visible LED businesses joined the UV LED market, advancing product development. However, increased competition — coupled with technology challenges — saw the UV-C LED segment remain sluggish, with disinfection product demand being largely met by the market incumbent UV mercury lamp. Covid-19 is changing this, says Yole.

Despite its relatively high cost and low efficiency, the UV-C LED is now rapidly displacing the market share of UV mercury lamps for some key reasons. LEDs do not contain mercury (widely banned in many electrical and

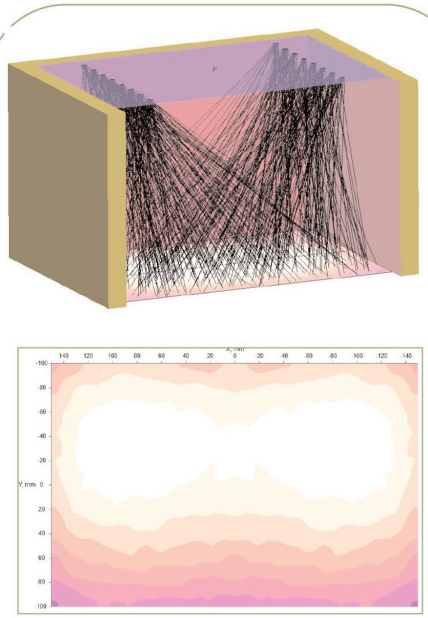


Emerging UV lighting applications in the COVID-19 era.

Optical design:

Dose	:	46 *	mJ/cm²
Wavelength	:	265	nm
Minimum irradiance on the target	:	0.383	mW/cm²
Uniformity parameter (min / medium)	:	75%	
Average irradiance on the target	:	0.51	mW/cm²
Optical power on the target	:	306	mW
Optical efficiency (target / source)	:	42%	
Total optical power emitted by the sources	:	729	mW

*This value is based on the results of the study by Inagaki (Japan) published in July 2020: [Rapid inactivation of SARS-CoV-2 with Deep-UV LED irradiation]). From these results, Piséo estimated the dose by taking into account the environment to be treated (surface) and the level of disinfection to be achieved. The dose used here is only an example. It does not engage the responsibility of Piséo.



Simulation carried out by PISEO with LightTools 9.0 software

Designing UV-C LED systems — design example: disinfection cabinet for medical equipment.

electronics products), while switching these devices on and off does not impact lifetime (as is the case with the UV lamp).

Importantly, the UV-C LED market now involves at least 95 industry players, including Crystal IS, Nitride Semiconductors, Nichia, Epitop, SemiLEDs, Seoul Viosys and Sensor Electronics Technology Inc (SETI). Some of these businesses — Nichia is the latest — have released data that indicates that UV-C LEDs can inactivate at least 99% of the SARS-CoV-2 virus on a surface, within seconds of exposure, signalling the that market is ready for Covid-19-fuelled growth. However, the replacement of the mercury lamp with the UV-C LED into an effective and safe product, as recently marketed by Seoul Viosys and SETI, is not trivial.

Businesses have released data that indicates that UV-C LEDs can inactivate at least 99% of the SARS-CoV-2 virus on a surface, within seconds of exposure, signalling the that market is ready for Covid-19-fuelled growth. However, the replacement of the mercury lamp with the UV-C LED into an effective and safe product is not trivial

System design and integration challenges

The design of any UV-C LED disinfection system must be adapted to the UV-C LED's specific properties, including optical emission and thermal management. Only limited lessons can be learned from the visible LED industry, as the much lower efficiency of the UV-C LED impacts thermal integration while UV-C radiation degrades the materials used in such systems, both of which will decrease the reliability of the end-product.

Product design must also take into account safety issues associated with radiation from UV-C LEDs. Energy emitted from these components is much higher intensity than normal sunlight, making UV-C LED disinfection systems a hazard to humans if technical safety standards are not followed. Indeed, the Global Lighting Association recently published guidance on the safety requirements of such products following, as it said: "the proliferation of UV-C disinfecting devices".

At the same time, existing regulations only apply to safety, and have not yet been extended to the disinfection process of the latest systems. Indeed, no defined test process yet exists that would allow the performance of different products to be compared. For example, KR Biotech data indicates that the Violeds system can inactivate 99.457% of the SARS-CoV-2 virus in a second, but where is the detail on the test procedure or on influencing factors such as room-size and surface type?

Still, while the jury may be out on the latest UVC-LED systems, these early products will create more momentum in this fast-growing market, reckons the report. Right now, many industry players are looking to design and build UV-C LED disinfection systems, and the design, integration and test services from a photonics innovation center such as Piseo can ensure that the finished product is both effective and safe. ■

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MOCVD tunnel junctions for GaN LEDs

Researchers say they have solved key challenges with much reduced forward voltage.

University of California Santa Barbara (UCSB) in the USA claims the highest performance so far for tunnel-junction micron-sized blue light-emitting diodes (TJ μLEDs) grown by metal-organic chemical vapor deposition (MOCVD) [Panpan Li et al 2020 Semicond. Sci. Technol., vol35, p125023, 2020].

In particular, very low forward voltages (V_f) were achieved by enhancing the tunneling probability and the activation efficiency of the p-GaN layers by inserting an indium gallium nitride (InGaN) layer into the tunnel junction and by using a selective-area growth (SAG) process, respectively. The performance of the TJs is comparable to that from molecular beam epitaxy (MBE) growth processes, it is claimed.

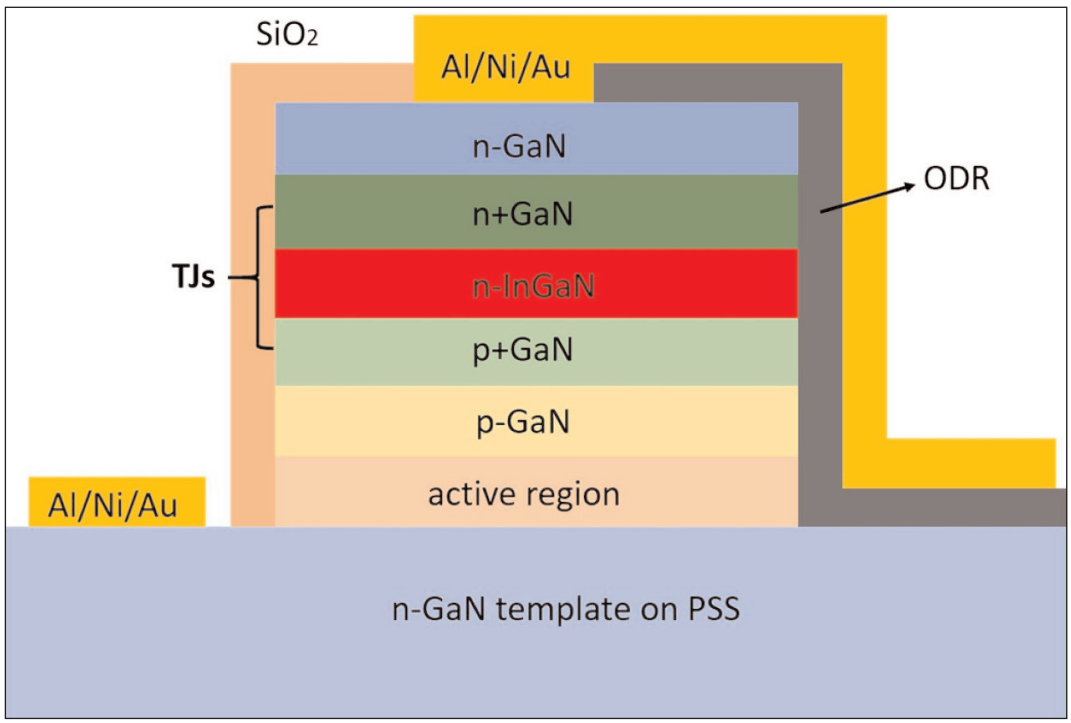

Figure 1. Schematic structure of InGaN TJ μLEDs.

The InGaN insertion layer uses a difference in charge polarization relative to GaN to introduce band-banding effects that reduce the tunneling distance, hence increasing the tunneling probability.

The researchers see their work as overcoming size

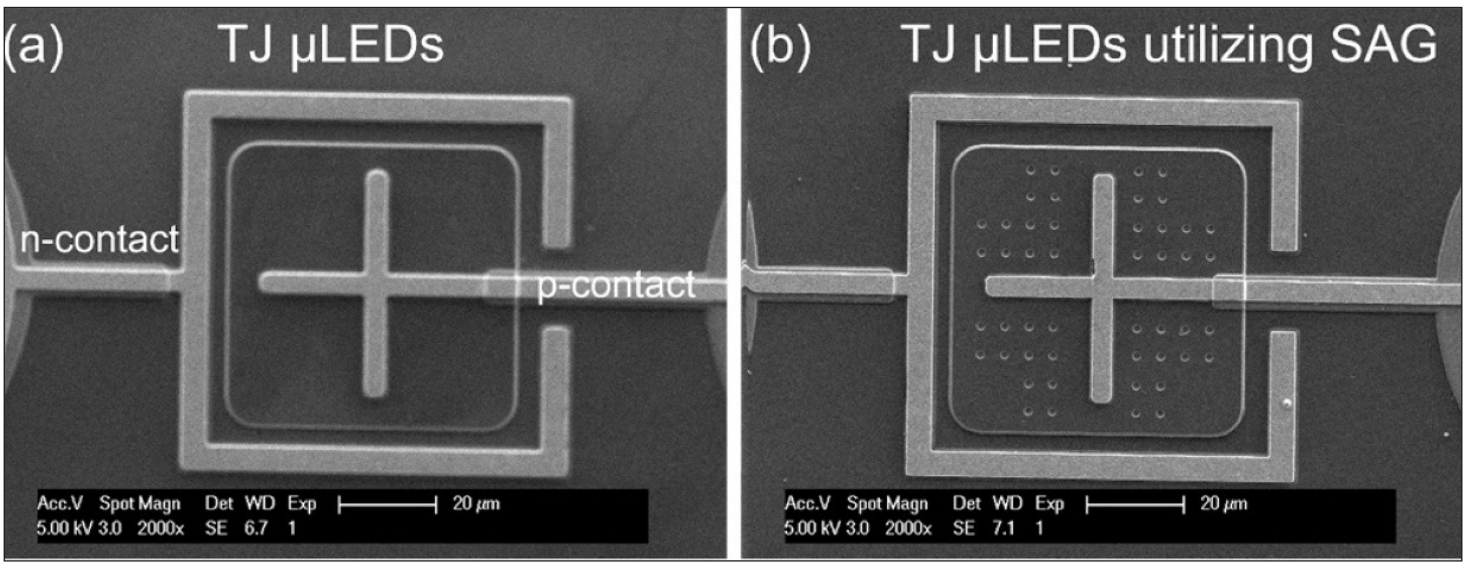

Figure 2. Scanning electron microscope images of fabricated 60 μmx60μm (a) InGaN TJ μLEDs and (b) SAG InGaN TJ μLEDs.

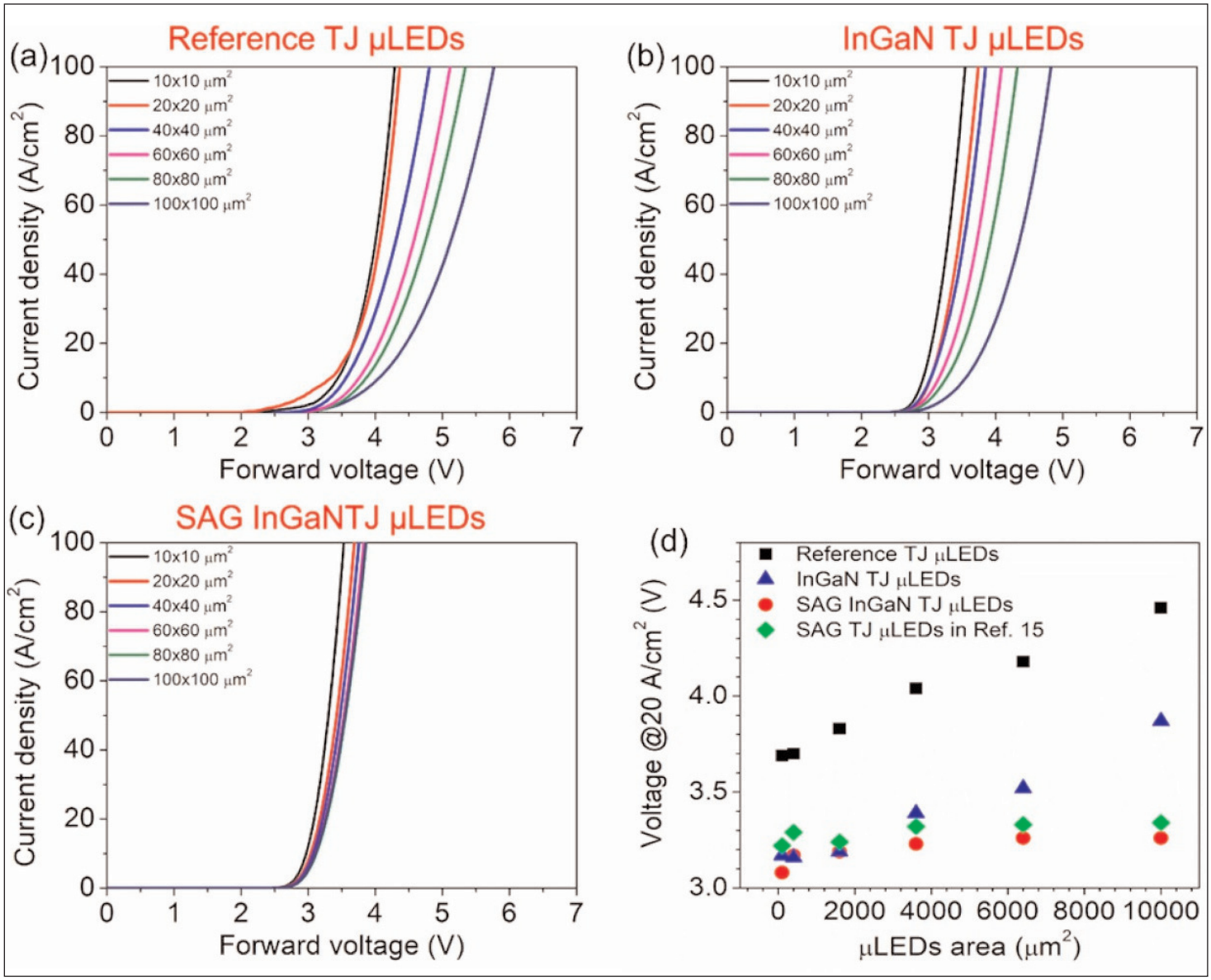

Figure 3. (a)–(c) Current density–V_f curves of μLEDs with sizes from 10μm to 100μm; (d) plot of V_f at 20A/cm² as a function of size.

limitations on TJ μLEDs, enabling low V_f even for larger μLEDs and for regular-size LEDs. MOCVD is a much preferred process over MBE in large-scale, high-output manufacturing contexts. "This work solves the key challenges of MOCVD-grown TJs," the team adds.

Tunnel junctions are seen as an alternative to transparent conductive oxides (TCOs) like indium tin oxide (ITO) for improving current spreading and thus emission uniformity and efficiency in GaN-based LEDs. Unfortunately, up to now the increased V_f penalty has wiped out any potential benefit in terms of reduced light absorption.

Further, TJs could provide interconnections between stacked 'cascaded LEDs' of devices with different color emissions, possibly enabling a reduced complexity assembly process for blue/green/red LED displays. Other potential benefits could be seen for producing edge-emitting laser and vertical-cavity surface-emitting laser (VCSEL) diodes.

The researchers used commercial blue LED material on patterned sapphire substrate (PSS) as a template for the overgrowth of TJ structures. Solvents including aqua regia were used to clean the surface before the overgrowth of III–N materials by MOCVD. The layer structure (Figure 1) consisted of 3nm silicon-doped n-$In_{0.15}Ga_{0.85}N$, 20nm n^+-GaN, 350nm n-GaN, and 15nm n-GaN cap. A sample without the InGaN interlayer was also produced for comparison. A further variation was a structure produced by SAG.

The material was etched into square micro-LEDs of varying sizes from 10μm to 100μm sides before rapid thermal annealing for 30 minutes at 700°C to re-activate the p-type doping.

The SAG process involved the creation of silicon dioxide pillars — these were removed before the re-activation anneal. The team explains: "The apertures on the p-GaN surface by SAG create additional vertical out-diffusion paths for the hydrogen with a much shorter

diffused distance than that to sidewall."

Hydrogen is the main factor passivating the magnesium (Mg) acceptors that provide p-type doping in GaN. The researchers explain: "It is well known that decomposing the Mg–H complex in the p-GaN by thermal annealing and removing hydrogen atoms are the key points to activate the p-GaN." While the presence of hydrogen is practically inevitable in processes involving organic compounds (e.g. MOCVD), MBE has an advantage here since recipes can be designed that avoid the element's presence.

The LED fabrication involved reactive-ion etch with silicon tetrachloride to expose the n-GaN contact layer, ion-beam deposition of an omnidirectional reflector (ODR) constructed from silicon dioxide and tantalum pentoxide, sidewall passivation with 25nm silicon dioxide, and deposition of aluminium/nickel/gold metal contacts. Finally, the devices were diced, mounted on silver headers, and encapsulated in silicone.

The SAG and non-SAG devices with 3nm n-InGaN interlayer in the tunnel junction achieved similar, reasonably uniform light output intensity for devices up to 100μm. The paper does not contain images of the reference devices without InGaN, but the team reports: "We notice that the luminous images of the reference TJ μLEDs were not uniform with a brighter electrical luminous (EL) intensity at the edge and a darker EL intensity at the center area." The researchers ascribe the improvement with InGaN interlayer to "higher tunneling probability at the InGaN TJs".

The difference between the InGaN TJ and the SAG InGaN TJ was revealed in the Vf performance, with the SAG process resulting in a lower value that is maintained up to dimensions of 100μm (Figure 3). A low V_f means that the input power is lower for a given current injection, increasing efficiency.

The V_f at 20A/cm^2 injection varied between 4.6V to 3.7V for the reference TJ LEDs without InGaN interlayer with sizes from 100μm to 10μm, respectively. The higher V_f in the larger devices is explained by the increased difficulty in hydrogen escaping from the p-GaN layers during the annealing activation process. The corresponding voltages for the InGaN TJ devices were 3.86V and 3.16V. The enhanced tunneling probability with InGaN interlayer increased the current flow for a given potential.

There was a much smaller variation between 3.08V and 3.25V for the SAG InGaN TJ. The enhanced out-diffusion of hydrogen through the SAG apertures explains the improved performance. These values are 0.1–0.2V lower than for SAG TJs produced without InGaN interlayer reported earlier this year by UCSB.

The team comments: "We note that the V_f of the μLEDs with ITO contact from the same epitaxy wafer is varied from 2.93V to 2.97V and independent on the sizes."

The researchers compared with external quantum efficiency (EQE) for the InGaN TJ μLEDs with and without SAG enhancement. LEDs with ITO contacts were also produced on the same wafer. The device dimensions were all 100μm. The EQE at 20A/cm^2 was 48% for the ITO contact and 54% for the SAG InGaN TJ. The plain InGaN TJ achieved ~50% EQE.

The researchers attribute the increased EQEs to "improvement of transparency, current spreading, and light extraction efficiency". ■

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Author: Mike Cooke

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Improving p-GaN gate HEMT reliability

Researchers have introduced a GaON 'concrete wall' to block hot-electron damage.

Hong Kong University of Science and Technology has used a gallium oxynitride (GaON) surface reinforcement layer (SRL) to boost the gate voltage window and long-term reliability of p-type gate GaN-channel power high-electron-mobility transistors (HEMTs) [Li Zhang et al, IEEE Electron Device Letters, vol42, issue 1 (January 2021), p22]. The team claims "the highest maximum gate voltage for a 10-year lifetime", compared with other reports of p-GaN HEMTs.

Team leader Kevin J Chen explains: "This main idea of this work is to reinforce the vulnerable (to hot-electron bombardment) surface region of the p-GaN layer with a stronger material, i.e. GaON. It is like replacing a glass wall with a concrete wall."

The surface reinforcement layer was put at the interface between Schottky metal and p-GaN in the gate stack (see Figure 1). A p-GaN gate is used to achieve enhancement-mode behavior with the device off at 0V gate potential, i.e. 'normally off'. This is desired in power applications for reduced power consumption/waste and for fail-safe operation. The p-GaN gate structure has been commercialized due to its "good balance among performance, reliability, and manufacturability," the researchers explain.

Although a Schottky contact with the p-GaN enables a lower gate leakage than for devices with an ohmic contact, the gate potential is then limited to less than 7V, due to time-dependent gate breakdown (TDGB) behavior. At the same time, the optimum gate potential for low dynamic on-resistance is in the range 5–6V, giving a very small operation window. Parasitic inductance can lead to oscillation/ringing effects that threaten the performance of the device by allowing the gate potential to wander outside the safe window.

The TDGB has been blamed on a small number of 'hot' electrons from the two-dimensional electron gas (2DEG) channel spilling over the aluminium gallium nitride (AlGaN) barrier layer into the p-GaN depletion region. These electrons are then accelerated in the electric field under the gate, reaching their highest kinetic energy at the metal/p-GaN interface region.

The researchers comment on the effect of the SRL: "With a wurtzite crystalline structure and a wider bandgap of ~4.1 eV, GaON tends to exhibit enhanced covalent bond strength and is expected to present stronger immunity to the bombardment of hot electrons generated under forward gate bias. Thus, GaON plays the role of reinforcing the GaN surface layer against the possible covalent bond breakage induced by hot electrons."

Chen's team has previously reported the use of GaON in metal-insulator-semiconductor field-effect transistors (MIS-FETs).

For the p-GaN gate HEMTs, the researchers used 6-inch GaN on silicon (GaN/Si) wafers designed for E-mode p-GaN gate power HEMTs. The layer structure

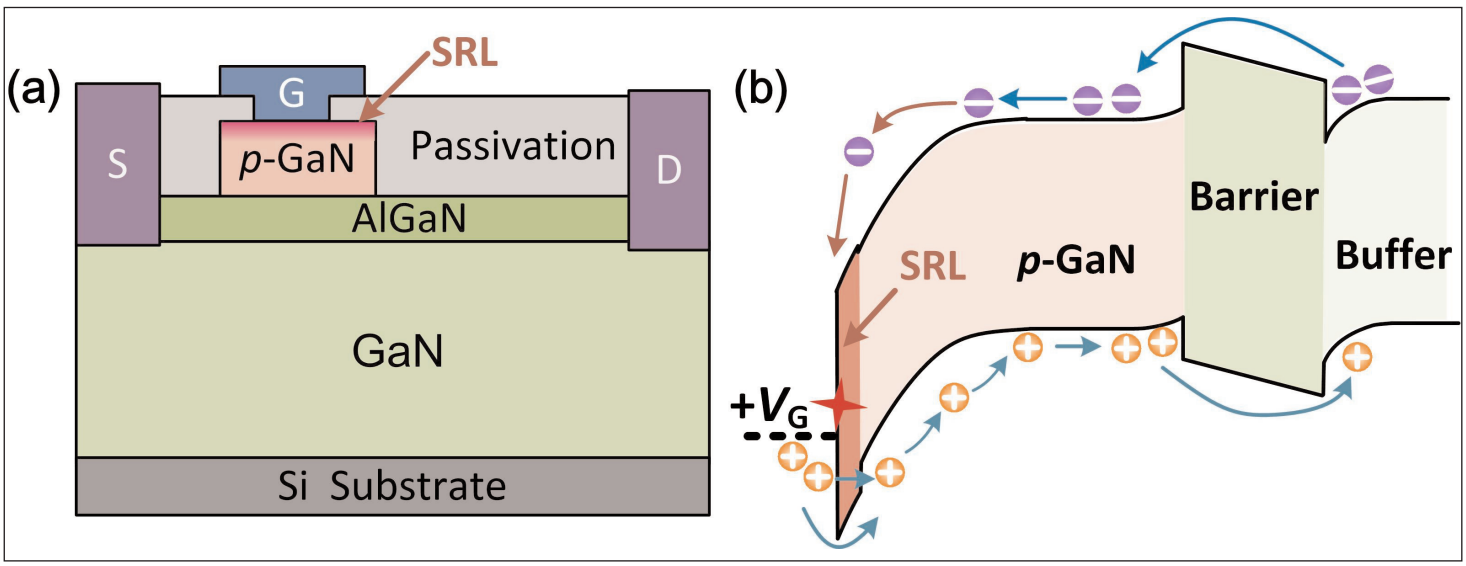

Figure 1. (a) Schematic cross section of p-GaN gate HEMT with SRL and (b) energy-band diagram for gate region at forward gate bias.

was 4.2μm high-resistivity GaN buffer, 420nm GaN channel, 15nm $Al_{0.2}Ga_{0.8}N$, and 100nm p-GaN cap. The cap layer was doped with ~$3x10^{19}/cm^3$ magnesium.

The GaON SRL was created using an inductively coupled oxygen plasma treatment, followed by 30-minute annealing at 800°C in nitrogen. The high temperature is "crucial to reconstruct the plasma-oxidized GaN surface and form a crystalline oxidation layer," the team reports. Secondary-ion mass spectrometry (SIMS) showed oxygen penetration into the p-GaN of around 5nm.

The surface roughness was only slightly increased by the plasma/annealing needed for the SRL: 0.44nm, compared with the initial 0.42nm root-mean-square, according to atomic force microscopy.

The p-gate with SRL cap was then formed by boron trichloride (BCl_3) inductively coupled plasma etch. Passivation was formed by plasma-enhanced atomic layer deposition (PEALD) of 4nm AlN, and plasma-enhanced chemical vapor deposition (PECVD) of 60nm SiN_x. Source/drain contact windows were then opened up for deposition of annealed titanium/aluminium/nickel/gold ohmic contacts.

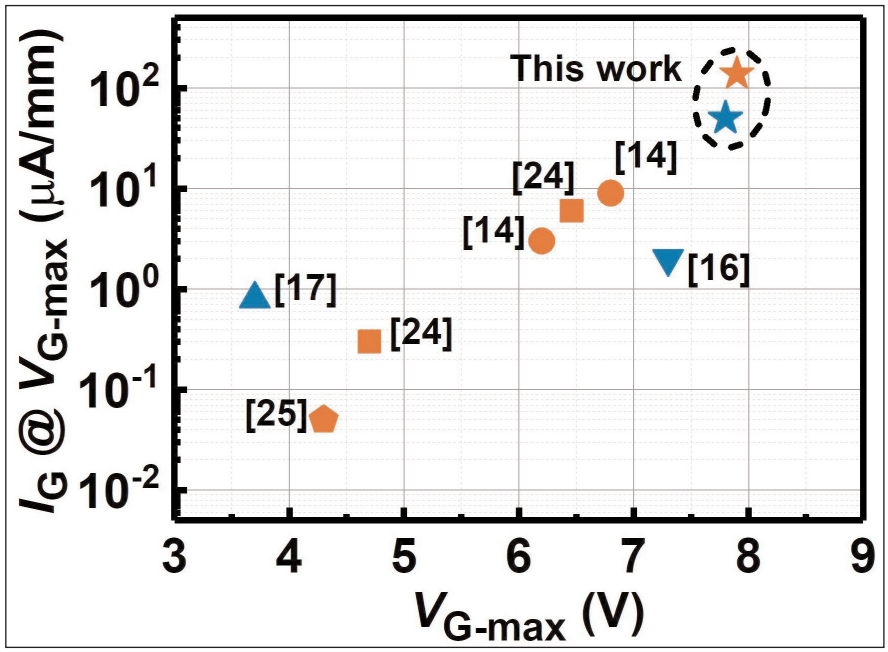

Figure 2. Comparison of p-GaN gate HEMTs with SRL ('this work') and other p-GaN gate HEMTs. Blue labels extracted at 25°C, orange ones at 150°C.

The device isolation was achieved using multi-energy fluorine ion implantation. The nickel/gold gate contact was made after another contact window opening process. The devices were completed with contact pads and interconnection to the HEMT contacts.

The HEMT dimensions were 4μm gate length with 2μm contact window, along with 15μm and 2μm gate–drain/source spacings, respectively.

The threshold voltage (V_{TH}) for the device was +1.4V for 0.01mA/mm drain current, the same as for a comparison device without the SRL. Both transistors also exhibited a low 90mV/decade subthreshold swing and a high on/off current ratio of more than 10^8. The 11Ω-mm specific on-resistance (R_{ON}) is described as 'low'.

In off-state measurements, with the gate and substrate grounded to the source voltage level, the drain bias reached 740V before breakdown for 1μA/mm current. The main leakage source beyond 550V drain bias was from the substrate.

The team comments: "These results show that the deployment of SRL neither significantly modify the forward conducting characteristics (e.g. V_{TH} and R_{ON}) nor compromise the reverse blocking capabilities of the devices."

The forward gate breakdown voltage was increased to 12.7V from 10.5V by the SRL insertion, while reducing the gate leakage by two orders of magnitude. The team explains this as being due to "reduced effective acceptor doping concentration and higher Schottky barrier height (φ_b) between the gate metal/GaON interface".

Using a Fowler–Nordheim tunneling fit to the gate current–voltage behavior, the researchers estimate φ_b to be 1.1eV with SRL and 0.6eV without. The higher barrier reflects the wider ~4.1eV bandgap of GaON, relative to the 3.4eV for GaN.

The breakdown voltages increased somewhat at 150°C, to 13.4V with SRL and 11.4V without, an effect tentatively attributed to "alleviation of hot-electron bombardment as a result of mitigated electron acceleration process at elevated temperature". The two orders of magnitude reduction in gate leakage was maintained at the higher temperature.

Time-dependent gate breakdown tests were carried out at a range of biases. The failure was defined as the "critical point where gate current increases suddenly". The SRL enabled an increased estimate of the maximum gate voltage ($V_{G\text{-}max}$) for a 10-year/1% failure level of 7.8V, compared with 5.9V without SRL. The expanded gate voltage range for the SRL device is seen as providing "appreciable design flexibility for gate driver circuits".

The researchers compared their SRL devices with reports in the literature, showing that their device gives the highest maximum gate voltage for a 10-year lifetime (Figure 2). The higher gate leakage at the higher gate stress, according to the team, "provides further evidence that the p-GaN surface region has been reinforced to better sustain the bombardment of highly energetic carriers by the deployment of GaON SRL." ■

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Author: Mike Cooke

EVs/HEVs drive power-module-related patent applications

Automotive OEMs are becoming more active in power modules, says Knowmade.

The last decade has seen electric/hybrid electric vehicle (EV/HEV) applications driving packaging innovation in power electronics and creating new equations to solve for module makers, in particular further downsizing, higher power density, higher reliability and lower cost/higher manufacturability. On top of that, automotive OEMs are asking for highly standardized power modules, while most module makers focus on proprietary module designs through which they can offer more differentiating added value. In this context, automotive OEMs and tier-1s will become increasingly intrusive in the power module area, reckons patent analysis & technology intelligence firm Knowmade's new 'Next-Generation Power Modules Patent Landscape 2021' report, which spans wide-bandgap (WBG) power modules and generic/IGBT (insulated-gate bipolar transistor) power modules addressing critical challenges for the next generation of power modules (heat dissipation, thermomechanical issues, management of parasitic signals, module miniaturization, etc) and, more specifically, challenges arising from EV/HEV high requirements.

Furthermore, EV/HEV applications are also pushing the adoption of new WBG semiconductor technologies, especially silicon carbide (SiC) metal-oxide-semiconductor field-effect transistors (MOSFETs) whose commercial availability has been increasing continuously. However, to fully benefit from power SiC technology, it is crucial to enable high-temperature operation (at 200–300°C) in SiC modules (for example through new packaging materials) as well as high-speed operation (by minimizing parasitic inductance).

As a result, the last decade was marked by extensive innovation in power module design and packaging, leading to a very high number of patent publications.

Knowmade has hence selected and analyzed over 7000 inventions filed by more than 300 different organizations. The report gives a complete analysis of the next-generation power module competition and technology developments regarding patents, with a focus on EV/HEV modules and SiC power modules, which are driving innovation at the design and packaging levels.

"IP competition is becoming more global and module makers have been progressively joined by competitors from the EV/HEV supply chain," notes Rémi Comyn PhD, technology & patent analyst Compound Semiconductors and Electronics, at Knowmade. Top module makers in Europe (Infineon, Semikron) and Japan (Mitsubishi Electric, Fuji Electric, Hitachi) have been very active in order to maintain their leadership in the power module patent landscape since 2010. "Interestingly, major foreign module makers are increasingly competing with their counterparts in Europe, by filing more and more

Figure 1: Main patent assignees and their IP dynamics in the next-generation power module patent landscape.

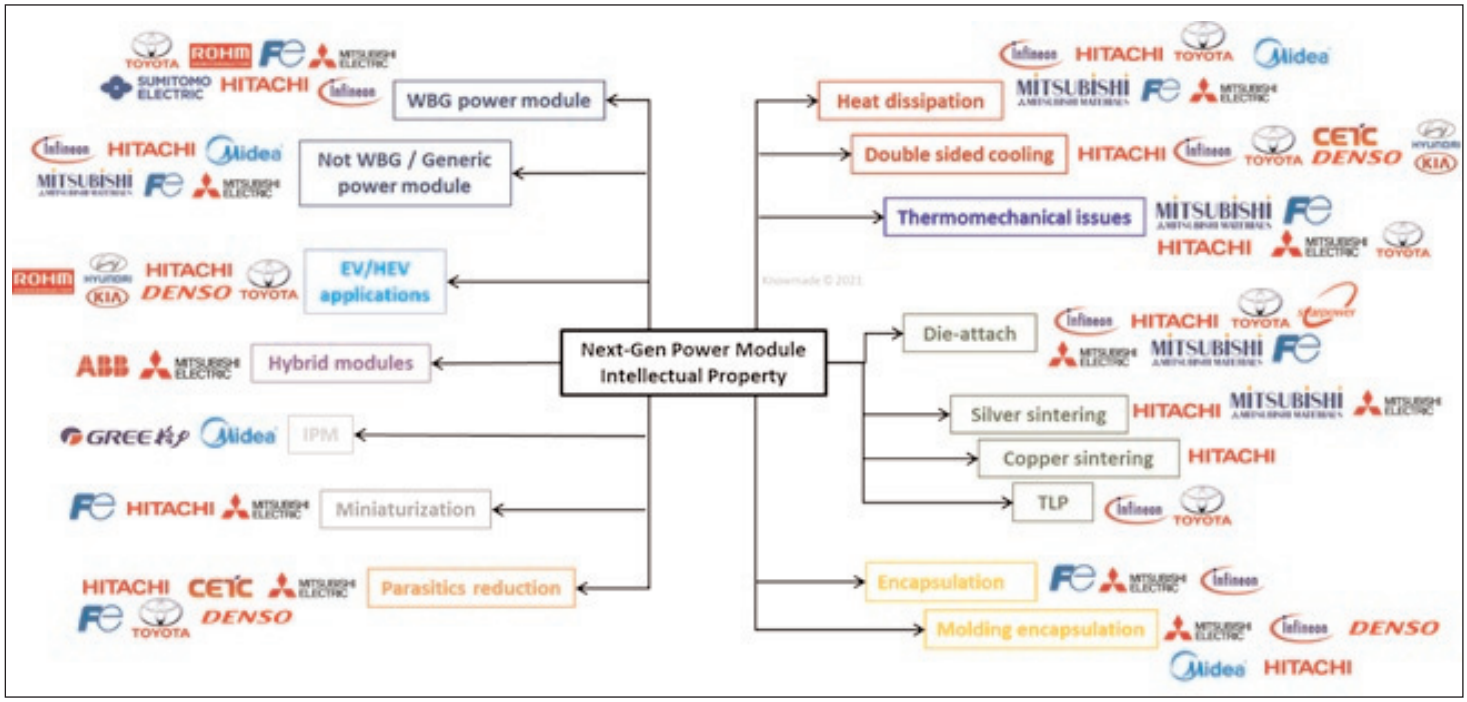

Figure 2: IP activity of top patent applicants in the next-generation power module patent landscape.

European patent applications," adds Comyn. Certain automotive OEMs (Toyota Motor, Hyundai Motor) and tiers-1 (Denso, Bosch) are now well-established patent assignees. In addition, several notable players from the EV/HEV supply chain have joined the IP competition, including semiconductor manufacturers (Cree/Wolfspeed), OEMs (Ford, BYD) and tier-1s (Valeo, Continental, ZF).

For EVs/HEVs, the difficult challenges have led to several IP collaborations between module makers/automotive tier-1s and automotive OEMs (Hyundai Motor/Infineon, ABB/Audi, Toyota Motor/Denso, Valeo/Siemens, etc. In China, major modules makers (CRRC, Macmic, Starpower) have demonstrated moderate patenting activity as of 2020, while new IP players have stepped up (CETC).

The WBG power module patent landscape is dominated by leading SiC MOSFET IP players. "Numerous IP players in the power module patent landscape have built up a significant portfolio of patents related to SiC MOSFET technologies, especially trench MOSFET technology (Rohm, Infineon, Fuji Electric, Toyota Motor, etc) targeting automotive applications. Accordingly, they now develop their own technology for full-SiC power modules," notes Comyn. "Most of them already had a foot in power module technology, except Cree/Wolfspeed, which started from APEI's acquisition filing patents specifically for SiC power modules."

Knowmade expects the number of patents for SiC power modules to continue growing in the next five years, as development is still on-going for many module makers (at the die and module levels). According to the present segmentation, IP players such as Hitachi, Mitsubishi Electric and Toyota Motor are also developing key technologies (reduction of stray inductance, silver and copper sintering, TLP for die-attach) in order to address WBG-related challenges. Lately, Knowmade has identified several newcomers to the WBG power module patent landscape, including Audi, ON Semiconductor, Danfoss & Shindengen Electric Manufacturing.

In the 'Next-Generation Power Modules Patent Landscape 2021' report, the body of patents is segmented into the four main challenges that are common to IGBT modules and SiC modules: parasitics, heat dissipation, thermomechanical issues and thermal reliability, and miniaturization. "Overcoming these challenges will be even more critical for SiC power modules to become mainstream, since the added value of the technology depends on their capability to operate at higher switching speed and higher temperature than IGBT modules," says Comyn.

The patents are also segmented by key technologies that are developed for next-generation power modules, for example die-attach (copper and silver sintering, TLP bonding), encapsulation (transfer molding), and double-sided cooling structure.

Furthermore, the report includes additional segments for patents related to intelligent power modules (IPM), hybrid modules (Si IGBT/SiC diodes or MOSFETs and GaN/Si cascode) and EV/HEV applications.

A significant part of the report is dedicated to the in-depth analysis of the IP portfolios of 40 leading players. Knowmade's IP analysts provide an overview of the portfolio (IP dynamics, enforceability, protected countries, technology, technical challenges, applications, etc), highlight the noteworthy patents relating new products and technology developments related to WBG, EV/HEV and related challenges, and review the very latest patented inventions. ■

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Vertical power trigate silicon carbide MOSFET

A novel vertical power tri-gate MOSFET reduces on-resistance by 1.78x compared with commercial SiC MOSFETs.

Purdue University and Sonrisa Research Inc in the USA report "a dramatic reduction in specific channel resistance" for a novel vertical power tri-gate metal-oxide-semiconductor field-effect transistor (MOSFET) in 4H-polytype silicon carbide (SiC) that incorporates sub-micron FinFET channels [Rahul P. Ramamurthy et al, IEEE Electron Device Letters, vol42, issue 1, p90 (January 2021].

Combined with wafer thinning, the structure could enable more than a 2x reduction in on-resistance, "permitting twice as many devices on a wafer and dramatically reducing the cost of SiC power MOSFETs in the 650V regime," according to the team.

The fin structures increase the effective width of the current-carrying regions without increasing the device area. Reducing on-resistance is particularly important in SiC devices using inversion layer channels, since the mobility is reduced by a factor of 10 relative to silicon. The compensating factor for interest in SiC devices is its higher blocking capabilities, giving higher breakdown voltages as a result of higher critical electric fields, which is a property it shares with the fellow wide-bandgap material gallium nitride (GaN).

The researchers, two of whom have since moved on to Intel Corp and Wolfspeed Inc respectively, particularly targeted 650V applications, since some two-thirds of power applications fall within ratings less than 1000V.

The epitaxial wafer used consisted of a 350μm-thick heavily doped n^+ 4H-SiC substrate, a 5.2μm $1.4x10^{16}/cm^3$ n-type drift layer, and a 1.6μm $1.0x10^{17}/cm^3$ n-type junction FET layer. Double ion implantation with MeV-level acceleration resulted in

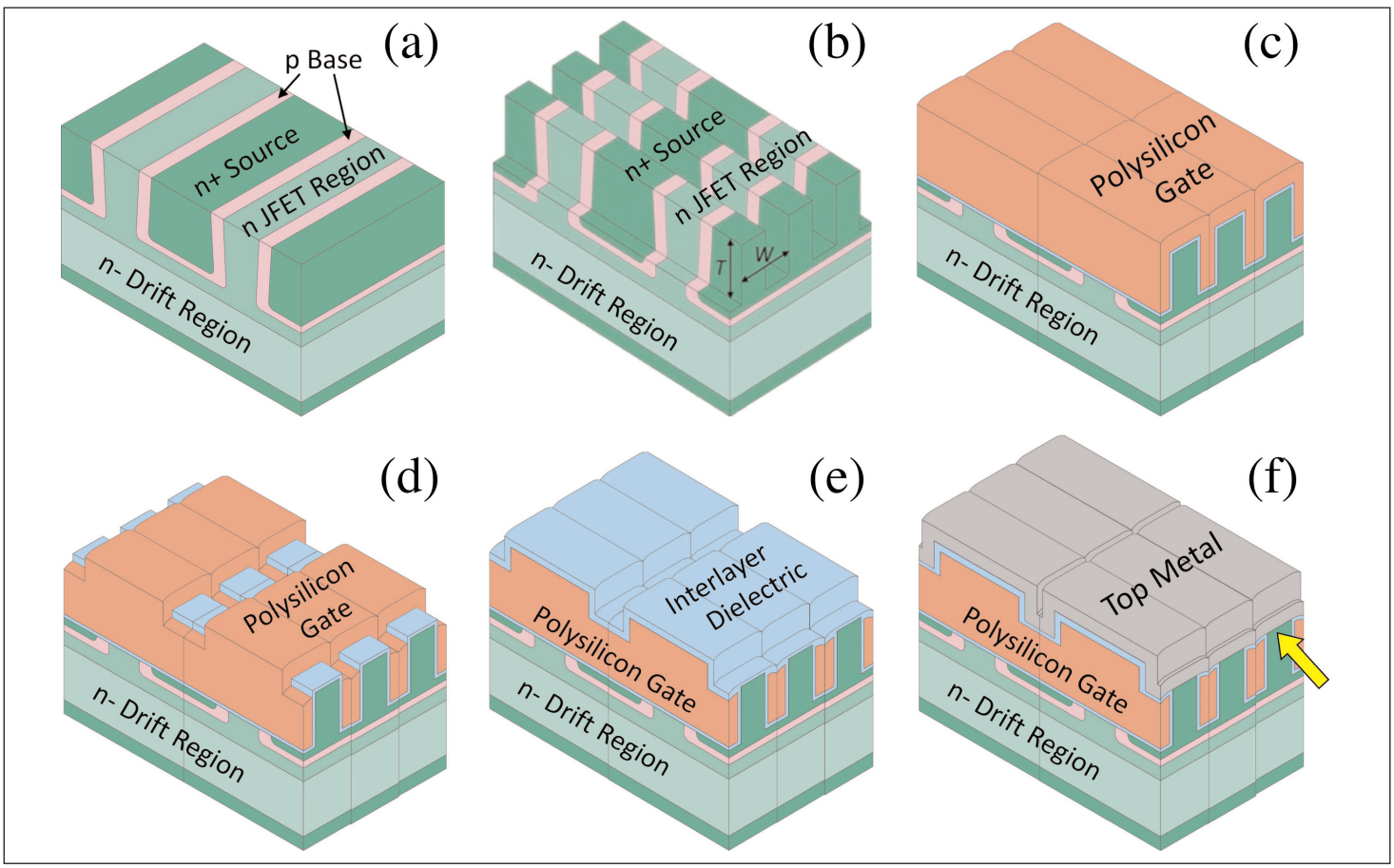

Figure 1. Outline of tri-gate MOSFET fabrication sequence: (a) implant p-base and n^+ source regions, (b) etch trenches, (c) deposit gate oxide and polysilicon gates, (d) pattern polysilicon gates, (e) form ILD, and (f) clear thin oxide on fins with BHF dip, form ohmic contacts and deposit top metal.

the formation of 2μm-deep 5μm-wide retrograde p-type base regions, in which 1.3μm-deep 4μm-wide n^+ source regions were added using a self-aligned short-channel technique. The p-type base regions were formed in stripes separated by 4.5μm.

The channel was formed by etching fins across the implanted stripes: 0.8μm deep, 0.5μm wide and spaced by 0.5μm. The etched surfaces were smoothed with hydrogen plasma etch at 1500°C and 15kPa pressure.

The gate stack consisted of low-pressure chemical vapor deposition (LPCVD) polysilicon, thermally oxidized at 580°C to create a 47nm insulator layer, and diffusion-doped polysilicon forming the gate electrode. The oxidized polysilicon insulator was thermally annealed at 1175°C in nitric oxide (NO) before the electrode deposition. The gate electrodes were patterned into 7.5μm-wide stripes to allow access in the 2μm-wide gaps to the source regions.

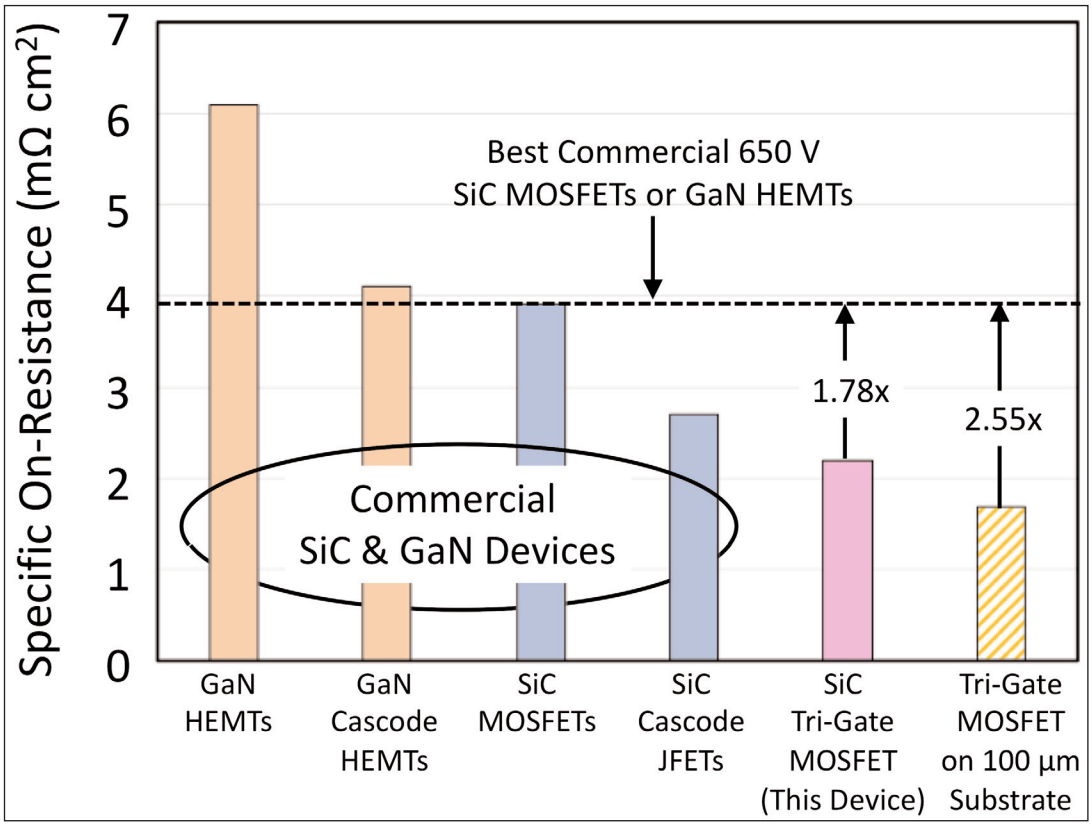

Figure 2. Specific on-resistance of commercial SiC and GaN devices, along with SiC tri-gate MOSFET and its expected performance enhancement from 100μm wafer thinning.

Further thermally oxidized polysilicon was deposited as a thick interlayer dielectric (ILD). The top of the fins in the source region were cleared of insulating material with a buffered hydrofluoric (BHF) acid dip before self-aligned nickel contacts were deposited and annealed. The device was completed with top metal layers of titanium and gold.

The resulting device was aimed at 650V blocking, enabled by floating-field-ring edge terminations. Avalanche breakdown occurred at 706V, and the gate-oxide broke under ~9MV/cm electric field.

The gate threshold was at 0.5V. The subthreshold behavior is described as "unusual" due to the apparent presence of unequally performing channels being created on opposite sides of the fins. The researchers suggest that this could be due to shadowing effects in the implant process, which could be eliminated "by insuring that the base and source implants are performed with the wafer in the same orientation with respect to the ion beam."

The gate controls the current flow from the source across the p-type region by creating an inversion layer there. Once across the p-base, the flow continues down to and through the drift region to the drain. The structure enabled a specific on-resistance at 18V gate potential of 2.19mΩ-cm^2, compared with 4.07mΩ-cm^2 for a comparison conventional planar double-implanted MOSFET (DMOSFET) on the same wafer.

The team estimates that an industry-standard wafer thinning process down to 100μm could reduce the new transistor's resistance to 1.54mΩ-cm^2, compared with 3.42mΩ-cm^2 for the conventional DMOSFET. Using further extraction techniques, the researchers calculate a specific on-resistance for the channel of 0.67mΩ-cm^2, compared with 2.38mΩ-cm^2 for the DMOSFET.

This work also allowed the inversion electron mobility to be estimated at 21, 13 and 10cm^2/V-s for the upper fin surfaces and the trench bottoms and sidewalls, respectively. The researchers comment: "The MOS properties of the etched sidewalls clearly need to be optimized, and considerable room exists for improvement."

The team adds: "Looking to the future, we can expect further performance improvement when the MOS interface on the trench sidewalls is optimized, since measured inversion mobility on a- and m-face epilayers is reported to be ~8x higher than the mobility on the sidewalls of our etched trenches" ■

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Author: Mike Cooke

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event calendar

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

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

21–24 March 2021
2021 IEEE International Reliability Physics Symposium (IRPS)
— now a virtual, online conference
E-mail: IRPSreg@ieee.org
www.irps.org

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

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

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

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

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

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

advertisers' index

6–10 June 2021
(postponed from 28 March –1 April 2021)
OFC 2021: Optical Networking and Communication Conference & Exhibition
Moscone Center, San Francisco, CA, USA
E-mail: OFC@csreg.zohodesk.com
www.ofcconference.org

9–13 June 2021
(postponed from 21–25 June 2020)
IEEE Applied Power Electronics Conference and Exposition (APEC 2021)
Phoenix, AZ USA
E-mail: registration@apec-conf.org
www.apec-conf.org

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

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

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

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

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

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

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

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

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

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

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

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

24–28 October 2021
(postponed from 13–17 September 2020)
13th European Conference on Silicon Carbide and Related Materials (ECSCRM 2020-2021)
Vinci International Convention Centre, Tours, France
E-mail: ecscrm-2020@univ-tours.fr
www.ecscrm-2020.com

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

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