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Gallium nitride and silicon carbide for EV applications



GaN RF market growth • Cree's Q1 impacted by COVID-19
Record-mobility transparent tin dioxide thin films



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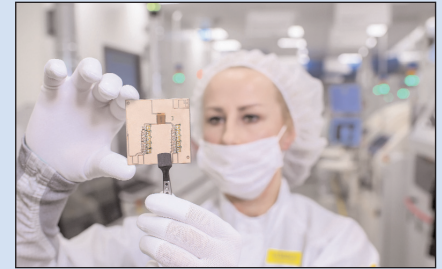


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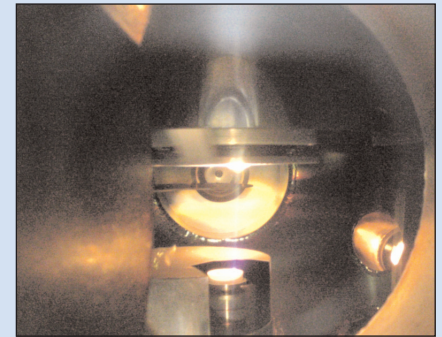
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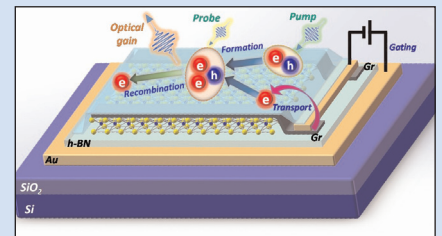
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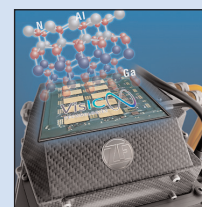
p17 Vitesco has chosen ROHM as a preferred partner for SiC power devices for 800V and 400V inverters in EVs.



p50 University of Tokyo has used pulsed laser deposition to achieve record-mobility of tin dioxide thin films.



p52 Excitonic complexes in 2D semiconductors have been exploited to achieve optical gain, offering the prospect of low-power nanolasers for high-speed communications.



p20 Cover: GaN MISHEMT developer VisIC has partnered with automotive supplier ZF to create high-performance and high-efficiency electric drivelines for vehicles, focusing on the largest, 400V segment of the electric vehicle market.

COVID-19 compounded by trade war

Global smartphone shipments fell (by 17% year-on-year) to 275 million in first-quarter 2020 as the COVID-19 coronavirus pandemic led to shut-downs of major economies, starting with China, according to Strategy Analytics (see page 6). IDC concurs, adding that China shipments fell by 20.3%, Europe by 18.3% and the USA by 16.1% (page 8). The Chinese market saw better-than-expected demand in March as COVID-19 infections there began to slow, it adds. However, the global market is expected to return to annual growth only in fourth-quarter 2020. TrendForce adds that Q2/2020 should see another record year-on-year decline, and has cut its full-year forecasts to an 11.3% decline (see page 68).

For the March quarter, US-based RF component maker Qorvo's revenue was down on initial guidance by \$32m, after COVID-19 "impacted the smartphone supply chain and customer demand more than anticipated" (page 10). The June quarter is expected to be down 5.9% year-on-year. Similarly, Skyworks was down 5% year-on-year (and down on initial guidance by \$44m). Its June quarter is expected to be down by 10% year-on-year, before a revival in second-half 2020 (page 12).

For Cree (which makes LEDs as well as GaN and SiC power & RF devices), March-quarter revenue was down 21% year-on-year and \$9.5m below guidance (page 36). Its June quarter is also expected to be down by just over 20%. However, the latter is due mainly to supply constraints. "We have started to see a recovery in LED demand," it says. "While the underlying demand for our power & RF devices is improving, we continue to navigate near-term headwinds including the impact of COVID-19 related to more stringent safety measures that we implemented to protect our employees, which will lower factory utilization and productivity," it adds.

Likewise, San Jose-based optoelectronic device maker Lumentum's March-quarter revenue was down 7% year-on-year due to a \$10m larger-than-expected impact on its supply chain as COVID-19 spread beyond China late in the quarter (page 46). Its June quarter will be impacted by over \$90m.

Much of the revenue loss is due to the effects of COVID-19. However, Skyworks notes that, excluding revenue from China-based smartphone and telecom network infrastructure maker Huawei (formerly its second largest customer, contributing 12% of total revenue) - which in May 2019 was added to the US Department of Commerce's 'Entity List' prohibiting the export to Huawei of certain products without obtaining a license - then first-quarter revenue would have been up 4% year-on-year rather than down 5% (with Mobile revenue in particular growing by over 9%). "Business with Huawei remains at a much lower level than it was historically," it says.

Nevertheless, for San Jose-based opto device maker NeoPhotonics, Huawei comprised 52% of revenue (up from 41% the prior quarter), from products now deemed to be exempt from the export restrictions, and as demand in China has recovered. However, NeoPhotonics warns that the US Department of Commerce has now added other Chinese companies to the Entity List, which could restrict its exports to China's FiberHome.

In addition, the US Commerce Department now (since mid-May) aims to ban the use of US-made equipment or software worldwide for designing and making chips supplied to Huawei, presenting a further headwind (this time to suppliers to chip makers), in addition to COVID-19.

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Semiconductor Today covers the R&D and manufacturing of compound semiconductor and advanced silicon materials and devices

(e.g. GaAs, InP and SiGe wafers, chips and modules for microelectronic and optoelectronic devices such as RFICs, lasers and LEDs in wireless and optical communications, etc).

Regular issues contain:

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

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Smartphone shipments fall 17% year-on-year in Q1/2020 to 275 million

Samsung remains top at 21% market share, followed by Huawei at 18% and Apple at 14%

Global smartphone shipments fell 17% year-on-year from 330.4 million units in first-quarter 2019 to 275 million units in first-quarter 2020 (the smartphone industry's worst ever quarterly performance), according to a report from the Strategy Analytics Wireless Smartphone Strategies (WSS) service.

"Demand for smartphones slammed to a halt in the quarter, as the Covid-19 virus scare shut down major economies like China and shoppers placed their spending plans on hold," says Linda Sui, director at Strategy Analytics.

Samsung maintained first position with 21% global smartphone marketshare, Huawei held steady in second at 18%, while Apple nudged up to 14% share in third place.

"Samsung shipped 58.3 million smartphones worldwide in Q1/2020, slumping 19% annually from 71.8 million units in Q1/2019... Samsung's lowest quarterly smartphone shipments for eight years,"

says executive director Neil Mawston. "Despite a strong lineup of A, S and Note series models, Samsung was unable to escape the virus-led plunge in smartphone demand. However, market share fell only slightly from 21.7% to 21.2%.

Huawei's smartphones shipments slipped by 18% from 59.1 million in Q1/2019 to 48.5 million in Q1/2020. Despite US-China trade wars and the Covid-19 virus, Huawei's global smartphone marketshare fell only slightly, from 17.9% to 17.6%. China remains Huawei's core region, accounting for most of its sales.

"Apple iPhone shipments fell a better-than-expected 9% annually from 43.1 million units in Q1/2019 to 39.2 million in Q1/2020," notes director Woody Oh. Apple's global smartphone marketshare has risen from 13% to 14.3%. "Apple's new iPhone SE model, with lower pricing and larger presence in emerging markets like India, will give volumes a further bump in the coming months," he adds.

Xiaomi maintained fourth place but, with shipments remaining level at 27.5 million units, it rose from 8.3% global smartphone marketshare a year ago to a record 10% in Q1/2020. "Xiaomi is dominating the huge India market at the moment and this is giving the company a big boost in smartphone shipments," notes director Linda Sui.

OPPO maintained fifth position, as global smartphone marketshare rose slightly from 7.7% a year ago to 8.2%, despite shipments falling by 11% from 25.4 to 22.6 million units. "OPPO continues to expand into Western Europe and elsewhere, with high-profile models like the Reno 3 5G," continues Sui. "However, OPPO has stepped back somewhat from the US smartphone market in recent months, and that region remains a key gap in its portfolio strategy."

www.strategyanalytics.com/access-services/devices/mobile-phones/smartphone/smartphones/reports

COVID-19 to reduce GaAs revenue in 2020, but recovery could be swift

Deployment of 5G devices and networks to power recovery

With a heavy dependence on cellular terminals, recent forecasts of declining handset shipments in response to the COVID-19 pandemic will result in lower gallium arsenide (GaAs) device revenue in 2020, reckons the Strategy Analytics Advanced Semiconductor Application insight 'A First Look at the Effects of COVID-19 on GaAs Revenue'. Based on current trends in several application segments, the insight

forecasts a likely trajectory for GaAs revenue out to 2025.

"GaAs RF device revenue growth has struggled in recent years and revenue actually declined for the first time in many years in 2019," notes Eric Higham, director of the Advanced Semiconductor Applications (ASA) service. "GaAs revenue links closely to trends in the cellular segment, so recent forecasts of sharp drops in smartphone shipments

caused by the COVID-19 pandemic will contribute to further declines in GaAs revenue," he adds. "The complete effects of COVID-19 on the supply chain remain unclear, but I'm optimistic about the future of GaAs device revenue. Based on the most recent information, 5G will become a strong growth engine and GaAs device revenue should be reaching new highs in the next few years."

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Power and compound semiconductor fab spending to rebound in second-half 2020, then grow 59% to record \$6.9bn in 2021

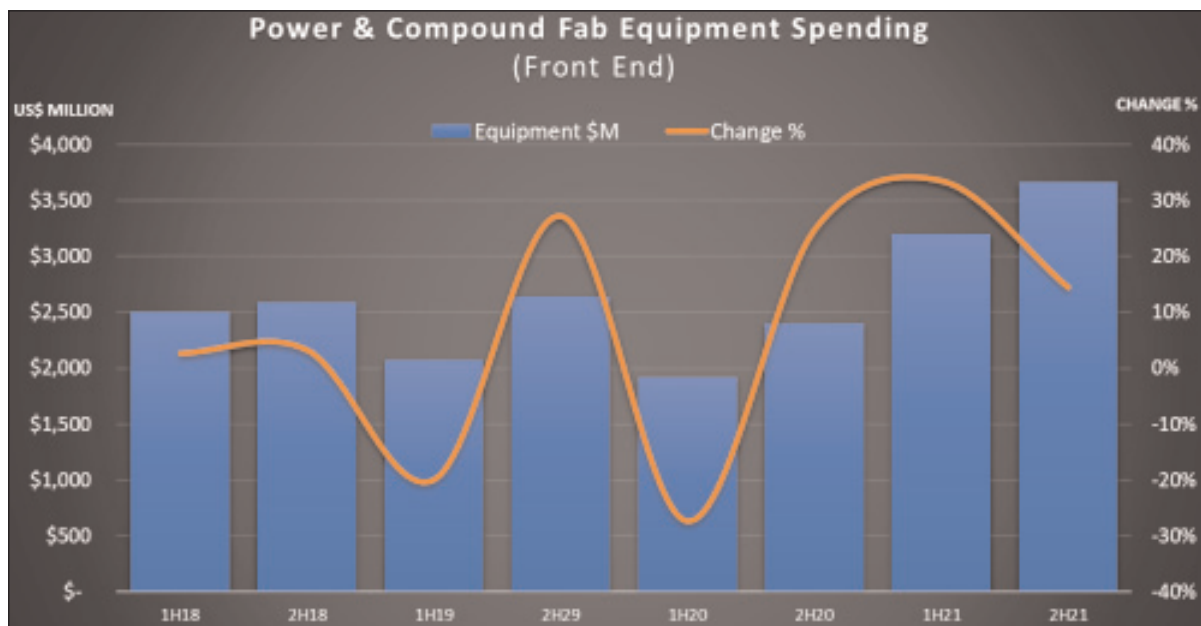
Annual spending to fall 8% overall in 2020

Global fabrication plant equipment spending for power and compound semiconductor devices is expected to rebound in second-half 2020 to meet resurgent end-product demand and jump 59% to a segment record of US\$6.9bn in 2021, according to the 'Power & Compound Fab Report to 2024' from

industry association SEMI. The 2020 rally will help to blunt a drop in annual spending, now projected to be 8%, as fabs ride the COVID-19 recovery wave, adds the report.

Power and compound semiconductor devices are used to control electrical energy for devices across an array of industries such as computing, communications, energy and automotive. Since the widespread enactment of stay-at-home orders to curb the spread of the COVID-19 coronavirus, demand for servers, laptops and other electronics at the heart of online communications has surged.

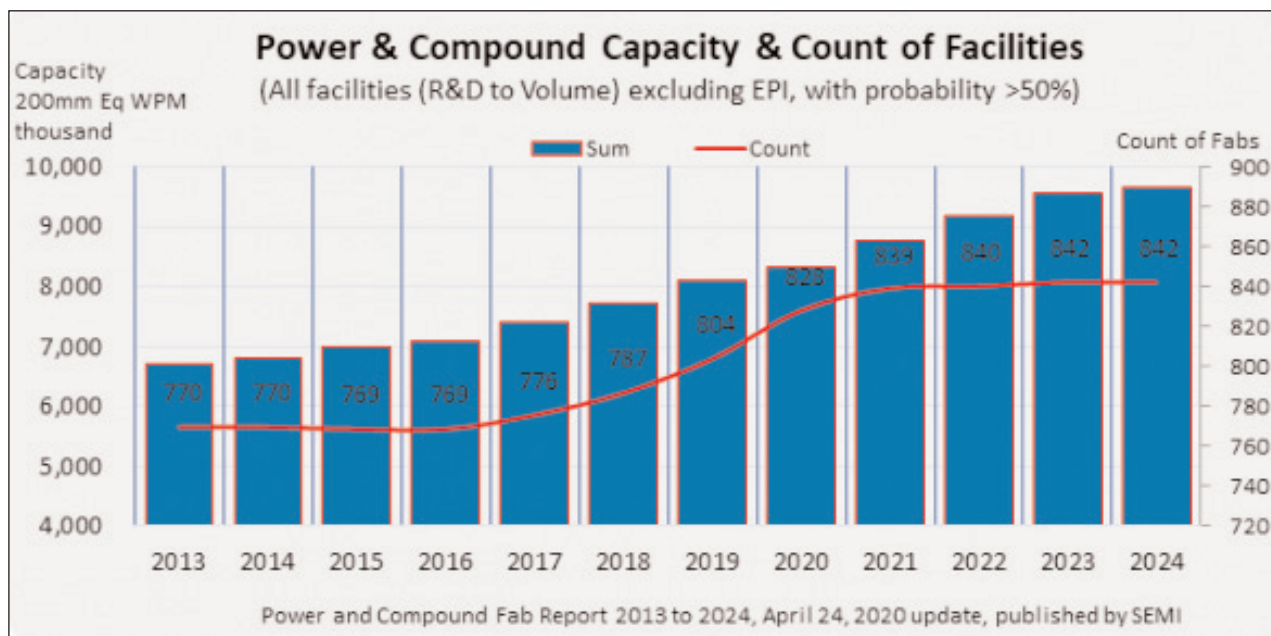
The report lists more than 800 power- and compound-related



facilities and lines and covers investments and capacities for the 12 years from 2013 through 2024. In 2019, the report tracked 804 facilities and lines with installed capacity of 8 million wafers per month (in 200mm-equivalent wafers). By 2024, 38 new facilities and lines will begin operation, fueling installed capacity growth of a cumulative 20% to 9.7 million wafers per month.

By region, China will expand power and compound semiconductor fab capacity more than any other region, by 50% and 87% respectively, over 2019-2024. Over the same period, Europe/Middle-East and Taiwan will lead the way in adding power fab capacity, while the Americas and Europe/Middle-East will be among those regions adding compound fab capacity, the report concludes.

www.semi.org



COVID-19 drives smartphone market's largest year-on-year quarterly revenue drop, to 275.8 million

Annual growth expected to return only in Q4/2020

Worldwide smartphone shipments fell by 11.7% year-on-year to 275.8 million in first-quarter 2020, according to preliminary data from the International Data Corporation (IDC) Worldwide Quarterly Mobile Phone Tracker. Although the first quarter usually experiences a sequential (quarter-over-quarter) decline in shipments (averaging 15–20% in the last three years), this is the largest annual (year-on-year) decline ever.

Q1/2020 marked the beginning of the COVID-19 pandemic and the peak of the lockdowns in China, which extended to the rest of the world by the end of the quarter. The largest regional decline was in China, which saw shipments drop 20.3% year-on-year. Since China constitutes almost a quarter of worldwide shipments, this had a huge impact on the overall market. The global dependency on China for its smartphone supply chain also caused major issues as the quarter progressed. Other regions that contributed to the drastic worldwide decline were the USA and Western Europe, which fell by 16.1% and 18.3%, respectively.

"What started as primarily a supply-side problem initially limited to China has grown into a global economic crisis with the demand-side impact starting to show by the end of the quarter," says Nabila Popal, research director with IDC's Worldwide Mobile Device Trackers. "While the supply chain in China started to recover at end of the quarter, as IDC expected, major economies around the world went into complete lockdown, causing consumer demand to flatline. Consumers get increasingly cautious about their spending in such uncertain times and it is hard to think smartphone purchases won't suffer as a result. This drop in demand, combined with the lockdowns and closures of retail shops across the globe, strongly

Smartphone shipments (m), market share & year-on-year change.

| Company | Q1/2019 | | Q1/2020 | | YoY Change |
|--------------|--------------|-------|--------------|-------|---------------|
| | Units | Share | Units | Share | |
| 1. Samsung | 71.9 | 23% | 58.3 | 21.1% | -18.9% |
| 2. Huawei | 59.1 | 18.9% | 49 | 17.8% | -17.1% |
| 3. Apple | 36.8 | 11.8% | 36.7 | 13.3% | -0.4% |
| 4. Xiaomi | 27.8 | 8.9% | 29.5 | 10.7% | 6.1% |
| 5. vivo | 23.2 | 7.4% | 24.8 | 9% | 7% |
| Others | 93.5 | 29.9% | 77.5 | 28.1% | -17.2% |
| Total | 312.3 | | 275.8 | | -11.7% |

impacted all consumer device markets, including mobile phones. As the uncertainties of the lockdowns and total economic impact linger, vendors are reconsidering their outlook for 2020," she adds.

"The Chinese market saw better-than-expected demand in March as the number of new COVID-19 cases began to ease," says IDC research manager Will Wing. "Nevertheless, the rate of recovery in March is mostly due to pent-up demand and is unlikely to be sustained as the global economic downturn is expected to have an adverse impact on the Chinese economy and consumer sentiment as well and only allow the market to achieve annual growth in the fourth quarter."

Smartphone company highlights

Samsung shipped 58.3 million smart-phones in Q1/2020 and regained its top position, with 21.1% market share, despite an 18.9% year-on-year decline. This is primarily due to the continued success of the A series despite the launch of its premium 5G flagship, the Galaxy S20. However, the S20's higher price did help grow profits, according to Samsung. Looking ahead, Samsung (like others) will face an uphill battle due to a lack of consumer demand, especially with two new premium devices (Note 20 and Fold 2) coming in second-half 2020.

Huawei held the number two position with a 17.8% share of the global smartphone market despite a decline in shipments of 17.1%

year-on-year. The firm reduced the impact of the downturn with early price cuts on Mate 30 and P30 series and in Honor's V30 and 9X series along with a diversified online-offline channel mix which helped reach consumers even during periods of hard lockdown.

Apple shipped 36.7 million iPhones in Q1/2020, which placed it third with 13.3% share. However, shipments were down only 0.4% year-on-year, which is the lowest annual decline among the top 3 vendors. This is primarily due to the continued success of its iPhone 11 series. Looking forward, the launch of the recent SE (2020) device targeting the lower-priced segment could work well for Apple if consumers shift their buying preferences towards more budget-friendly devices in the uncertain economic climate of 2020.

Xiaomi's market share surpassed 10% for the first time, with year-on-year growth of 6.1%. In India, the firm launched the new Poco and Redmi products just before the full lockdown began, helping some of its Q1/2020 numbers.

vivo returned to the top 5 in Q1 with 9% market share and 7% year-on-year growth, the largest annual growth rate among the top 5. Success in India has also been a key driver for vivo's low-end and mid-range Y and S series. Nevertheless, due to the full lockdown in India, vivo also faced delays in its product launch, concludes IDC.

www.idc.com

Demand for disease prevention products causes shortage across UV-C LED supply chain

UV-C LED packaging market growing at 60% CAGR to 2024

The rapid spread of the COVID-19 coronavirus has generated a corresponding boom in the disease-prevention business, according to the report '2020 Deep UV LED Application Market and Branding Strategies' by the LEDinside research division of TrendForce.

As a case in point, the demand for UV-C LEDs (with wavelengths <280nm), which have disinfection/sterilization properties, has rocketed since the Chinese Lunar New Year, in turn causing massive shortages across the entire supply chain.

Given the extreme shortage of UV-C LED chips, LED package suppliers looking to place orders for these chips need to exercise caution when setting chip specifications; these suppliers may also need to bear the risk of possible chip shortages, notes LEDinside. The current shortage in the UV-C LED market has led to an adjustment to UV-C LED chip quotes, in turn resulting in purchasers being unable to procure chips even with high bid prices.

Some UV-C LED suppliers are already seeing order fulfillment schedules that will last till August, says TrendForce research manager Joanne Wu. In addition, owing to

increased orders for UV-C LEDs, several suppliers are expected to see double-digit year-on-year growth in their UV-C LED revenue this year, in particular those that have maintained UV-C LED chip and package operations for many years, including Seoul Viosys, Asahi Kasei (Crystal IS), Stanley, Bioraytron (a joint venture between Epileds and HPLighting) and San'an Optoelectronics. UV-C LED chip suppliers primarily include San'an Optoelectronics, Photon Wave, Opto Tech, and Epileds.

Whereas UV-C LED suppliers have historically relied on increased efficiency and competitive prices to receive branding contracts, the coronavirus pandemic in 2020 has compelled brands and consumers alike to place a high priority on disinfection. Demand for UV-C LEDs has extended from China to the USA, Europe and Japan, culminating in peak market demand. TrendForce therefore estimates that UV-C LED packaging market revenue is rising at a compound annual growth rate (CAGR) of 60% during 2019–2024.

In response to the increased demand for disease prevention measures, brand vendors have released a host of UV-C LED prod-

ucts, including disinfection bags, disinfection boxes, maternity products, UV torchlights, and portable disinfection/sterilization products.

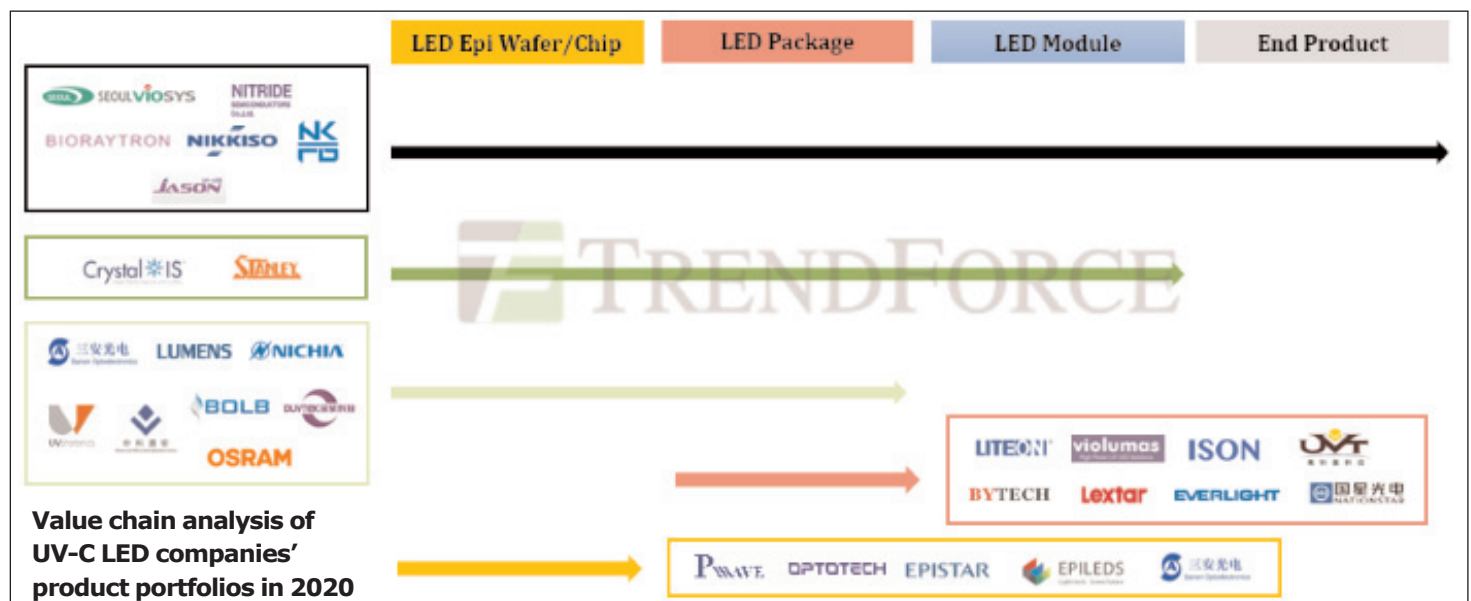
UV-C LED makers have been committed to developing the field of home appliance brands for many years. As UV-C LED technology becomes more mature and is more accepted by big brands, UV-C LEDs are eventually entering a period of booming in growth 2020, says LEDinside. Major UV-C LED suppliers for the home appliance market include Seoul Viosys, Bioraytron, Lite-on and San'an Optoelectronics.

TrendForce also expects UV-C LED to see widespread use in commercial applications such as air conditioning, surface sterilization, and water sterilization. UV-C LED suppliers for such applications include Seoul Viosys, Asahi Kasei, Stanley, Violumas, San'an Optoelectronics and Nichia.

Also, the passenger car market plans to adopt UV-C LED products as well, in the form of devices for external use and disinfection modules integrated into air conditioners.

All the aforementioned applications are expected to yield steady demand in the UV-C LED market.

www.ledinside.com



Qorvo quarterly revenue exceeds revised guidance, driven by 5G handsets and infrastructure, defense, Wi-Fi 6 and Internet of Things

Profits exceed guidance, despite impact of COVID-19

Qorvo Inc of Greensboro, NC, USA (which provides core technologies and RF solutions for mobile, infrastructure and defense applications) has reported full-year revenue growth of 4.8% from \$3.090bn for fiscal 2019 to \$3.239bn for fiscal 2020 (ended 28 March).

Fiscal fourth quarter 2020 revenue was \$787.8m, down 9.4% on \$869.1m last quarter but up 15.7% on \$680.9m a year ago. This was below the original guidance of \$800–840m provided on 29 January. However, it is above the revised guidance of \$770m provided on 3 March (after the COVID-19 coronavirus “impacted the smartphone supply chain and customer demand more than anticipated”), driven by broad-based demand in 5G handsets and infrastructure, defense, Wi-Fi 6 and Internet of Things (IoT).

In particular, by business segment, Mobile Product (MP) revenue was a stronger-than-expected \$556m, down 16% on \$662m last quarter but up 25.5% on \$443m a year ago, as mobile and handset demand was greater and global supply chain disruptions less impactful than anticipated. “Shipments of our 5G solutions grew sequentially and 5G design activity continued to increase,” says president & CEO Robert Bruggeworth.

Infrastructure & Defense Products (IDP) revenue was \$232m, down only slightly on \$238m a year ago but up 12% from \$207m last quarter due to growth in infrastructure and Wi-Fi.

“Qorvo delivered a strong quarter under challenging circumstances,” says Bruggeworth. “We are operating well, focused on keeping our employees, partners and communities healthy, while supporting customers and advancing technology. Our technologies and operations are more important than ever as

we support global deployments in 5G handsets and infrastructure, defense, Wi-Fi 6 and IoT.”

Highlights of the quarter in Mobile Products are listed as:

- supporting Samsung’s Galaxy S20 platform with a broad set of high-performance and highly integrated 4G and 5G components (including mid-high-band and ultra-high-band 5G solutions);
- supplying a leading smartphone maker with the complete main path — including low-band (LB), mid-high-band (MHB) and ultra-high-band (UHB) integrated solutions — as well as the Wi-Fi front-end module (FEM), switches and tuners for their recently launched flagship 5G smartphone;
- expanding the firm’s position in UHB solutions at leading Android smartphone makers and across all 5G chipset solutions.

Highlights of the quarter in Infrastructure & Defense Products are listed as:

- enabling sub-6GHz 5G network deployments (for cellular infrastructure) by ramping shipments of GaN power amplifiers and small-signal components (with demand being driven by the ramp of massive MIMO antennas);
- accelerating Wi-Fi 6 shipments and securing cable amplifier design wins (in Qorvo’s connectivity and broadband businesses) to support increased data to the home (expanding the global customer base of Qorvo’s Wi-Fi 6 solutions, including its front-end modules and BAW filters);
- seeing growth in data centers, computing and gaming consoles with differentiated programmable power management ICs;
- sampling broadband 100W (27–31GHz) and 130W (32–38GHz) millimeter-wave power amplifiers, expanding Qorvo’s portfolio of

GaN-based solid-state amplifiers for defense applications (including including SatCom, radar and electronic warfare).

On a non-GAAP basis, gross margin has risen from 48.2% a year ago and 49.3% last quarter to 49.6% (above the expected 48.5%), due to favorable product mix effects and better-than-expected manufacturing costs.

Operating expenses have risen further, from \$160.8m a year ago and \$175.6m last quarter to \$181m, but this was partly due to recent acquisitions, and better than the projected \$185m.

Net income was \$185.3m (\$1.57 per diluted share, above the \$1.55 guidance and a record for a fiscal Q4), down from \$220.8m (\$1.86 per diluted share) last quarter but up from \$150.9m (\$1.22 per diluted share) a year ago.

Cash flow from operations was \$214.3m. Capital expenditure (CapEx) was \$35.1m (cut from \$40.7m last quarter). Free cash flow was hence \$179.2m (taking full-year free cash flow for fiscal 2020 to over \$780m, or 24% of revenue).

“Qorvo’s revenue, gross margin, and cash flow performance demonstrate how well we are operating in a challenging environment,” says chief financial officer Mark Murphy.

During the quarter, Qorvo spent \$125m in repurchasing stock. Overall, cash and cash equivalents fell from \$1097.7m to \$750m. This was largely because Qorvo completed two acquisitions: Custom MMIC and Decawave.

“Custom MMIC expands our leadership in GaAs and GaN RF products for defense and aerospace applications, while Decawave positions us as a leading provider of ultra-wide-band (UWB) system solutions for proximity awareness, ►

secure payments and secure access in smartphones, automotive and IoT," says Bruggeworth. "We're pleased to add Qorvo scale to both of these well-established high-performing teams to build on their successes and accelerate their growth."

Qorvo has an untapped revolving credit facility and no near-term maturities. The weighted average maturity of outstanding debt is June of 2027. "With this financial flexibility, we can focus on advancing technology, supporting customers and making prudent organic and inorganic investments that support long-term earnings and free cash flow growth," says Murphy.

For fiscal first-quarter 2021 (to end-June), Qorvo expects revenue of \$710–750m. "Our revenue range for the June quarter is wider than normal, reflecting more uncertainty in our markets and the broader economy due to the effects of COVID-19," notes Murphy. Qorvo expects continued robust mobile 5G growth, though on lower base handset volumes and a return to year-on-year growth for IDP.

Mobile Products revenue should fall sequentially, due principally to COVID-19-related demand effects, albeit with parts of Asia partially offsetting weakness in the rest of the world. The firm's current outlook sees smartphone unit shipments declining by more than 10%

for the calendar year.

"However, we still see 5G-enabled handset demand for calendar 2020, in line to slightly below what we guided in early March," notes Murphy.

IDP revenue should grow again sequentially, returning to strong year-on-year growth due to 5G infrastructure customer demand and the ramp of Wi-Fi 6 (as investment in the latest wireless infrastructure to support connectivity is more important than ever) and sustained strength in defense.

Due in part to lower volumes, gross margin is expected to fall sequentially to 47.5%. "Our efforts to improve the portfolio, right-size our manufacturing footprint and drive productivity are yielding favorable results. As a result, we expect year-on-year gross margin expansion, despite a top-line adversely impacted by COVID-19 and trade effects," says Murphy.

"We expect the ongoing effects of COVID-19 to weigh on our utilization. That, along with continued throughput improvements we've made in Richardson, Texas, afford us the flexibility to defer further

We still see 5G-enabled handset demand for calendar 2020, in line to slightly below what we guided in early March

investment in Farmers Branch [Qorvo's new, idled fab in Texas] until additional capacity is needed," he adds.

"We are continuously monitoring the demand and supply effects of COVID-19 and are sizing our inventories and cost structure accordingly. With uncertainty in the demand profile, we intend to maintain lean inventories, both in-house and in the channel," Murphy continues.

Operating expenses should rise to \$187m in fiscal Q1/2021 due to higher personnel costs, including incremental costs associated with the full-quarter effect of recently acquired businesses. Diluted earnings per share are expected to fall to \$1.13.

"While our June quarter guidance reflects the ongoing demand and supply effects of COVID-19, we are encouraged by continued growth in 5G handsets and infrastructure, and we remain confident in the long-term growth drivers of our business," says Murphy.

CapEx in the near term should remain consistent with spend over the last several quarters. In fiscal 2020, CapEx was \$164m (just over 5% of revenue). "Our spend in fiscal 2021 will remain focused on BAW, GaN and other areas, which advance a differentiated position for Qorvo to best serve customer needs," concludes Murphy.

Qorvo prices offering of additional \$300m of senior notes, upsized from \$250m

Qorvo has priced its offering of an additional \$300m worth of its 4.375% senior notes due 2029 at 102.250% of par value plus interest deemed to have accrued from 15 April to the closing date. This brings the total outstanding principal amount of the notes to \$850m.

The offering was upsized from the \$250m initially announced. Qorvo expects to close the sale of the additional notes on or about 11 June, subject to the satisfaction of customary closing conditions.

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

Qorvo expects to use the net proceeds of the offering for general corporate purposes.

The additional notes will be senior unsecured obligations of Qorvo and will be initially guaranteed,

jointly and severally, by each of Qorvo's existing and future direct and indirect wholly owned US subsidiaries that guarantee Qorvo's obligations under its existing credit facility.

The additional notes will not be registered under the Securities Act or any state securities laws and may not be offered or sold in the USA absent registration or an applicable exemption from such registration requirements.

www.qorvo.com

Skyworks' March-quarter revenue falls

5% year-on-year to \$766.1m

Non-Huawei Mobile revenue grows 9%, driven by early 5G ramp with Chinese customers

For fiscal second-quarter 2020 (to 27 March), Skyworks Solutions Inc of Woburn, MA, USA (which manufactures analog and mixed-signal semiconductors) has reported revenue of \$766.1m, down by 14.5% on \$896.1m last quarter and by 5% on \$810.4m a year ago. This is below the initial guidance (given on 23 January) of \$800-820m but in line with 4 March's reduction in guidance by \$45m to \$760-770m due to the impact of the COVID-19 coronavirus pandemic.

Also, despite COVID-19, revenue is up 4% year-on-year if you exclude revenue from China-based smartphone and telecom network infrastructure maker Huawei Technologies Co Ltd, which on 15 May 2019 was added to the 'Entity List' of the US Department of Commerce's Bureau of Industry and Securities (BIS), prohibiting the sale to Huawei of products covered by the Export Administration Regulations (EAR) without obtaining an appropriate license. (Huawei was previously Skyworks' second largest customer, contributing 12% of total revenue in fiscal first-half 2019.)

"Business with Huawei remains at a much lower level than it was historically, although we are able to continue to ship under the ban, which is still effective," notes chief financial officer Kris Sennesael. Nevertheless, China overall still comprised about 20% of Skyworks' total revenue in fiscal Q2/2020.

By market sector, revenue for Mobile (Integrated Mobile Systems and Power Amplifiers) has fallen by mid-teens sequentially (from 73% to 70% of total revenue), in line with normal seasonality, and flat on year-on-year despite the reduction in revenue from Huawei. Excluding Huawei, Mobile revenue grew by more than 9% year-on-year, driven by content gains as well as an early

5G ramp with Chinese customers (e.g. Oppo, vivo, Xiaomi).

Broad Market revenue fell by mid-single-digits sequentially (while rising from 27% to 30% of total revenue).

On a non-GAAP basis, gross margin rebounded slightly from 50.1% last quarter to 50.2% (although it is still down on 50.7% a year ago).

Operating expenses were \$135m (17.6% of revenue), up slightly from \$134m last quarter but level year-on-year, as Skyworks "continues to prudently manage OpEx while making the necessary investments to accelerate future growth of the business," says Sennesael.

Net income was \$229.5m (\$1.34 per diluted share, below the original guidance of \$1.46), down from \$288.8m (\$1.68 per diluted share) last quarter and \$256.6m (\$1.47 per diluted share) a year ago.

Operating cash flow was \$280.4m. Capital expenditure (CapEx) was \$60.7m. Free cash flow was hence \$220m (free cash flow margin of 29%). Skyworks again paid \$75m in dividends. The firm also repurchased 3.2 million shares of common stock for a total of \$283.8m.

(In the last 12 months, Skyworks has returned 92% of free cash flow to shareholders through a combination of dividends and share buybacks.) During the quarter, cash and

investments hence fell from \$1229m to \$1108m. The firm has no debt.

Since the end of the quarter, Skyworks' board of directors has declared a cash dividend of \$0.44 per share of common stock (payable on 11 June to stockholders of record at the close of business on 21 May). "We intend to continue with our share repurchase program," notes Sennesael.

"During the March quarter, we expanded our engagement with leading customers, securing key design wins across numerous applications from the mobile phone to wireless infrastructure, IoT [Internet of Things], automotive, machine-to-machine and medical applications," says president & CEO Liam Griffin.

"In Mobile, we are leveraging our Sky5 platform across multiple flagship 5G handset launches, including Samsung, Oppo, Vivo, Xiaomi and other tier-1 players," he adds. Skyworks is expanding its technology reach across its customized Diversity Receive platforms with new 5G-centric solutions being deployed across a growing set of customers, driving sharp gains and design-win count.

In IoT, Skyworks is supporting high-performance 5G and Wi-Fi-enabled tablets specifically developed for health, safety and telemedicine applications. "Across mobile operators, we are powering 5G mobile hotspots with Verizon and AT&T, supporting the expanding work-from-home trend," notes Griffin. "We are extending our market leadership in Wi-Fi 6 with home and enterprise gateways at Cisco. We're enabling home security applications at Honeywell and ramping wireless remote patient monitoring systems with GE. We're also launching asset-tracking and fleet-management solutions

We are powering 5G mobile hotspots with Verizon and AT&T, supporting the expanding work-from-home trend. We're enabling home security applications at Honeywell and ramping wireless remote patient monitoring systems with GE

with Juniper and Blackberry," he adds.

"In the infrastructure space, we're supporting 5G Massive MIMO and small-cell base-station deployments across the USA, Europe and Japan. In automotive, we're accelerating connectivity content with leading brands including Volkswagen, Renault, Hyundai, and Nissan."

"These highlights demonstrate our technology leadership underpinned by a diverse and growing set of critical product categories, resolving increasingly complex architectures and preparing our customers for the performance gains demanded in 5G," says Griffin.

"Our design-win momentum reflects our execution across a rapidly evolving business environment, one in which our wireless technologies are playing an essential and critical role," continues Griffin.

"We are enabling markets from telemedicine to emergency response, remote work, online education, real-time security, streaming entertainment and safe store-to-door food delivery. Our mission of connecting everyone and everything all the time has never been more relevant," he adds.

"From an inventory point of view, we are running slightly higher than normal," says Sennesael. In the March quarter, Skyworks increased its inventory by \$44.9m, boosting days of inventory to 165 days. "But, it is by design," says Sennesael. "We have increased our buffer stocks, we have increased even finished goods inventory. We kept the loading in our factories. Again, it's all in support of the ramp in the second half. We want to

make sure we continue to deliver on time to our customers," he adds. "We had a temporary suspension in our Mexican factory. We were able to continue to deliver products to our customers. That situation now has been resolved, while we are building this inventory that has very few or little risk from an E&O [excess and obsolete] point of view.

As announced on 14 April, following an order by the government of the state of Baja California, Mexico in an effort to reduce the spread of the COVID-19 coronavirus, Skyworks temporarily suspended its back-end assembly & test operations in Mexicali (out of which 70–75% of Skyworks' revenue is normally generated). On 27 April, state and local officials permitted Skyworks to resume operations.

Otherwise, to date Skyworks says that it has not experienced any significant disruptions to ongoing operations or to its supply chain as a result of COVID-19. In response to the pandemic, Skyworks continues to implement multiple protocols in its facilities worldwide, including social distancing, daily pre-shift temperature screening, enhanced use of personal protective equipment, heightened sanitation standards and remote-work options wherever possible. In addition, it continues to implement rotating shifts with reduced staffing at its global manufacturing sites. Implementation of these protective measures allows Skyworks to better safeguard employee health while simultaneously maintaining business and manufacturing operations and continuing to provide products critical to sectors deemed

'essential' under the applicable laws, regulations and orders of the jurisdictions in which the company has facilities.

"During this time of social distancing and decreased travel, the technology Skyworks provides has become a primary means of connecting people all over the world," says Griffin. "The rollout and adoption of 5G and other advanced wireless technologies, such as Wi-Fi 6 and Enhanced GPS have become the pillars in support of the vast connected economy," he adds.

"Given the supply chain and demand disruptions associated with COVID-19, visibility is limited for the June quarter, resulting in a wider revenue range compared to prior quarters," says Sennesael. For fiscal third-quarter 2020 (to end-June), Skyworks expects revenue to fall to \$670–710m, despite Broad Market revenue increasing, driven partly by the work-from-home, learn-from-home trends that results in strength in PC, tablets, wearables, Wi-Fi, hotspots, the adoption of Wi-Fi 6 and all the wireless protocols. Gross margin should fall only slightly to 50%. With operating expenses level at \$135.5m, diluted earnings per share should be \$1.13.

"Our target model [for gross margin] is 53%. If it wasn't for the headwinds, we would have been there already," says Sennesael. "In second-half 2020 and beyond, when those headwinds become tailwinds, we will see some nice further gross margin improvements."

www.skyworksinc.com

Skyworks launches dual 2.4GHz front-end module supporting simultaneous Wi-Fi 6 connectivity and LAA support

Skyworks has launched the SKY5-5242-11, a dual 2.4GHz, 802.11ax high-linearity, high-efficiency front-end module (FEM) designed for Wi-Fi 6-enabled devices including handsets, tablets and mobile devices supporting WLAN and

Bluetooth protocols.

Building on Skyworks' portfolio of products for 5G applications, the highly integrated FEM includes two transmit and receive chains, an extremely low-EVM floor power amplifier, low-noise amplifier with

bypass, and a single-pole triple-throw (SP3T) antenna switch. The three transmit modes for high linearity, high efficiency and low gain provide optimal performance.

www.skyworksinc.com/en/Products/Front-end-Modules/SKY55242-11

Anokiwave appoints VP/general manager of Aerospace & Defense portfolio

Anokiwave Inc of San Diego, CA, USA — which provides highly integrated silicon core chips and III-V front-end integrated circuits for millimeter-wave (mmW) markets and active antenna-based solutions — has appointed William 'Bill' Nevius as VP & general manager of its Aerospace and Defense portfolio.

Nevius will lead the firm's strategic defense accounts and build on the long history of partnerships in the community to expand its reach into the market with enabling technology for SatCom, radar, electronic warfare (EW), comms and space applications.

The appointment comes at a strategic time for Anokiwave with what it describes as tremendous opportunities for growth in this market by leveraging the advances of mmW commercial off-the-shelf (COTS) silicon commercial technologies into aerospace & defense systems. Anokiwave has been providing mmW solutions to the A&D



Bill' Nevius, VP & general manager Aerospace and Defense portfolio.

market for more than 20 years and, with Nevius joining, the team will have a more strategic focus in further expanding and bringing value to the defense community. Nevius joined Anokiwave in March and brings 30 years of experience in the advanced defense systems industry. Prior to joining Anokiwave, he held positions at Ball Aerospace as director C3I, director business development, advanced systems manager, and program manager. Anokiwave reckons that Nevius' background as a naval aviator and defense industry executive brings a deep insight and personal experience of the needs and workings of

aerospace & defense markets.

"Bill is a recognized leader in the aerospace and defense industry and is already exposing Anokiwave to new opportunities and customers," says chief operating officer Carl Frank. "Bill's engineering education, military operations, procurement experience, and successful industry leadership will serve Anokiwave well in his new role of refining and expanding our push into aerospace and defense markets."

Nevius holds a bachelor's degree in Mechanical Engineering (US Air Force Academy) and master's degree in Aeronautical Engineering (US Naval Postgraduate School). He graduated from the US Naval Test Pilot School and Navy Fighter Weapons School (TOPGUN). Nevius holds an international patent on a sensor technology for biotechnology applications.

www.anokiwave.com/A&D

Anokiwave adds investment and strategy industry veteran to board

Anokiwave Inc of San Diego, CA, USA — which provides highly integrated silicon core chips and III-V front-end integrated circuits for millimeter-wave (mmW) and active antenna-based 5G communications, mobile satellite communications, and aerospace & defense markets — says that John D. McClellan has joined its board of directors (effective 1 February).

McClellan has more than 30 years of experience in corporate leadership, private equity and strategy consulting. He is a partner at Pear Tree Partners L.P, which provides investment and advisory services to early-stage and growth capital companies. His previous positions include CEO of Palladium Inc, managing director at Thomas H. Lee Partners, CEO of Sprague Energy Corp, and president of EPIK Communications, which he

founded. He started his professional career at the strategy consultancy Monitor Group, where he was a leader in their telecoms practice and rose to the board of directors and served as CEO of its software division Decision Architects.

McClellan holds an M.B.A. with high honors from Harvard University, and a B.A. in Political Economy from Williams College. He has served as an outside director on the boards of Citizens Bank of Massachusetts, The Access Group, and ESM Software Group, and also currently serves on the board of SciAps Inc.

"We are pleased to welcome John to our board of directors at this important stage of Anoki-

Anokiwave is positioned to help accelerate the development of 5G networks

wave's evolution," says Anokiwave's founder, chief technology officer & president Nitin Jain. "As a highly respected and seasoned executive with valuable financial strategy and investment industry experience, we look forward to John's expert engagement and assistance in guiding our objectives to bring breakthrough mmW IC solutions to market," he adds.

"As a leader in the mmW market and the highest-volume supplier of commercial mmW silicon ICs, Anokiwave is executing exceptionally well in the rapidly evolving active antenna markets," comments McClellan. "Anokiwave is positioned to help accelerate the development of 5G networks," he adds. "As a board member, I look forward to adding more breadth and strategic thinking to their already very talented team."

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Infineon extends CoolSiC MOSFET range to 1700V

Having added the 650V voltage class to its portfolio in February, Infineon has complemented its CoolSiC MOSFET range by launching the 1700V class with its proprietary trench semiconductor technology. Maximizing the strong physical characteristics of silicon carbide, this ensures that the new 1700V surface-mounted devices (SMD) offer what is said to be superior reliability as well as low switching and conduction losses. The 1700V CoolSiC MOSFETs are targeting auxiliary power supplies in three-phase conversion systems such as motor drives, renewables, charging infrastructure and high-voltage direct current (HVDC) systems.

Such low-power applications usually operate below 100W. In these cases, designers very often prefer a single-ended flyback topology. With the new 1700V CoolSiC MOSFETs in SMD package, this topology is now even enabled for DC-link connected auxiliary circuits up to 1000V_{DC} input voltage. High-efficiency and

high-reliability auxiliary converters using a single-ended flyback converter can now be implemented in three-phase power conversion systems, leading to the smallest footprints and a reduced bill-of-materials.

"Trench technology of a CoolSiC MOSFET balancing performance and reliability in operation is now available for 1700 V," says Dr Peter Friedrichs, senior director SiC in Infineon's Industrial Power Control Division. "It combines the best of SiC properties: low losses with small footprint, in a high-voltage SMD package. This helps our customers to significantly reduce the complexity in their auxiliary power supplies."

The 1700V blocking voltage eliminates design concerns regarding overvoltage margin and reliability of power supplies, says Infineon. CoolSiC trench technology features the lowest device capacitances and gate charges for transistors of this voltage class, claims the firm. The result is a reduction in power loss

of more than 50% as well as 2.5% higher efficiency compared with state-of-the-art 1500V silicon MOSFETs, it is reckoned. The efficiency is 0.6% higher, compared with other 1700 SiC MOSFETs. The low losses enable compact SMD assembly with natural convection cooling without the need for a heatsink.

The new 1700V CoolSiC trench MOSFETs are optimized for flyback topologies with +12V/0V gate-source voltage compatible with common PWM controllers. Thus, they do not need a gate driver IC and can be operated directly by the flyback controller. On-resistance ratings are 450mΩ, 650mΩ or 1000mΩ. The new 7-lead D²PAK SMD package offers extended creepage and clearance distances over 7mm. With that, it fulfills the usual 1700V application requirements and PCB specifications, minimizing isolation efforts for the design.

CoolSiC MOSFETs 1700V in D²PAK-7L package are available now and in series production.

Modular evaluation platform to test CoolSiC MOSFET driving options

Since double pulse testing is a standard procedure for designers to learn about the switching behavior of power devices, Infineon Technologies has introduced a modular evaluation platform to facilitate the testing of drive options for its 1200V CoolSiC MOSFET in TO247 3-pin and 4-pin packages.

The center of the evaluation platform comprises a motherboard with interchangeable drive cards. The drive options include a Miller clamp and a bipolar supply card. Additional variants will be launched in the near future. In shortening time-to-market for a variety of applications, the portfolio is targeted at helping to pave the way for silicon carbide (SiC) to become mainstream.

The motherboard of the evaluation platform is split into two sections: the primary supply side and the

secondary side. On the primary side, the 12V supply and the pulse-width modulation (PWM) will be connected. On the secondary side is the secondary supply of the driver, the half bridge with connections for the shunt for current measurement and the external inductance.

The positive operating voltage of the drivers can be adjusted between +7.5V and +20V, while the negative voltage can be regulated between +1V and -4.5V. The motherboard was designed for a maximum voltage of 800V and maximum pulsed current of 130A. For measuring at temperatures of up to 175°C, the heatsink can be used together with a heating element.

Serving as a reference design for two drive options, the cards feature driver ICs from the EiceDRIVER family suitable for

high-frequency switching of silicon carbide power devices. The first modular card contains the 1EDC Compact 1EDC20I12MH with an integrated active Miller clamp, which is typically activated below 2V. The second drive card includes the 1EDC Compact 1EDC60H12AH allowing a bipolar supply, where VCC2 is +15V and GND2 is negative. With these two driver cards, the portfolio already covers a large part of the options preferred by designers for driving SiC MOSFETs.

All three components of the modular evaluation platform — motherboard, Miller clamp and bipolar drive cards — can be ordered now. An extra drive card for short-circuit detection will be added to the portfolio this summer. A card for SMD package testing will follow in second-half 2020.

www.infineon.com/cool-sic-mosfet

SUNY Poly professor receives \$625,000 DOE funding for NREL-led research to reduce SiC power electronics manufacturing costs

Could support wider adoption of more robust SiC-based devices versus silicon-based chips for high-performance applications

State University of New York (SUNY) Polytechnic Institute says that associate professor of nanoengineering Dr Woongje Sung has been awarded \$625,000 in funding from the US Department of Energy's Advanced Manufacturing Office as part of what is a collaborative research effort with the National Renewable Energy Laboratory (NREL). Led by NREL, the research is expected to be carried out during the next two-and-a-half years.

Leveraging SUNY Poly's capabilities, the research aims to reduce the cost of manufacturing silicon carbide (SiC)-based power devices, for use in high-performance applications (e.g. automotive, industrial, aeronautical).

SiC-based power devices are currently more expensive to fabricate than the more conventional silicon (Si)-based chips that, because of their inherent properties, are unable to support operations in more extreme heat, and which are also less energy efficient.

The research will concurrently support hands-on opportunities for at least one SUNY Poly graduate student and post-doctoral researcher who will take part in the design of the SiC-based devices, work directly with the fabrication facility, and characterize the fabricated devices.

The DOE award will "help to catalyze a more cost-effective manufacturing process for SiC power devices, in concert with SUNY Poly's top-tier academic and high-tech research ecosystem," says SUNY Poly's interim president Dr Grace Wang.

"By laying the groundwork for a more efficient and cost-effective fabrication process for SiC-based power devices, Dr Sung is driving advancements in a wide range of power electronics applications which are the backbone of countless technologies that we rely on," comments SUNY Poly's interim dean of the College of Nanoscale Science and Engineering (CNSE) Dr André Melendez.

"Our SUNY Poly team, including a graduate student and a post-doctoral researcher, is undertaking this project to evaluate various options for the creation of critical manufacturing process steps that can lead to lower-cost SiC devices, in order to address a significant barrier to the mass adoption of SiC power devices as compared to conventional silicon devices," says Sung.

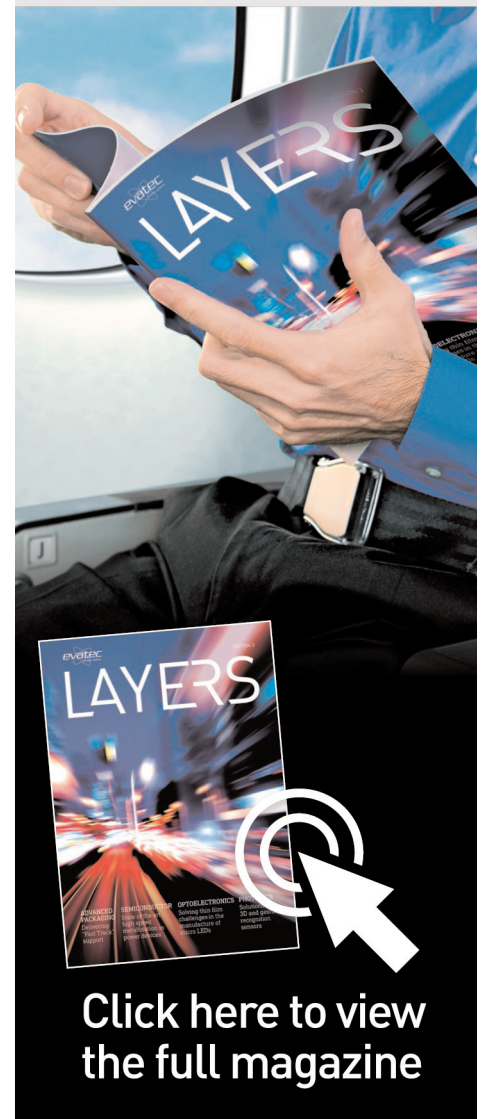
The DOE Advanced Manufacturing Office award follows \$2,103,000 in funding that Sung recently received from the DOE's Advanced Research Projects Agency-Energy (ARPA-E) as part of what is a collaborative research effort with teams from Ohio State University and North Carolina State University.

As part of that effort, Sung is aiming to develop scalable, manufacturable and robust technology (SMART) for silicon carbide power integrated circuits (SMART SiC Power ICs) that open the door to robust switching capabilities in a range of high-performance energy applications, including automotive and industrial, as well as for electronic data processing and energy harvesting.

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NRL develops GaN-based resonant tunneling diode with beyond-5G performance

PAMBE-grown gallium nitride resonant tunneling diodes achieve record current outputs and switching speeds

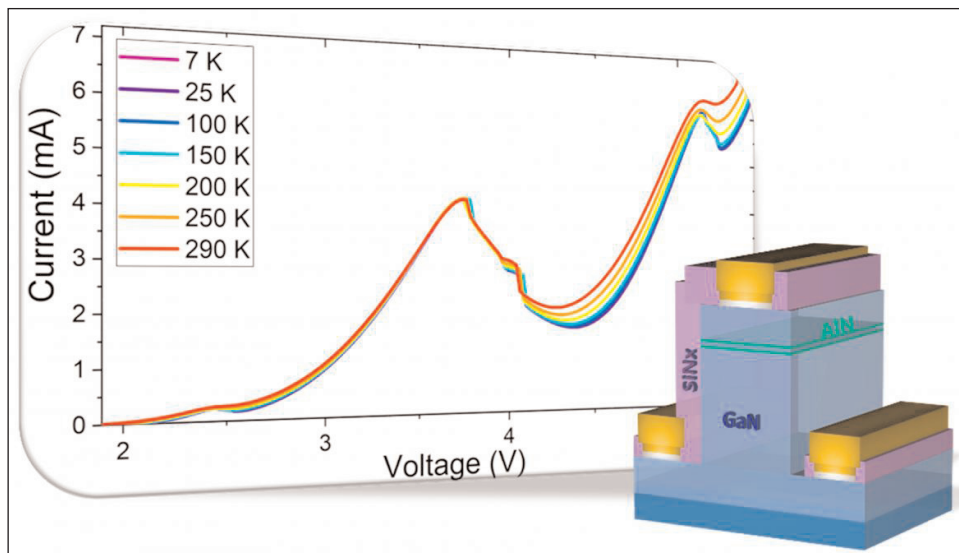
Working with colleagues at Ohio State University, Wright State University and industry partners, research physicist David Storm and electrical engineer Tyler Growden of the US Naval Research Laboratory (NRL) have developed a gallium nitride (GaN)-based resonant tunneling diode (RTD) yielding direct measurement of record switching speeds in GaN/AlN RTDs, beyond the anticipated speed of 5G (Growden et al, 'Superior growth, yield, repeatability, and switching performance in GaN-based resonant tunneling diodes', *Applied Physics Letters* (2020), 116, 113501).

"Our work showed that gallium nitride-based RTDs are not inherently slow, as others suggested," Growden says. "They compare well in both frequency and output power to RTDs of different materials."

The diodes enable extremely fast transport of electrons to take advantage of the quantum tunneling phenomenon, where electrons create current by moving through physical barriers due to their simultaneous particle- and wave-like nature.

Grown by plasma-assisted molecular beam epitaxy (PAMBE), Storm and Growden's design for GaN-based diodes achieved both record current outputs and switching speeds.

Temperature-dependent measurements — combined with non-equilibrium Green's function-based quantum transport simulations — suggest the presence of both three- and two-dimensional emitters, giving rise to three repeatable negative differential resistance (NDR) regions below a bias of +6V. Repeatability measurements consisting of 3000 sweeps resulted in a standard deviation, relative to the mean, of <0.1%. Also, a study of valley current density versus perimeter-to-area-ratio shows the presence of a surface leakage



Simplified view of the GaN-based resonant tunneling diode developed at NRL's Electronic Science and Technology Division and its performance characteristics. NRL expects this RTD to enable technologies beyond 5G and created a process to deliver manufacturing yield of about 90%. NRL graphic by Tyler Growden.

current mechanism, which reduces the peak-to-valley current ratio (PVCR). However, a room-temperature PVCR>2 was observed, which represents a marked improvement over recent reports.

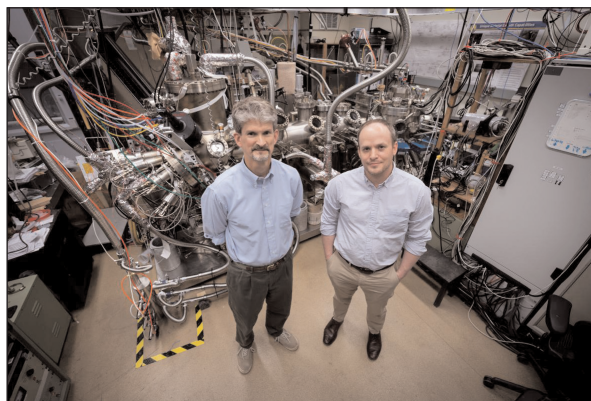
Such performance enables applications in the millimeter-wave region and frequencies in terahertz, including in communications, networking, and sensing.

Unfortunately, since they require sharp interfaces at the atomic level and are very sensitive to many sources of scattering and leakage,

achieving a high yield of operational tunneling devices can be difficult, says Storm. "Until now, gallium nitride was difficult to work with from a manufacturing perspective," he adds. However, the team has developed a repeatable process to increase the diodes' yield. Sample preparation, uniform growth and a controlled fabrication process at every step were key to the diodes achieving satisfactory results on a chip, say the researchers. Measurements carried out on hundreds of devices, of varying sizes, revealed a yield of about 90%; previous typical yields range around 20%. The high yield was largely "due to our design," Storm says.

Storm and Growden say they are committed to continue refining their RTD design to improve current output without losing power potential.

<https://aip.scitation.org/doi/10.1063/1.5139219>
www.nrl.navy.mil



Storm and Growden with their MBE system.

ROHM chosen by Vitesco as preferred partner for silicon carbide power devices

Development partnership targets 800V and 400V SiC inverters for electric vehicles

A development partnership has been agreed for the silicon carbide (SiC) components of power semiconductor maker ROHM Semiconductor of Kyoto, Japan to be used by the powertrain business of Continental Vitesco Technologies of Regensburg, Germany (a supplier in the field of vehicle electrification) to further increase the efficiency of its power electronics for electric vehicles (EV). Due to their higher efficiency, SiC semiconductors make better use of the electric energy stored in a vehicle battery, so an EV has a longer range, or the battery cost can be reduced without impacting the range.

"Energy efficiency is of paramount importance in an electric vehicle. As the traction battery is the only source of energy in the vehicle, any losses caused by power conversion need to be minimized. We are therefore developing a SiC option within our modular power electronics system," says Thomas Stierle, executive vice president of Vitesco's Electrification Technology business unit. "To get the maximum efficiency out of the power electronics and the e-motor we will use SiC power devices from our preferred partner," he adds.

ROHM provides power solutions combined with gate driver ICs, notes Dr Kazuhide Ino, corporate officer, director of Power Device business unit at ROHM Co Ltd. "Together with Vitesco Technologies we want to further improve the energy efficiency of the electronic system in electric vehicles to use the full potential of the SiC technology for a sustainable mobility," he adds.

Vitesco is already developing and testing silicon carbide technology in an 800V inverter concept to confirm

the efficiency potential of the technology. The approach of this program is to look at the complete system of inverter and motor to identify the best combination of device technology and switching strategy. In this context, silicon carbide semiconductors — e.g. SiC MOSFETs for 800V battery systems — offer more efficient switching in the inverter (higher frequency, steeper switching slopes) and cause fewer harmonic losses in the electric motor. Also, silicon carbide technology is a key enabler for super-fast charging technology that uses 800V. In the course of the cooperation, ROHM and Vitesco will work on creating the optimum combination of ROHM's silicon carbide technology for high-volume manufacturing and best fit of inverter design for the highest efficiency.

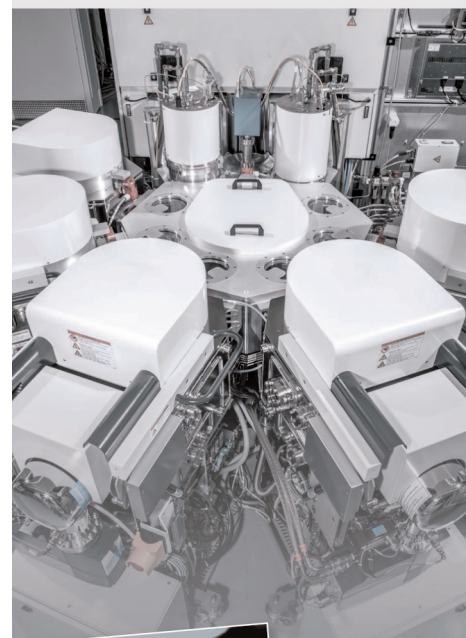
"The SiC option is a very promising future part of our modular power electronics system comprising of software, power output stage, and switching strategy", says Dr Gerd Rösel, head of innovation in Vitesco's Electrification Technology business unit. "We will work with ROHM on an 800V SiC inverter solution as well as on a 400V SiC inverter solution." Vitesco plans to begin production of the first silicon carbide inverter in 2025, when the demand for silicon carbide solutions is expected to rise significantly.

The preferred partnership will also be benefiting from short distances: Vitesco and ROHM both have sites in Nuremberg (ROHM Semiconductor Group's SiCrystal GmbH), not far from Vitesco's headquarters at Regensburg.

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



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VisIC partners with ZF to develop EV inverters

D³GaN technology in 400V driveline systems to extend range and reduce system cost

VisIC Technologies Ltd of Nes Ziona, Israel — a fabless developer of power conversion devices based on GaN metal-insulator-semiconductor high-electron-mobility transistors (MISHEMTs) for automotive, data-center and industrial applications — has partnered with Germany-based global automotive supplier ZF Friedrichshafen AG to create next-generation, high-performance and high-efficiency electric drivelines for vehicles.

The partnership will see the two firms deepen their development efforts, based on VisIC's D³GaN technology. The focus of the joint effort will be on 400V driveline applications, covering the largest segment of the electric vehicle (EV) market.

"Our partnership with ZF for the development of GaN-based power inverters in electric vehicles



illustrates the breakthrough of gallium nitride technology in the automotive industry," says VisIC's CEO Tamara Baksht. "VisIC's D³GaN technology was developed for the high-reliability standards of the automotive industry and offers the lowest losses per $RD_{S(on)}$," she claims. "It also simplifies the system solution and enables high-efficiency and affordable power train solutions."

ZF's adoption of wide-bandgap semiconductor technology, such as silicon carbide and gallium nitride, has enabled it to develop cost-effective and highly efficient electric drivelines. Through their extended R&D partnership, ZF and VisIC are deepening their existing joint efforts in the application of gallium nitride for inverters.

For electric vehicles (from hybrid up to full electric), gallium nitride technology offers significantly better switching speed, range improvements as well as smaller and lighter package size, reducing total system cost. "We are pleased about the cooperation with VisIC and are convinced that, together, we can further improve future electric drive systems based on gallium nitride technology," says Dr Dirk Walliser, senior VP corporate R&D at ZF.

www.visic-tech.com

GaN Systems releases Class-D audio amplifier and companion SMPS evaluation kit

GaN Systems Inc of Ottawa, Ontario, Canada (a fabless developer of gallium nitride-based power switching semiconductors for power conversion and control applications) has announced the debut and availability of a new amplifier evaluation kit for high-sound-quality Class-D audio systems.

The evaluation kit includes a 2-channel, 200W-per-channel (8Ω) Class-D audio amplifier and companion 400W continuous power audio-grade switch-mode power supply (SMPS). This solution highlights an easy plug-and-play design with features such as multi-audio signal inputs, bridge-tied load output, and open-loop/closed-loop toggling. With GaN, the design is very efficient and operates without heatsinks. These features allow audio design engineers to create premium audio products at shorter time to market

and at an affordable price, claims the firm.

The convergence of audio trends, including demand for more power, size and weight reduction, and growing consumer demand for better audio quality requires innovative approaches to enhance sound quality, increase efficiency, and reduce size, which is served by GaN power semiconductors, says GaN Systems. Applications include smart speakers to automotive and high-end home audio systems.

The evaluation kit performance includes the following features:

- 200W/Ch (8Ω), 300W/Ch (4Ω) amplifier with 96% efficiency;
- 400W continuous, 550W peak companion SMPS;
- <0.01% THD+N (8Ω, 1W, 20Hz to 20kHz);
- ±0.5dB frequency response to 50kHz;

- high efficiency and no heatsinks, reducing size, weight, and total system cost;
- good EMI/EMC performance due to reduced ringing/noise.

"Class-D audio amplifiers are reaching a new level of performance with GaN," says Paul Wiener, GaN Systems' VP of Strategic Marketing. "Industry experts and audiophiles alike have tested and listened to the output of our design and are truly impressed," he claims. "The audio quality — combined with the thermal and EMI/EMC performance — provide a great solution."

Also, GaN Systems has issued a white paper 'See, Feel, and Hear the Difference with GaN Class-D Amplifier and Companion SMPS' reviewing the its audio evaluation kit using the standard set of industry performance and validation tests.

www.gansystems.com/class-d

Navitas launches 650V, 6mm x 8mm PQFN-packaged GaNFast power ICs with integrated cooling pad

Navitas Semiconductor Inc of El Segundo, CA, USA has launched a new range of 650V-rated GaNFast power ICs in 6mm x 8mm PQFN packaging with a proprietary, integrated cooling pad for high-efficiency, high-density power systems.

Founded in 2014, Navitas introduced what it claimed to be the first commercial gallium nitride (GaN) power ICs. The firm says that its proprietary 'AllGaN' process design kit (PDK) monolithically integrates GaN power field-effect transistors (FETs) with GaN analog and logic circuits, enabling faster charging, higher power density and greater energy savings for mobile, consumer, enterprise, eMobility and new energy markets.

Navitas says that GaNFast power ICs enable next-generational upgrades across diverse markets, from 25–100W consumer and mobile USB-C fast chargers and adapters for smartphones and laptops, to 200-800W TV and all-in-one computers and on up to multi-kW electric vehicles (EV), industrial and data-center power supplies.

"As we've seen in recent releases from Xiaomi and Lenovo, GaNFast power ICs run at high speeds and drastically shrink the size and cost of passive components in fast chargers and adapters," notes Navitas' chief technology officer/ chief operating officer & co-founder Dan Kinzer. "The NV612x-series delivers a cool 10-15°C reduction in temperature with an enlarged thermal interface to the PCB and a direct thermal and electrical connection to the system ground, enabling the world's highest power density and passing all thermal specifications and agency approvals," he adds.

Navitas says that, while competing solutions require additional,

complex, external driving and protection components, the unique and proprietary monolithic integration of GaN FET, GaN digital and GaN analog circuits means that the new GaNFast ICs deliver what is claimed to be the simplest, smallest, fastest and now even cooler performance. This combination of simplicity and capability drives what it says is the world's smallest-size fast chargers to achieve power densities as high as 1W/cc at 65W and 1.25W/cc at 300W, far beyond any other discrete GaN or silicon solutions.

For power electronics designers, the new NV612x-series of GaNFast power ICs offers a solution to thermal problems by providing an immediate improvement in heat dissipation through the printed-circuit board (PCB), says Navitas. The 6mm x 8mm range with advanced cooling pad is offered at the same price as the existing 5mm x 6mm GaNFast range and, in some cases, the new low temperature may enable the designer to substitute a smaller-die version to reduce system costs further.

The new range of 650V-rated power ICs (300mΩ NV6123, 175mΩ NV6125 and 125mΩ NV6127) includes complete gate drive and protection circuits plus GaN power FETs in 6mm x 8mm surface-mount PQFN, low-inductance (high-speed) packaging.

Design-support includes detailed datasheets, electrical models (SPICE), mechanical models (.stp) plus a thermal-layout application note (AN011). All parts are in high-volume mass production and available immediately from Navitas distribution partners, with prices starting as low as \$1.19 in 1000-unit quantities.

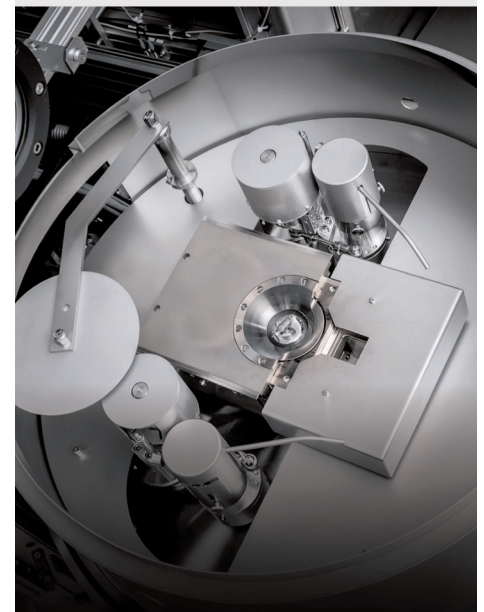
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Buffalo reports gallium oxide transistor with breakdown exceeding 8kV

Polymer passivation of field-plated lateral Ga₂O₃ MOSFETs beats comparable SiC and GaN transistors

In research supported by the US Air Force Office of Scientific Research and by the US National Science Foundation (NSF), researchers in the University of Buffalo's Department of Electrical Engineering have developed a gallium oxide (β -Ga₂O₃) metal-oxide-semiconductor field-effect transistor that can handle voltages of more than 8000V (Shivam Sharma et al, 'Field-Plated Lateral Ga₂O₃ MOSFETs With Polymer Passivation and 8.03 kV Breakdown Voltage', IEEE Electron Device Letters, vol41, issue6 (June 2020), p836).

Associate professor Uttam Singiseti (senior author of the paper) and students in his lab have been studying the potential of gallium oxide, including previous work exploring transistors made from the material.

Gallium oxide has an ultrawide bandgap energy of about 4.8eV. This exceeds that of the incumbent power electronics material silicon (1.1eV) as well as its potential replacements including silicon carbide (about 3.4eV) and gallium nitride (about 3.3eV). Systems made with wide-bandgap materials can be

thinner, lighter and handle more power than systems made of materials with narrower bandgaps.

A key innovation in the new transistor revolves around the passivation process (i.e. coating the device to reduce the chemical reactivity of its surface), for which a layer of SU-8 epoxy-based polymer was added.

Tests conducted in March — for MOSFETs with a gate-drain length (L_{gd}) ranging from 30 μ m to 70 μ m and across two process runs — showed consistently higher breakdown voltages in passivated devices compared with non-passivated devices. The tests also showed that the transistor can handle a maximum voltage of 8032V before breaking down (for L_{gd} up to 70 μ m), which is more than similarly designed transistors made of silicon carbide (SiC) or gallium nitride (GaN) that are under development.

"The higher the breakdown voltage, the more power a device can handle," says Singiseti. "The passivation layer is a simple, efficient and cost-effective way to boost the

performance of gallium oxide transistors."

Simulations suggest a figure of over 10MV/cm for field strength (the intensity of an electromagnetic wave at a given spot, which eventually determines the size and weight of power electronics systems).

"These simulated field strengths are impressive. However, they need to be verified by direct experimental measurements," Singiseti says.

The transistor could lead to smaller and more efficient electronic systems that control and convert electric power in electric cars, locomotives and airplanes, improving their range.

"To really push these technologies into the future, we need next-generation electronic components that can handle greater power loads without increasing the size of power electronics systems," says senior author Uttam Singiseti, adding that the transistor could also benefit microgrid technologies and solid-state transformers.

<https://ieeexplore.ieee.org/document/9081968>
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SweGaN's buffer-free GaN-on-SiC HEMT epi demonstrates competitive microwave performance and device efficiency

Joint study with Chalmers shows that 250nm-thick GaN layer does not compromise material quality and device performance

SweGaN AB of Linköping, Sweden, which manufactures custom gallium nitride on silicon carbide (GaN-on-SiC) epitaxial wafers (based on a unique growth technology) for RF and power electronics devices, has announced a new benchmark for GaN high-frequency devices based on its QuanFINE material, reckoning that the demonstration promises commercial benefits for the entire GaN RF value chains including telecom, space and military markets.

In a new joint study with the Department of Microtechnology and Nanoscience at Chalmers University of Technology in Gothenburg, SweGaN explored QuanFINE epi performance, based on GaN high-electron-mobility transistor (HEMT) technology at Chalmers University (Chen et al, 'Microwave Performance of 'Buffer-Free' GaN-on-SiC High Electron Mobility Transistors', IEEE Electron Device Letters, vol41, issue 6 (June 2020), p828).

The team performed a new benchmark comparing the conventional 1.8µm-thick Fe-doped GaN buffer epi-structure to SweGaN's 'buffer-free' QuanFINE GaN HEMT heterostructures for microwave applications. The study revealed that the new concept, using a total GaN layer thickness of 250nm, does not compromise the material quality and device performance. Further, the device results indicate that the 'buffer-free' QuanFINE material can outperform conventional materials at the device level in the long run.

SweGaN says that, for customers and manufacturers, the ultimate benefits resulting from the new 'buffer-free' concept include lower trapping, better carrier confinement and lower thermal resistance, which could lead to higher device power efficiency and better reliability of GaN high-frequency devices.

"The new QuanFINE concept possesses many interesting features that are very attractive for both high-frequency and power electronics, says Niklas Rorsman, research professor at Chalmers. "As an example, the possibility of a pure AlN back-barrier will be beneficial both for good electron confinement and thermal resistance," he adds.

"Currently, GaN-on-SiC epitaxial wafers for Ka-band applications are either immature or suffer from severe trade-offs, says SweGaN's chief technology officer Dr Jr-Tai Chen. "Our QuanFINE epiwafers are a highly feasible solution that can resolve issues our customers are dealing with regarding short-channel effects in the high-frequency devices," he adds. "We already have numerous product companies interested in our material as well as end users in the value chains," continues Chen. "Four key target groups for QuanFINE epiwafers include the world's leading foundries, IDMs (integrated device manufacturers), fabless companies, and end users, in Europe, Asia and USA."

Key demonstrations from the joint collaboration include the following:

- physical simulations (TCAD) indicated that QuanFINE can be highly favorable for improved electron confinement;
- pulsed-IV measurements demonstrated a unique advantage of using the QuanFINE concept, showing a lower buffer-induced dispersion compared to the conventional thick, Fe-doped buffer;
- large-signal measurements demonstrate that the QuanFINE concept can provide highly competitive output power levels and efficiency, vastly beneficial to product companies and end users.

According to SweGaN, the QuanFINE concept is a thin undoped GaN channel layer in between an AlGaN barrier layer and a low-TBR (thermal boundary resistance) AlN nucleation layer that acts as a sandwich-like double heterostructure, offering sufficient two-dimensional electron gas (2DEG) confinement with much lower trapping effects compared with conventional Fe- and C-doped epi-structures. Moreover, the further reduction of GaN channel thickness will pave the way to small-gate-length device ($L_g < 150\text{nm}$) compared with conventional AlGaN back-barrier epi-structures that suffer from weak thermal dissipation performance.

Further studies of the carbon impurity and thickness of the unintentionally doped (UID) GaN layer are expected to further improve the 'buffer-free' QuanFINE concept.

<https://ieeexplore.ieee.org/document/9068265>

SweGaN named finalist in Nordic region's Techarena Challenge

SweGaN has been chosen as one of the Nordic region's 50 leading firms in the Techarenan Challenge 2020. Events to select the Techarenan

Challenge 2020 'Startup Company of the Year' and 'Growth Company of the Year' take place in Stockholm on 9–10 June and 13

November, where the 50 finalists will pitch to this year's jury.

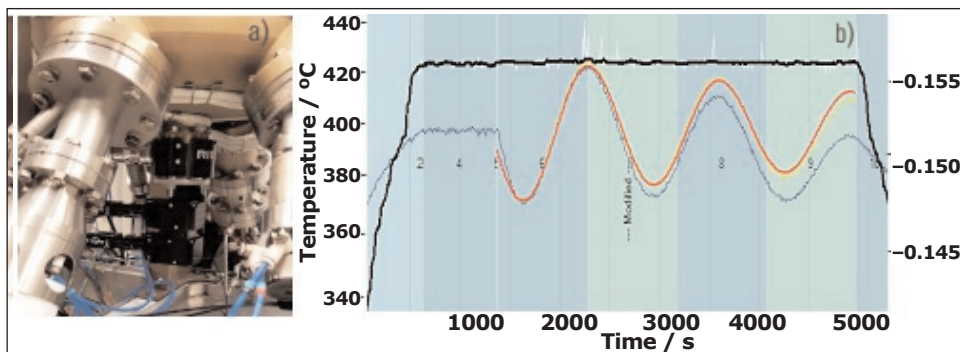
www.swegan.se
www.techarenan.news

LayTec's EpiTT Band Edge tool used for ZnO substrate temperature and growth rate control in MBE

In a recent project, the group of professor C. Meier at the University of Paderborn — which focuses on modern methods of nanofabrication and nanotechnology with the aim of developing novel devices for photonics, plasmonics and nonlinear processes — has grown zinc oxide structures using molecular beam epitaxy both by homoepitaxy on ZnO and by heteroepitaxy on sapphire and silicon substrates.

In-situ metrology system maker LayTec AG of Berlin, Germany is supporting this research with a newly developed version of its EpiTT Band Edge tool that combines long-wavelength (1550nm) pyrometry with short-wavelength ZnO band-edge temperature sensing as well as with 405nm in-situ reflectance.

While temperature sensing on silicon substrates and growth rate measurements during growth of



EpiTT Band Edge for oxide semiconductor MBE: (a) the optical head, as mounted on a Riber C12 MBE system, and (b) example in-situ data — ZnO substrate temperature (black line) and 405nm reflectance (blue line). After surface roughening effects have been numerically removed (yellow line), the best fit (red line) yields a growth rate of 0.078nm/s.

ZnMnO/ZnO heterostructures are covered by the EpiTT's standard performance, the Figure shows the performance of the EpiTT Band Edge even during ZnO/ZnO homoepitaxy: the temperature of the ZnO substrate is measured throughout the process by the integrated Band Edge tem-

perature module, and 405nm reflectance gives access to the homo-epitaxial growth rate. At this wavelength, close to the ZnO band-edge, the tiny ($\pm 0.5\%$) Fabry-Perot oscillations of ZnO grown on ZnO (with different doping levels) can be resolved, notes LayTec.

LayTec reports use of EpiTT FaceT for process control of GaAs-based laser facet passivation in MBE

After in January reporting the use of its EpiTT FaceT temperature metrology system for improving the yield of facet coating processes in large production molecular beam epitaxy systems for high-power gallium arsenide (GaAs)-based lasers, LayTec is now sharing the latest data on the EpiTT FaceT's performance: beyond facet tem-

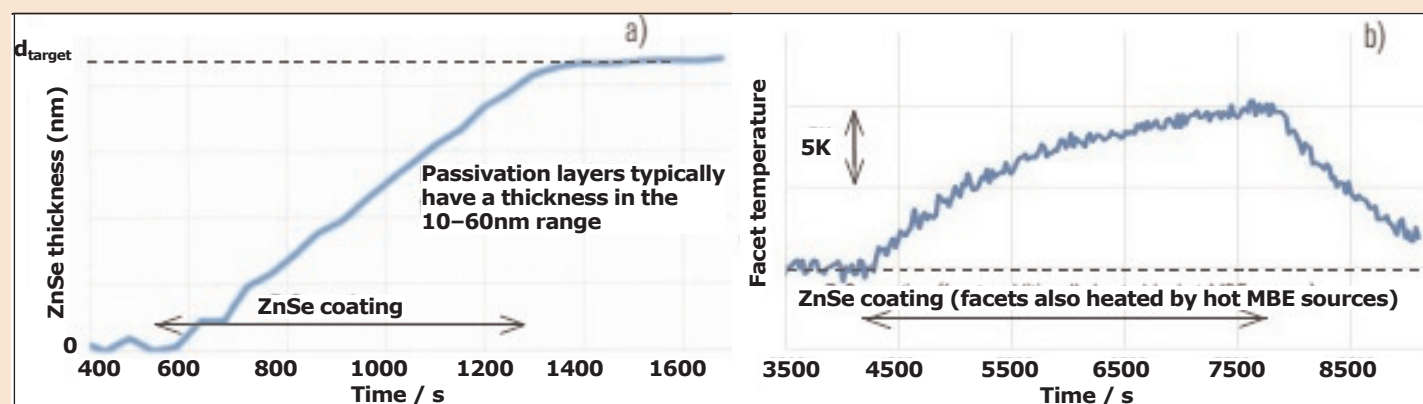
perature sensing in the range between room temperature and 400°C it has added real-time in-situ thickness sensing of the nanometer-scale zinc selenide (ZnSe) facet coating layers.

(a) shows the increase in ZnSe thickness (d) on the facets, as measured with a resolution better than 0.5nm by short-wavelength

reflectance during the MBE process. (b) demonstrates the response of facet temperature to heat transfer from the MBE sources during coating.

LayTec says the comprehensive and precise process control is vital to prevent catastrophic optical damage (COD) in the laser devices.

www.laytec.de/epitt



Monitoring ZnSe facet coating on a stack of GaAs-based edge-emitting lasers.

Riber's Q1 revenue down 19% year-on-year

For first-quarter 2020, Riber S.A. of Bezons, France — which makes molecular beam epitaxy (MBE) systems as well as evaporation sources and effusion cells — has reported revenue of €5.3m (62% from Europe, 34% from Asia and just 4% from the USA). This is down 19% on €6.6m a year ago (of which only 30.1% came from Europe, 32.3% from Asia, and as much as 37.6% from the USA).

Revenue for MBE systems was €2.3m, down 44% on €4.1m a year ago. This includes billing for just one production system, compared with two a year ago. Difficulties related to export licenses led to a delay in the billing of a research system in Q2/2020.

Revenues for Services & Accessories grew strongly by 79% from €1.7m to €3m.

In line with previous quarters (and just €0.8m a year ago), revenue for Evaporators (cells and sources) is negligible due to the lack of investment in the organic light-emitting diode (OLED) screen industry.

The order book at the end of March was down 18% from €32.2m a year ago to €26.5m. Due to the difficulties of finalizing contracts in Asia linked to the pandemic, MBE system orders are down by 25% from €25.3m to €18.9m (comprising 11 systems to be delivered in 2020, including three production units). Orders for Services and accessories are up 11% from €6.8m to €7.6m. Evaporator orders were zero, compared with just €0.1m a year ago.

To minimize the impact of the Covid-19 coronavirus pandemic on its business, Riber has adapted its organization. Due to actions rolled out since 13 March, Riber has kept almost all staff operational, working either from home or on site. More specifically, it is still able to produce and deliver, while continuing to develop its strategic projects. However, the firm faces a slowdown in its commercial activity, with certain orders deferred, especially in China (Riber's leading region), where the 5G market is still very buoyant.

www.riber.com

Riber revises order book after refusal of export license

Riber has revised its order book following the French authorities' refusal to grant export licenses for two deals signed previously. At the same time, the firm has announced receipt of a new order for a research system in Asia.

The equipment manufactured and marketed by Riber is classified as 'dual-use goods', which require an export license from the French authorities for sales to countries other than the European Union, North America and Japan.

Following extensive discussions, the French authorities refused to grant Riber an export license for two deals concerning three

machines, whose orders were announced on 6 and 10 December 2019. Acting in accordance with international regulations, Riber has therefore canceled these orders, worth a total of €4m.

In this context, the order book at end-March 2020 has been revised down from €26.5m to €22.5m.

Riber says that the negotiations underway should make it possible to sign significant contracts that will compensate for these cancellations. For example, the firm has just received a new order from an Asian research center for a research machine (for which the export license has been obtained).

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Knowledge is key

Veeco's Q1 revenue at high end of revised guidance

Operating expense reductions ahead of target, yielding better-than-expected margin and profit

For first-quarter 2020, epitaxial deposition and process equipment maker Veeco Instruments Inc of Plainview, NY, USA has reported revenue of \$104.5m, down 7.7% on \$113.2m last quarter but up 5.1% on \$99.4m a year ago, and at the high end of the \$100–105m guidance range (which had been revised on 31 March from mid-February's initial guidance of \$95–120m), driven by strength in data storage business in the Scientific & Industrial segment.

"Due to disruptions related to various governmental measures implemented to contain the [COVID-19] virus in mid-March, we withdrew our [original] financial guidance for the first quarter. Shortly thereafter, as an essential business supporting critical infrastructure, we maintained operations at all our manufacturing facilities with minimal disruptions," says CEO William J. Miller Ph.D.

"Our supply chain, manufacturing and service operations have been successful in maintaining our ability to source materials, ship products and provide support for our customers with only minor disruptions."

The Scientific & Industrial segment contributed 47% of total revenue, up from 28% last quarter, with ion beam system shipments to data storage customers (driven by demand in cloud computing) comprising a higher-than-normal proportion of revenue.

The Front-end Semiconductor segment (formerly part of the Scientific & Industrial segment, before the 2017 acquisition of lithography, laser-processing and inspection system maker Ultratech) contributed 30% of total revenue, down from 35% last quarter but up from 23% a year ago, driven by shipments of multiple ion beam deposition systems (for EUV mask blank customers) and laser spike annealing (LSA) systems (for leading-edge technology nodes).

The LED Lighting, Display & Compound Semiconductor segment — which includes photonics, 5G RF, power devices and advanced display applications — contributed 15% of total revenue, falling back from 23% last quarter but still up slightly on 14% a year ago, as the firm sold further slow-moving inventory of LED-related metal-organic chemical vapor deposition (MOCVD) systems and shipped multiple wet etch & clean systems to RF device makers for 5G-related power amplifiers.

The Advanced Packaging, MEMS & RF Filter segment — lithography and Precision Surface Processing (PSP) systems sold to integrated device manufacturers (IDMs) and out-sourced assembly & test (OSAT) firms for Advanced Packaging in automotive, memory and other areas — has fallen further, from 23% of total revenue a year ago and 14% last quarter to just 8%, reflecting the softness in the lithography sector of the advanced packaging market that's lasted for well over a year.

By region, China has fallen back from 22% of total revenue last quarter to just 10%, mainly from legacy MOCVD system and service revenue. Driven by sales to data storage customers, the USA has rebounded from 23% to 38% of total revenue and Europe, the Middle East & Africa (EMEA) has rebounded from 7% to 15%. The rest of the world (including Japan, Taiwan, Korea and Southeast Asia) has correspondingly fallen back from 48% to 37% of total revenue (mainly EUV mask blank and LSA systems).

On a non-GAAP basis, gross margins has risen

further, from 35.5% a year ago and 40.2% last quarter to 44.9% (well above the 39–41% guidance). This was driven by improved product mix and reduced reserves, along with reduced manufacturing costs and service-related expenses, some of which were a result of COVID-19 related restrictions.

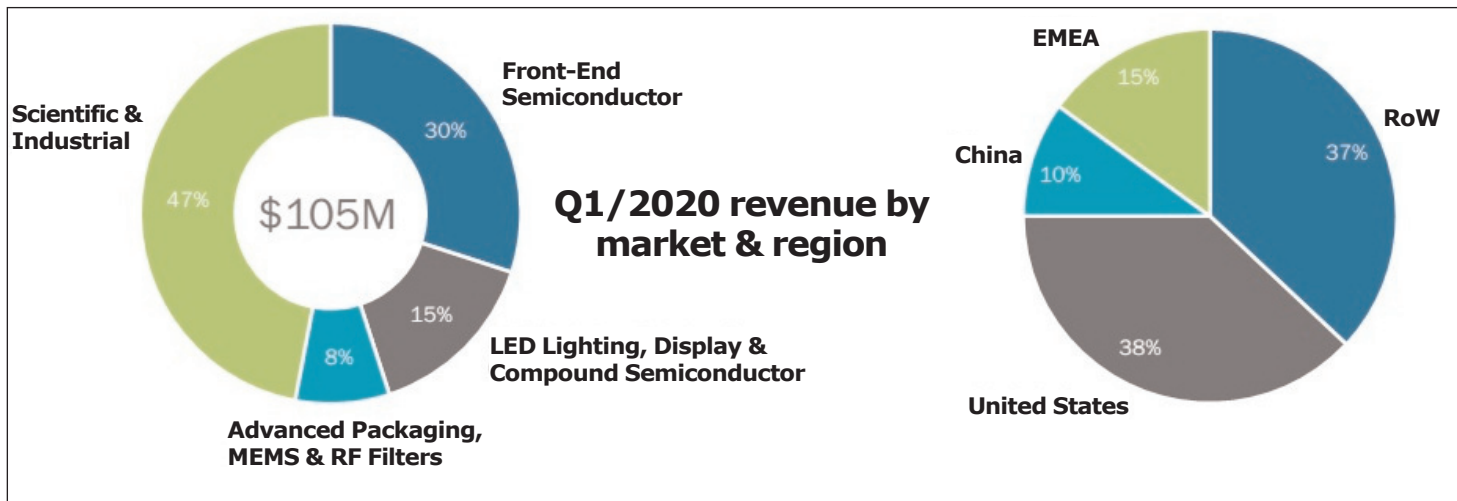
Operating expenses (OpEx) have been cut further from \$40m a year ago and \$38m last quarter to \$34.2m (much better than the \$37m target). "We are ahead of schedule on our expense target reduction and, in addition, Q1 OpEx benefited from less travel and other variable expenses as a result of COVID-19-related restrictions," notes chief financial officer John Kiernan.

"We improved gross margin and reduced operating expenses, driving solid non-GAAP EPS," says Miller. Compared with a loss of \$6.4m (\$0.14 per diluted share) a year ago, net income has doubled from \$5.4m (\$0.11 per diluted share) last quarter to \$10.9m (\$0.22 per diluted share), better than the guidance of \$0–11m (\$0.00–0.22 per share). This is the third consecutive quarter of non-GAAP profitability (and the most profitable quarter in several years).

Working capital increased, as accounts receivable rose to \$84m (from a historically low \$45.7m last quarter), resulting in days of sales outstanding (DSO) rising from 36 to 73 days, due mainly to the timing of when customer payments were due (with some falling just outside of the quarter). This was partially offset by accounts payable rising from \$21m to \$36m, doubling the days of payables outstanding (DPO) from 28 to 57 days. Inventory has been cut further, from \$133m to \$130m, due to progress in selling slow-moving inventory.

Capital expenditure (CapEx) was \$1.1m (cut from \$2.7m last quarter). During the quarter, cash and short-

We are not seeing significant traction of 3D sensing or laser diodes, but we are encouraged with recent GaN MOCVD order activity for power electronics



term investments fell from \$245m to \$242m. Long-term debt was \$303m, representing the carrying value of \$345m in convertible notes (maturing in January 2023).

In April, Veeco finalized the sale of a non-core product line that was designated as held for sale in the March balance sheet. The sales price was \$11.4m, of which \$9.7m was paid on closing the transaction, with the balance to be paid in 18 months.

The divestment is part of Veeco's two-phase business transformation (begun last year) that aims to: (1) return the company to profitability (reducing costs and de-layering the company, involving eliminating over 30% of VP-level and above positions — including the chief operating officer role and promoting John Kiernan to chief financial officer at the beginning of this year — while trimming about 7% of staff); and (2) drive growth.

"Our cash balance, quality of our backlog and the cost reductions we realized over the last several quarters give me confidence in our ability to weather uncertainties," says Miller.

However, given the level of uncertainty resulting from the COVID-19 pandemic, Veeco is refraining from providing Q2/20 revenue guidance.

Specifically, the firm had a few systems for one Chinese LED manufacturing customer (sited close to Wuhan) push out of Q2.

"The other area that we're experiencing some delays is really an acceptance of new products, which is really driven by travel restrictions that our engineers from our factories are unable to visit the customer sites," says Miller. "In compound semiconductor markets, we are not seeing significant traction of 3D sensing or laser diodes, but we are encouraged with recent GaN MOCVD order activity for power electronics," he adds.

"Otherwise, the rollout of our backlog and timing of bookings appear to be on track," says Kiernan.

"Currently all our facilities are running at or near-normal capacity," says Miller. "We've had no supply chain disruptions. We're not seeing significantly reduced or changed customer demand. The quality of our funnel is strong. We had a strong order flow in April. Our cash collections in April are so far strong."

For Q2/2020, gross margin is expected to be more than 40%. "Gross margins have been trending positive over the last number of quarters as a result of transforma-

tional actions taken to improve profitability. But, given the size of individual transactions and product mix, our gross margin will likely fluctuate from quarter-to-quarter," says Kiernan. "We do not expect gross margin to remain as high as 45% we achieved in Q1."

"From an OpEx perspective, we expect to incur lower spending related to travel and other variable costs due to COVID-19-related restrictions in the near term, but we continue to maintain our longer-term \$36m or less quarterly OpEx target at current revenue levels when business activity returns to normal," says Kiernan. "Although there is uncertainty related to the anticipated impact of the COVID-19 outbreak, we believe our business model, our current cash and short-term investments, and the recent steps we've taken to rationalize expenses leave us well positioned to manage our business through the crisis as it continues to unfold," he adds.

"Our semiconductor technologies enable a variety of important megatrends that are expected to perform well, such as cloud and high-performance computing, artificial intelligence (AI) and 5G RF."

www.veeco.com

Veeco raises \$125m in private offering of 2027 convertible notes

Veeco has completed a private offering of \$125m of 3.75% convertible senior notes due 2027, offered to qualified institutional buyers.

Of the net proceeds of \$121.9m (after fees and expenses), Veeco is using \$10.3m to pay the cost of capped call transactions and \$81.2m to repurchase and retire \$88.3m of

its outstanding 2.70% convertible senior notes due 2023 in separate, privately negotiated transactions. Veeco is using the remainder for general corporate purposes.

Veeco announces governance and diversity improvements to board

Epitaxial deposition and process equipment maker Veeco Instruments Inc of Plainview, NY, USA has announced recent changes to its board of directors, including:

- John Peeler, chairman and former CEO, retiring from the board;
- Richard D'Amore, general partner of North Bridge Venture Partners and previously lead independent director, appointed as chairman; and
- Mary Jane Raymond, chief financial officer & treasurer of II-VI Inc, appointed to the Audit Committee.

John Peeler previously announced his decision to step down as chairman & director of the board, effective 7 May. While chairman, Peeler helped increase the board's diversity with the recruitment of Mary Jane Raymond, the second woman currently serving on the board, last

November. Having led the CEO succession plan, which resulted in the promotion of William J. Miller Ph.D. to CEO in 2018, and believing that good governance calls for both an independent chairman and a properly sized board of directors, Peeler elected to retire from the board.

Effective upon Peeler's retirement, Richard D'Amore, who the board has determined to be independent, has been appointed chairman.

D'Amore has been a general partner of North Bridge Venture Partners, an early-stage venture capital and growth equity firm,

D'Amore has been a general partner of North Bridge Venture Partners, an early-stage VC and growth equity firm

since its inception in 1994. D'Amore has served on Veeco's board for many years and has both a strong business background and considerable board experience, says Veeco. With D'Amore's appointment as chairman, the role of lead independent director is discontinued.

Raymond joined Veeco's board in conjunction with the firm's board diversity initiative. A financial expert, currently serving as chief financial officer of engineered materials and optoelectronic component maker II-VI Inc, Raymond was recently appointed to Veeco's Audit Committee. "With her strong executive financial background and technology industry experience, we look forward to her continued contributions to the board and Audit Committee," comments Miller. www.veeco.com

Aixtron changes composition of Executive Board

The Supervisory Board of deposition equipment maker Aixtron SE of Herzogenrath, near Aachen, Germany has appointed Dr Jochen Linck as a new member of the Executive Board, with effect from 1 December 2020 or earlier (for a term of three years), in the role of chief technical and chief operating officer. As of 1 April 2021, he will assume responsibility at Aixtron for the areas of development, purchasing, manufacturing and logistics, quality management and IT.

Executive Board member Dr Bernd Schulte will retire at the expiry of his contract on 31 March 2021. Schulte has been with Aixtron for more than 28 years (since 1993) in various positions and has been a member of the Executive Board since 2002. He currently manages the company together with Dr Felix Grawert. "Schulte has shaped Aixtron with his deep understanding of technology, close customer relationships and entrepreneurial

drive, and has made a significant contribution to the company's success," comments Supervisory Board chairman Kim Schindelbauer.

Linck has many years of experience in international management functions in various areas such as development, product management or launch management. The 54-year-old most recently served on the Executive Committee of Diebold Nixdorf Inc, a global provider of cash management and self-service machines for banking and retail. As managing director of DN Systems, he was responsible for the development and launch of a new product generation of ATMs. Prior to this, the engineer (who has a PhD in lean production) was a partner at McKinsey & Company, with a functional focus on product development, production and strategy in the mechanical engineering, aerospace and automotive industries.

In addition, the Executive Board is to be expanded to include a chief

financial officer, bringing the total number of members to three. The Supervisory Board's Nomination Committee is working to soon fill this position.

Executive Board member Dr Felix Grawert will take over as chairman & CEO on 1 April 2021, when the Executive Board will then consist of three members.

Aixtron's technologies address different growth markets, for which market researchers predict double-digit annual growth rates over the next few years. The firm intends to benefit from this growth and, with an expanded Executive Board, sees itself well set up for the future.

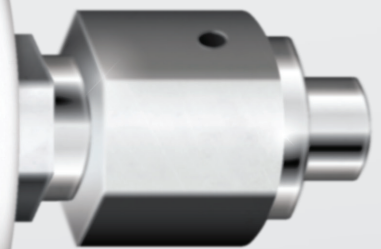
"The generational change in the Aixtron Group's leadership has started with the appointment of Dr Felix Grawert in 2017," says Schindelbauer. "The appointment of Dr Jochen Linck and the soon-to-be-appointed CFO will then complete the generational change."

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Aixtron's Q1 revenue falls 40% year-on-year to €41m

Order intake up 28% despite COVID-19 pandemic

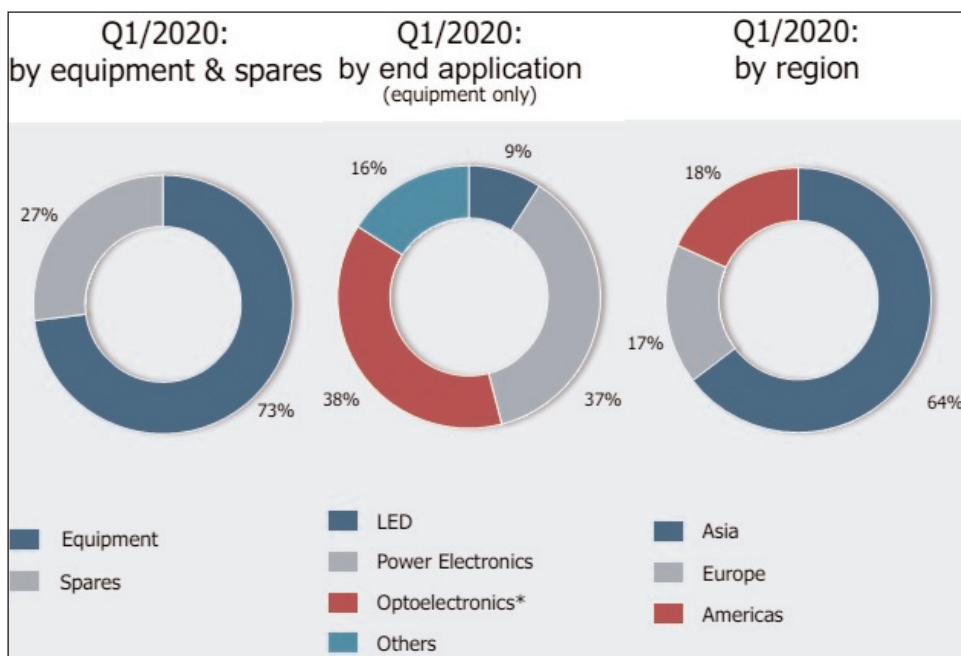
For first-quarter 2020, deposition equipment maker Aixtron SE of Herzogenrath, near Aachen, Germany has reported revenue of €41m, down 45% on €75.1m last quarter and 40% on €68.7m a year ago, due mainly to the low order intake last summer (Q2 and Q3/2019).

Revenue was only slightly below expected due to the delivery of a few systems to China being postponed to Q2/2020 at the request of customers as a result of restrictions related to the COVID-19 coronavirus pandemic. Also, some systems, especially in China, could not be commissioned (in terms of final acceptances) in Q1/2020 as planned. "Overall, however, revenues were in line with planning for the year as a whole," president Dr Felix Grawert. "Despite the special global situation, we remain fully operational and able to meet our customer demand," he adds.

Equipment revenue shrank by 47% year-on-year from €56.1m a year ago to €29.9m (falling from 82% to 73% of total revenue). Revenue from spare parts & services fell by 12% from €12.5m to €11m (although rising from 18% to 27% of total revenue).

Of equipment revenue, the proportion from metal-organic chemical vapor deposition (MOCVD) systems for producing LEDs — including red-orange-yellow (ROY) and specialty LEDs — comprised just 9% of total revenue (down from 56% a year ago). Systems for manufacturing optoelectronic components (i.e. lasers and solar, excluding LEDs) comprised 38% (up from 30% a year ago). Revenue from systems for manufacturing power electronics rose from just 9% to 37%.

Correspondingly, Asian revenue shrank by 54% from €56.7m to €26.3m (falling from 83% of total revenue to 64%), while the Americas grew by 15% from €6.5m to €7.5m (rising from 9% to 18% of total



revenue) and Europe grew by 31% from €5.4m to €7.1m (rising from 8% to 17% of total revenue).

Gross margin was 36%, down from 45% last quarter and 39% a year ago, including a 5% impact from under-utilization (of both production capacity and installation personnel) due particularly to the delayed system commissioning in China.

Mainly as a result of the low sales levels and lower gross margin, the operating result (EBIT) was -€1.1m (3% of revenue), compared with +€14.4m (19% of revenue) last quarter and +€9.7m (14% of revenue) a year ago.

"The low order intake in the summer of last year resulted in low revenues and correspondingly low earnings in Q1/2020," says Aixtron.

Operating cash flow was €4.7m. Capital expenditure (CapEx) has been cut further, to €1.5m. Hence, free cash flow was €3m. This was due mainly to customer prepayments (deposits) received rising from €51m last quarter to €60m (reflecting strong order intake), offset partially by a decrease in trade payables from €19.4m to €15.9m and a further increase in inventories from €79m to €85m (including

about €12m of prototype systems), both on-site at customers and in Aixtron's facilities. Trade receivables were €17.1m, representing 30 days sales outstanding (level with the end of last quarter).

During the quarter, cash and cash equivalents including short-term financial investments (bank deposits with a maturity of at least three months) hence rose from €298.3m to €300.8m, due to increased advance payments from customers and the settlement of receivables.

Order intake was €68.8m, down 15% from the exceptionally strong €81.4m last quarter but up 28% on €53.6m a year ago despite the global effects of the COVID-19 pandemic. This was due to continued strong demand in almost all business areas, especially for the increasing use of LED-based display applications, for the production of lasers for optical data transmission and 3D sensor technology (especially in mobile phones). The ongoing expansion of the 5G network and the increasing use of energy-efficient power electronics also continue to generate demand. RF & power electronics comprised 40% of total order intake: about

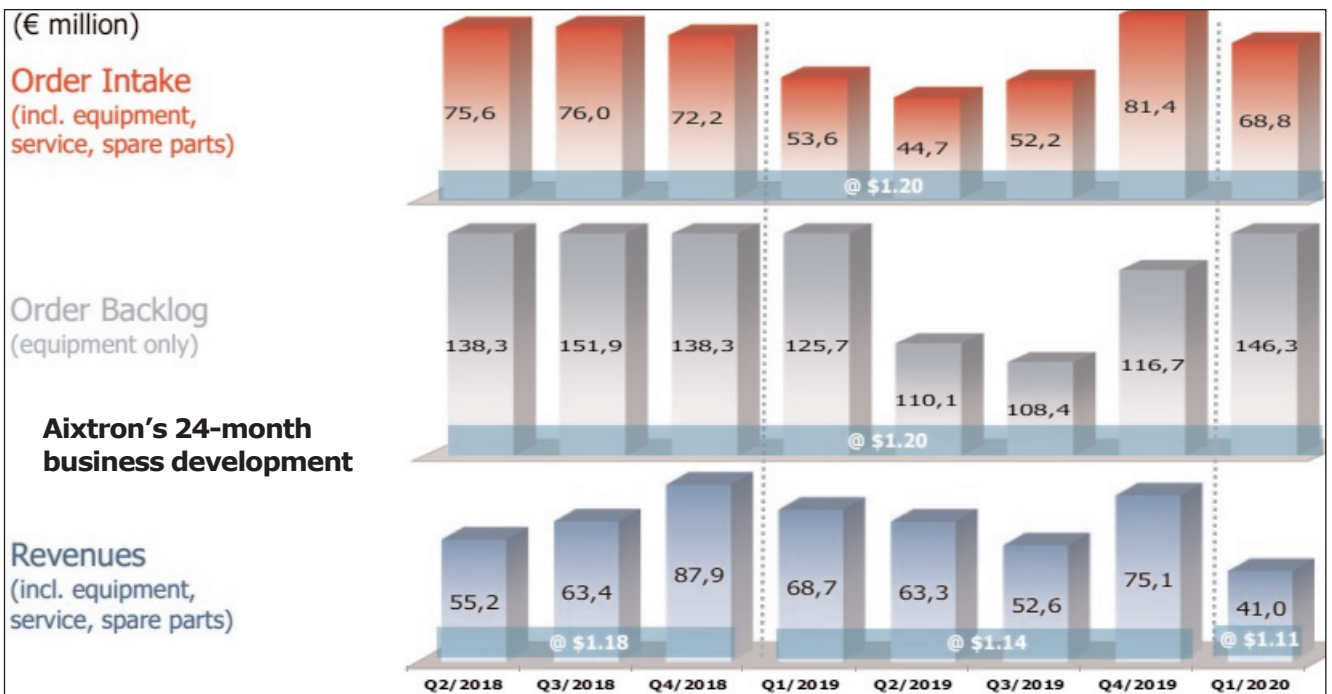
20% for gallium nitride (GaN) and 20% for silicon carbide (SiC). Equipment order backlog at the end of March was €146.3m, up 16% on €125.7m a year ago and

25% on €116.7m last quarter.

"From today's perspective, the COVID-19 pandemic has no significant impact on our business," says president Dr Bernd Schulte. "We should be able to make up for the delay in some deliveries to China in the first quarter and the postponement of installations mainly in China in the course of the year," he adds. "In some countries with strict lockdown orders by government, we have obtained the status of critical infrastructure suppliers with the help of our customers, and therefore all our branches worldwide are fully operational," notes Grawert. "Therefore, in light of the current order backlog and market development, the executive board confirms its guidance for fiscal year 2020."

Based on its existing corporate structure, the assessment of the order situation and the budget exchange rate of \$1.20/€, Aixtron expects order intake for full-year 2020 to grow to €260–300m (up from €231.9m in 2019).

Based on the equipment order backlog of €146.3m at the end of Q1, joined by an estimated €40–80m of order intake shippable during 2020 plus an estimated €33m of spares & services revenue, for 2020 Aixtron expects revenue of €260–300m. Gross margin should be about 40% and EBIT



margin should be 10–15% of revenue.

Regarding organic light-emitting diode (OLED) applications, Aixtron says that its South Korea-based subsidiary APEVA is making good technical progress with the qualification process at its Korean customer. "Some technical challenges have been solved. Other topics are still a work in progress," says Grawert. "The end of the Gen-2 project and, with this, a decision about a follow-on project, has come closer. But we are not there yet, and a few months of work are still ahead of us," he adds.

"In our MOCVD business, we are seeing solid interest around our mini- and micro-LED solutions, both for large display applications and for small wearable devices like watches. Furthermore, in optoelectronics, we see growing demand for lasers, in particular for telecom applications. In power electronics, we see strong interest from multiple market segments, gallium nitride power, gallium nitride RF, and silicon carbide, which gives us confidence that this market is moving from R&D to large-scale volume production," Grawert adds.

"Despite the pandemic, we continue implementing our strategy, a core part of which involves the renewal of our entire MOCVD

product portfolio over the next 18 months," says Schulte. "We do see continued customer interest in our products to further build out critical communications infrastructure, contactless sensing, energy efficient power electronics, and innovative displays. Technically, our focused investments into next-generation deposition tools for compound semiconductors and OLEDs will open new market opportunities for our equipment," he believes.

"We are working closely with our supply chain to ensure uninterrupted inflow of materials for the ongoing production of our products," says Grawert. "As part of these activities, we have pre-ordered materials for anticipated production capacities in the second half of this year," he adds. "We continue to serve customers with spare parts worldwide, and we have created backup solutions for critical cases," he adds.

Aixtron says that its executive board will continuously monitor the impact of the COVID-19 pandemic on the global economy and the movement of goods, in order to assess and — if necessary — take corrective action in the event of any potential impact on the firm's own supply chain, production, and customer demand.

www.aixtron.com

KLA's new Electronics, Packaging and Components Group ICOS, Orbotech and SPTS brought together to target growth

Process control and yield management solutions provider KLA-Tencor Corp of Milpitas, CA, USA has formed a new business group focused on growth in its Electronics, Packaging and Components (EPC) businesses. Led by executive VP Oreste Donzella and providing systems and services across the semiconductor and microelectronics value chain, the EPC group brings together the ICOS, Orbotech and SPTS Technologies organizations to target growth opportunities in new and expanding end markets.

"This new group integrates KLA's acquisition of the Orbotech and SPTS business to bring complementary technologies, products and services into one organization to drive innovation and results in fast-growing markets," says KLA's president & CEO Rick Wallace. "By applying the KLA operating model, we will enable common processes that allow the new group to deliver superior value to our customers across the electronics value chain,"

he adds. "This strategy is expected to accelerate profitability and growth in segments outside our core semiconductor process control markets, as outlined during our September 2019 investor day."

Global megatrends such as 5G, artificial intelligence (AI) and the Internet of Things (IoT) continue to drive growth across key industries like mobile, data center, automotive and virtual connectivity, notes KLA. This momentum is leading to innovation across specialty semiconductor process, advanced packaging and printed circuit board (PCB) manufacturing to enable new capabilities in the key industries, while supporting increasing quality requirements in manufacturing, the firm adds. Advanced packaging technologies and high-density interconnects are employed in high-performance computing (HPC) to enable AI. Wafer processing capabilities for new substrate materials like silicon carbide (SiC) and gallium nitride (GaN) are accelerat-

ing the transition to electric vehicles (EVs). Novel packaging designs, including integrated antenna in RF devices, are key enablers for the advancement of 5G connectivity. Finally, MEMS and IoT sensors for healthcare, smart homes and smart factories will help to transform and improve lives over the coming years, KLA adds.

KLA reckons that this new business organization will allow it to be more focused on meeting the changing needs of customers and the marketplace during this growth phase.

The EPC group joins KLA's existing business units, Semiconductor Process Control (which creates and deploys highly differentiated inspection and metrology products) and Global Support and Services (managing the firm's recurring revenue subscription-based services group and KLA Pro legacy systems).

www.kla.com
www.spts.com

SPTS wins Queen's Award for Enterprise in Innovation

SPTS Technologies Ltd of Newport, Wales, UK — a KLA firm that makes etch, physical vapor deposition (PVD), chemical vapor deposition (CVD) and molecular vapor deposition (MVD) and thermal wafer processing solutions for the MEMS, advanced packaging, LED, high-speed RF-on-GaAs, and power management device markets — has been honored with the Queen's Award for Enterprise in Innovation 2020 (its second such award, following the first in 2018), this time recognizing its development of the 300mm Mosaic fxP plasma dicing system for high-throughput and damage-free singulation of semiconductor devices.

With what is claimed to be the largest installed base of plasma dicing systems in the industry, Mosaic fxP systems are found in volume

production environments for applications including RFID, smart cards, power devices and integrated photonics. SPTS introduced its first 300mm plasma dicing system into the global advanced packaging sector with funding assistance from a Welsh Government R&D grant.

In addition to assessing the degree of innovation, the award's judging panel also evaluated SPTS on its responsible business practices, which included employee affairs, customer and supplier relationships, and its impact on the environment and contribution to society.

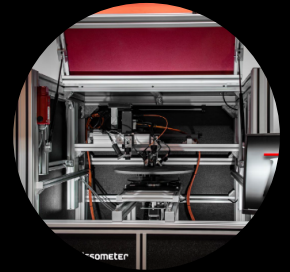
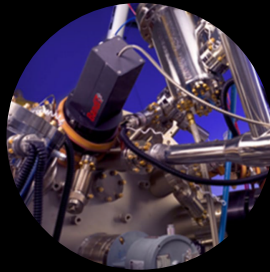
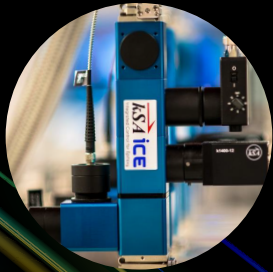
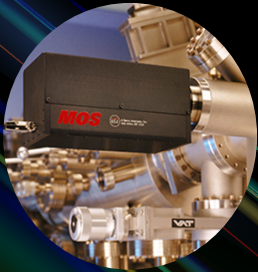
"We provide equipment to world-leading manufacturers of sensors, power chips, RF and LED devices," says Kevin Crofton, president of SPTS Technologies and senior VP at

KLA Corp. "Our ongoing program of research and development, coupled with the ability to commercialize our innovations, has been key to building and sustaining a profitable business," he adds.

"This award belongs to our entire organization — from those directly involved in the development of the Mosaic fxP to those who sold, built and supported the many Mosaic systems employed around the world," Crofton says. "We are also very pleased to share credit for this award with the Welsh Government, who demonstrated their commitment and support with the R&D grant that helped fund this and other advanced packaging development programs here at SPTS."

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Seoul Semiconductor files patent litigation against automotive LED light distributor Onyx

South Korean LED maker Seoul Semiconductor Co Ltd has filed a patent infringement lawsuit in the United States District Court for the District of New Jersey against automotive component distributor Onyx Enterprise Int'l Corp, which operates CARiD.com (one of the largest online platforms for offering car parts and accessories, distributing various automotive LED lights such as automotive headlamps, tail-lights and fog lights).

Seoul asserts that automotive LED products being sold on CARiD.com infringe 12 patents — including Seoul's WICOP (wafer-level integrated chip on PCB) technology, which was co-developed with its subsidiary Seoul Viosys Co Ltd.

WICOP is claimed to be the first technology to enable LED chips to be soldered to a PCB without lead-frames or gold wires, significantly enhancing heat dissipation and fitness for LED lenses. Such benefits have led to widespread applications of WICOP technology in automotive lighting, including daytime running lights (DRLs) and headlamps, as well as other LED products, such as LCD backlights for TV and mobile phones, smartphone flash LEDs, and high-power general lighting.

In October 2019, Seoul obtained a permanent injunction judgment against the sales of a Philips brand TV product for infringement of WICOP patents in litigation filed against Fry's Electronics in the

Texas Eastern District federal court. Also last year, Seoul filed a patent infringement lawsuit against the Factory Depot (another Philips brand TV product distributor) in the California Central District federal court.

"Several companies' products described as a CSP (chip-scale package) are copying Seoul's patented technology," says one of Seoul's IP department vice presidents. "To prevent the distribution of such products, Seoul has initiated this litigation. Establishing a fair competition culture of respecting intellectual property is essential for young entrepreneurs and small businesses."

www.SeoulSemicon.com

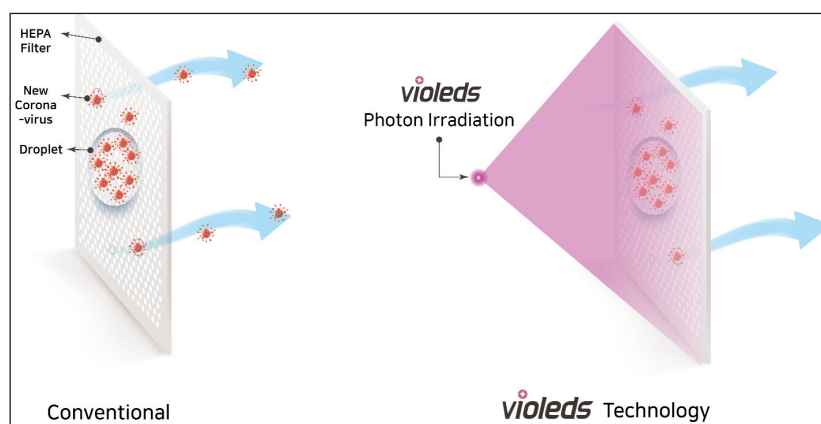
SETi releasing Violeds-based portable air purifiers for coronavirus disinfection

Sensor Electronics Technology Inc (SETi) of Columbia, SC, USA — a division of South Korean LED maker Seoul Semiconductor and UV LED product maker Seoul Viosys Co Ltd (SVC) that makes UV-A, UV-B and UV-C deep-ultraviolet LEDs (emitting at wavelengths of 200–430nm) — has launched portable air purifiers with Violeds technology (branded VAC) to reduce infection from various harmful bacteria as well as the SARS-CoV-2 coronavirus in the air.

HEPA filters in a conventional purification system can filter out fine dust and droplets measuring more than $0.3\mu\text{m}$, but viruses such as the new coronavirus and SARS virus (as small as $0.1\mu\text{m}$, after the droplet is dried) can pass through the HEPA filter as is.

Violeds technology has been proven to sterilize 99.9% of new coronavirus in 30 seconds, according to testing results.

The portable air purifier VAC with Violeds embedded in the air purifi-



USA initially, and SETi will also continue to respond to global corporate customer's demands and inquiries.

cation system sterilizes new coronavirus and various harmful bacteria. Conventional air purifiers and air conditioners collect various bacteria or viruses using only filters so, since they can't completely filter the virus out, there is a high risk of secondary air infection. However, VAC prevents harmful bacteria growing on the filter and significantly sterilizes them by irradiating the filter using Violeds' light immediately after virus capture in the air.

Online sales of VAC will commence in June in both South Korea and the

SETi says that it will lead product promotion to provide consumers with quicker access to sterilization solutions until the urgent situation from the global spread of the new coronavirus is stabilized. It will continue to sell the products in cooperation with potential global partners in the future. In addition, it will expand online sales to Europe and Southeast Asia in June, along with new portable surface sterilizers branded VSM.

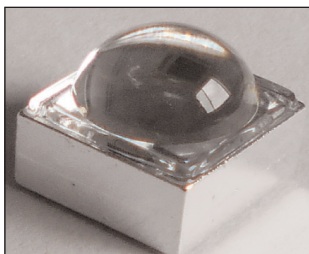
www.s-et.com

www.seoulviosys.com

Nitride Semiconductors launches 365nm UV-LED chip for semiconductor manufacturing exposure systems

Japan's Nitride Semiconductors Co Ltd (which was spun off from Tokushima University in 2000 and claims to have developed the first highly efficient ultraviolet light-emitting diode) has developed what it says is the first UV-LED for use as a light source in exposure systems in semiconductor and PCB manufacturing.

Exposure systems in semiconductor manufacturing currently still use UV lamps containing mercury. However, there are functional restrictions such as long standby time, short lifetime, low UV illuminance stability and inconvenient on/off control. It is therefore expected that the United Nations Environment Program Minamata Convention will promote switching



to semiconductor (LED) light sources due to environmental issues.

Nitride Semiconductors says that the new NS365L-9RXT 365nm-wavelength UV-LED chip has demonstrated high efficiency, energy saving and long-life, and that the UV output power is 3.2W (at a forward current I_f of 3A and forward voltage V_f of 4.6V).

The LED also has a narrow directional angle suitable for semiconductor exposure. For accurate exposure, parallel light is required. However, UV-LED light sources

generally have a wide directional angle (of about 120°), and the amount of light captured for exposure tends to be insufficient. Therefore, by combining a deep reflector with a lens of high UV transmittance, the firm has achieved a directional angle of 15° or less. This makes it possible to exchange the UV lamp light source of the conventional exposure system with UV-LEDs instead of purchasing new UV-LED exposure systems.

The new LED is also very compact, with a 9mm (length) x 9mm (width) x 8.5mm (height), so mounting density can be increased.

The unit price per 10,000 in mass production for the new NS365L-9RXT UV-LED is about \$50 each.

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Cree's quarterly revenue falls 10%

Covid-19 impacts LED Product sales in China and RF & power sales for 5G base-stations and electric vehicles

For fiscal third-quarter 2020 (ended 29 March), Cree Inc of Durham, NC, USA has reported revenue of \$215.5m, down 10% on \$239.9m last quarter and 21% on \$274m a year ago (and below the expected \$221–229m).

"Performance was negatively impacted by softening global demand and some disruptions to our manufacturing operations arising from the Covid-19 pandemic," says chief financial officer Neill Reynolds. However, manufacturing facilities in the USA continue to operate as essential businesses, adds CEO Gregg Lowe.

Revenue from LED Products (chips and components) was \$101.6m (47% of total revenue), down 15% on \$119.2m last quarter and 23% on \$132.8m a year ago (and below the expected \$105–109m). This was driven largely by the slowdown of the Chinese economy in light of the Covid-19 coronavirus outbreak and associated disruption to Cree's manufacturing facilities. "While the third quarter is usually seasonally weak, this was further amplified by the extended Lunar New Year holiday in China and subsequent global developments in response to Covid-19," says Reynolds.

Revenue for Cree's Wolfspeed silicon carbide (SiC) materials, power and gallium nitride (GaN) RF device business was \$113.9m (53% of total revenue), down on \$120.7m last quarter and 19% on \$141.2m a year ago (and below the expected \$116–120m). This was due primarily to ongoing softness in power and RF sales that have been negatively impacted by the lower China electric vehicle (EV) demand and slower-than-anticipated 5G base-station installations outside China, and a shutdown of Wolfspeed's facility at Morgan Hill in San Jose, CA (formerly the main facility of the Infineon RF Power Business, acquired in mid-2018) for about

two weeks in March to comply with county guidelines prior to receiving an essential business designation from the state of California. The facility resumed operations on 30 March after implementing several measures to ensure employee safety. Regarding the SiC materials business, it "continues to be fortified by our strategic long-term agreements and the business performed as expected in the quarter," notes Reynolds.

On a non-GAAP basis, gross margin was 29.8% (down from 38% a year ago). By sector, Wolfspeed gross margin has fallen from 48% to 40%, driven mainly by lower utilization caused by the Morgan Hill factory shutdown and by lower-than-expected yields related to the ramp of the new 150mm SiC MOSFET product. LED Products gross margin has fallen from 28% to 20%, due primarily to lower factory utilization given the extended shutdown of Chinese operations.

Operating expenses were \$86m, up slightly on \$85m last quarter (but better than the expected \$88m).

"In light of the ongoing Covid-19 situation, we are managing our operating expenses prudently, optimizing what needs to be done now to support future growth while deferring non-essential costs," says Reynolds.

While the underlying demand for our power and RF devices is improving, we continue to navigate near-term headwinds including the impact of Covid-19 related to more stringent safety measures we implemented to protect our employees, which will lower factory utilization and productivity

Net loss from continuing operations has risen from \$10.4m (\$0.10 per diluted share) last quarter to \$15.5m (\$0.14 per diluted share), compared with net income of \$20.5m (\$0.20 per diluted share) a year ago.

Cash used in operations was \$27.7m. Capital expenditure (CapEx) was \$69.8m. Free cash outflow was therefore \$97.5m.

During the quarter, cash and short-term investments hence fell from \$952m to \$853m. Cree has zero balance on its line of credit and convertible debt with a total face value of \$575m.

"Considering the uncertainty surrounding the Covid-19 pandemic, we elected to maximize our financial flexibility with our successful convertible notes offering [completed in mid-April, raising \$500m, and maturing on 1 May 2026]," notes Reynolds. "We decided to take advantage of favorable market conditions to de-risk all possible scenarios by securing extra capital to ensure we can meet our commitments regardless of the pace and duration of recovery post Covid-19," he adds. "Importantly, our new convertible debt structure lowers and extends our maturities [from 2023 to 2026] after a period of heavy CapEx investments at our Mohawk Valley fab [in Marcy, NY] and Durham materials factory [at Cree's headquarters in North Carolina]."

"While we expect the Covid-19 crisis will continue to adversely affect our performance this quarter [fiscal Q4/2020, to end June], it remains difficult to fully evaluate its impact on the overall demand environment and our manufacturing operations," notes Reynolds. "To account for this heightened level of uncertainty, we are providing a wider-than-usual guidance range."

For fiscal fourth-quarter 2020, Cree expects revenue to fall to \$185–215m. Specifically, LED Product revenue should fall to

\$85–100m. However, this is due mainly to supply constraints. “We have started to see a recovery in LED demand and we are encouraged by the improving order flow in the first few weeks of the fourth quarter, even though we expect the Covid-19 crisis to have a lingering effect on some customers,” says Reynolds. Wolfspeed revenue should fall to \$100–115m. “While the underlying demand for our power and RF devices is improving, we continue to navigate near-term headwinds including the impact of Covid-19 related to more stringent safety measures that we implemented to protect our employees, which will lower factory utilization and productivity,” says Reynolds. The SiC materials business is expected to see a decline in revenue in the short term as one non-semiconductor customer was not designated as an essential business and is not operating at this time. Cree has stopped shipping to them, which will cause revenue to decline in fiscal Q4.

Gross margin is expected to fall to 25–28%, including LED Product gross margin remaining low at 19–21% (due to lower volumes) and Wolfspeed gross margin falling to 33–35% (mainly reflecting lower factory utilization and productivity due to the safety measures, as well as continuing low yields on the 150mm MOSFET product line that have not yet fully returned to expected levels).

Operating expenses should shrink further to \$83–84m as Cree continues to prudently manage costs while executing its planned investments in the Wolfspeed business (preparing products for production on the Mohawk Valley fab that should ramp in 2022). Net loss is targeted to be \$16–25m (\$0.15–0.23 per diluted share).

“In 5G [RF business], we continue to be impacted by ongoing delays and in infrastructure rollouts,” says Reynolds. “While there continues to be significant uncertainty in these markets, customers who want to leverage the higher frequencies and

higher-efficiency output possible from gallium nitride and silicon carbide solutions for their 5G infrastructure products were very interested in our technology... We are encouraged to see early indications and improving demand for our products, despite overall near-term headwinds,” he adds.

“In our Power business in the near-term we expect Covid-19 to impact our customers operations as overall auto sales will be weaker in calendar 2020, but our customers tell us they remain committed to their EV investments and are planning to maintain their original ramp schedules,” says Reynolds.

“Despite the uncertainty, we are currently seeing a strengthening in our backlog related to both power and RF customers. However, we remain cautious in our outlook as it is not yet clear how the pandemic will impact and customer demand in the coming quarters,” he adds.

“We stand before a multi-decade growth opportunity for silicon carbide adoption and remain committed to investing in our capacity to meet this long-term demand,” says Lowe. “Importantly, many of our customers have indicated that their long-term plans remain in place, including our long-term wafer supply agreements, the delivery of electric vehicles to the market, and the rollout of 5G,” he adds. “We’re expecting decisions on a significant portion of our roughly \$9bn [SiC] pipeline in the coming 12-months.”

About half of the pipeline relates to the EV market. “The most recent report in Goldman Sachs suggests

In our Power business in the near-term we expect Covid-19 to impact our customers operations as overall auto sales will be weaker in calendar 2020, but our customers tell us they remain committed to their EV investments

a 4x increase in the total number EVs sold in 2025 versus 2019,” notes Lowe. “There’s also been considerable discussion about how the stay-at-home orders around the world have significantly reduced pollution in many major urban markets. This could be another catalyst for easy adoption as countries look to reduce automotive CO₂ emissions. For example, several environmental ministers from EU countries have circulated an open letter recommending that any Covid-19 stimulus package must have a green component specifically referencing sustainable mobility,” he adds. “Further, we’ve been maintaining an ongoing dialogue with our customers to support them through this tough crisis. While our automotive customers are addressing near-term challenges including some temporary shutdowns of their operations due to the outbreak, most have indicated they remain committed to delivering electric vehicles to the market with silicon carbide on their original timelines. Additionally, design-in activity for the longer-term programs remains very robust.”

For fiscal 2020, Cree is now targeting CapEx of \$240m, a slight increase from the \$230m announced in mid-February (which had been an increase from the \$200m announced at the firm’s Investor Day last November). This reflects the purchase of some tools at favorable pricing that will be used as part of the capacity expansion. “While near-term market conditions are fluid, we haven’t seen any changes in the long-term outlook at this time, which is why our long-term strategy to increase our silicon carbide capacity and related capital expenditure plans remain intact,” says Reynolds. “Having our new New York Mohawk Valley fab up and running by 2022 and expanding our materials factory in Durham, NC is critically important to deliver on our customer commitments and win additional business currently in the pipeline.”

www.cree.com

Osram launches compact Oslon Piccolo infrared LED for automotive interiors

Osram Opto Semiconductors GmbH of Regensburg, Germany has launched the Oslon Piccolo infrared LED, expanding its photonics portfolio for automotive interior applications.

Automotive interior design is undergoing a fundamental change, notes the firm. Displays are getting larger, the number of manual controls is decreasing, and customizable lighting solutions are creating a feel-good atmosphere. Advanced driver assistance systems (ADAS) and technologies previously designed for mobile devices – such as facial recognition, eye tracking or gesture control – are increasingly making their way into the automotive sector. These technologies are based on infrared light. The smaller and more powerful the required components, the easier they are to integrate into complex designs. Osram says that its Oslon Piccolo now offers an extremely compact infrared LED (IRED) that packs high power in a small package, making it suitable for automotive use.

Just as mobility will change in the coming years, so will the purpose

of the vehicles themselves, the firm adds. Autonomous driving will lead the way, creating the need for cars to be equipped with more and more functions to make the interaction between occupants and vehicles more intuitive. An autonomous vehicle will have a fundamentally different interior design than current models. The classic dashboard will be replaced by other user interfaces and options for communication.

Today, drivers can already use voice assistants for navigation and control simple functions via gesture control. Thanks to gesture recognition, completely new ways of interacting with displays are also being developed. For example, when navigating to a destination, the vehicle displays a map with the corresponding route. At the edges of the image, different menu items for operating the display are shown in a standardized way – which in turn takes away space from the map display. With the help of gesture recognition, menu items are only shown when the driver moves his hand towards the display, allowing

the route to appear full screen.

“Mobile applications, such as facial recognition, are influencing the design of interior displays of autonomous vehicles, meaning that manufacturers need to find ways to accommodate a range of advanced features in a small space,” says Mike Godwin, director of Automotive LED Lighting at Osram Opto Semiconductors in North America. “Because of its extremely compact dimensions of only 1.6mm x 1.6mm and a package height of only 0.81mm, the Oslon Piccolo can be installed easily in a small space, making it suitable for interactive automotive applications.”

With a DC power of 1.15W at 1A and very fast switching times of 10ns, the component is suitable as both a constant light source for a camera-based application and for 3D image acquisition with modulated or fast pulsed light. The automotive-qualified component (AEC-Q102) is available in two different wavelengths: 850nm (SFH 4170S A01) and 940nm (SFH 4180S A01).

www.osram.com

Synios S 2222 compact LEDs for low- and mid-power applications

Osram Opto says that its new Synios S 2222 family of LEDs is suitable for a wide range of applications, from customized lighting solutions for electronic devices, ambient lighting for trains and planes, to high-quality architectural lighting. The product family is said to be unique in its compact dimensions, combined with very good brightness values and the ability to cover the entire color palette.

The Synios S 2222 product family provides an efficient and flexible platform for a variety of low- and mid-power applications with injection current ranging from 10mA to 200mA. Customers can choose from six colors and combine them

to create more. In addition to white versions (3000–6500 K, CRI >80), the product family includes blue (445–460nm), green (520–540nm), yellow (583–595nm, conversion and direct emission), red (612–626nm) and deep red (626–636nm). The family’s uniform dimensions of 2.2mm x 2.2mm and solder pad design make it easy to integrate into many different solutions, says the firm. The low package height of only 0.6mm makes extremely flat lighting solutions possible.

Osram says it is responding to the need in the market for smaller and more discrete components with the highest possible performance. For example, the yellow con-

verted variant delivers brightness of 50lm at 140mA. Depending on the application, additional optics can be applied to the respective component due to the central chip location in the package.

“The Synios S 2222 product family features a unique package design that is easy to handle, allowing our customers to use automated pick-and-place systems for manufacturing,” says Mike Martens, senior product manager at Osram Opto Semiconductors in North America. “In addition, the high-quality LEDs give our customers ultimate flexibility by providing a wide range of colors to create distinctive lighting solutions.”

CompoundTek joins JEDEC Silicon Photonics Qualification and Reliability Standards Task Group

Singapore-based silicon photonic foundry provider CompoundTek has announced its participation in the JEDEC Silicon Photonics Qualification and Reliability Standards Task Group.

Established to lead the industry in creating sought-after guidelines, methodologies and standards for silicon photonic (SiPh) qualification and reliability, the Task Group is a new remit under JEDEC, an organization focused on developing open standards and publications for the microelectronics industry that spans a wide range of technologies.

Rapidly becoming a mainstay as integrated circuits in telecom networks, SiPh is also a key driver to the growth of niche capabilities in applications such as sensing, bio-medical, cryptography and quantum computing.

"In bringing together various industry experts, JEDEC has effectively enabled the advancing of know-how and technologies among an evolving global engineering community," comments S. Gunasagar, CompoundTek's senior director of Technical Integration and Development. "Dedicated to achieving reliability and exacting quality standards critical to SiPh industry, this goal resonates with CompoundTek's broader efforts to align infrastructure,



foundry and test standards within our ecosystem, which in turn improves supply chain and turn-around times to market," he adds. "It also reinforces our belief that standards will help customers resolve cost and operational problems during technology proliferation with established guidelines rather than solving the same problems repeatedly."

The firm recently embarked on establishing open standards for layout, design and automation of photonic integrated circuit (PIC) testing, in partnership with

Keysight Technologies Inc and the National Information Optoelectronics Innovation Center (NOEIC).

In January, CompoundTek operationalized Southeast Asia's first foundry-agnostic SiPh testing services hub in Singapore to facilitate its expanding solutions' portfolio and activities. CompoundTek reckons that this capability enables it to further contribute to the JEDEC Task Group with real-world insights, market trends and challenges faced in the industry.

<https://compoundtek.com>

Final payment to POET for DenseLight subsidiary delayed US\$5m Tranche 3 for remaining 19% stake delayed by COVID-19

POET Technologies Inc of Toronto, Ontario, Canada — designer and developer of the POET Optical Interposer and photonic integrated circuits (PICs) for the data-center and telecom markets — has received notice confirming a delay of the final US\$5m Tranche 3 payment in connection with the sale of the remaining 19% stake of its Singapore-based subsidiary DenseLight Semiconductors Pte Ltd, which had been scheduled for 31 May.

The buyer cited the wide-ranging impacts that the COVID-19 Coronavirus pandemic has had on businesses globally and the lengthy administrative process associated with transfers of funds outside of China.

POET previously received a first-tranche payment of US\$8m (for 30% of the shares of DenseLight) in early November, followed by the Tranche 2a payment of US\$4.75m (for 19% of the shares) in early February and the Tranche 2b

payment of US\$8.25m (for 32% of the shares) at the end of March, despite a delay due to business interruptions in China resulting from the COVID-19 outbreak.

POET says that it is continuing to work closely with the buyer to address the current challenges associated with the transfer of the final payment, and it remains confident that the remaining balance and timing will be resolved in a mutually beneficial manner.

www.poet-technologies.com

II–VI's record quarterly bookings 22% above forecast Revenue falls just 5.9% despite COVID-19, driven by 5G build-out

For its fiscal third-quarter 2020 (to end-March), engineered materials and optoelectronic component maker II–VI Inc of Saxonburg, PA, USA has reported revenue of \$627m, above the \$550–600m forecast (split 68% in communications, 11% in industrial, 7% in aerospace & defense, 6% in consumer, and 5% in semiconductor capital equipment).

Revenue is up 83% on \$342.4m a year ago, but the latter was before the acquisition last September of fiber-optic communications component and subsystem maker Finisar of Sunnyvale, CA, USA (whose results have been consolidated into II–VI's Photonic Solutions and Compound Semiconductors segments for the quarters to end-December 2019 and end-March 2020).

Compound Semiconductors revenue has hence grown from \$175.9m a year ago and \$205.9m last quarter to \$209.3m.

Photonic Solutions revenue was up from \$166.5m a year ago to \$417.7m (after falling back from \$460.4m last quarter).

The total revenue of \$627m is down just 5.9% on the strong \$666.3m last quarter, so the impact due to the COVID-19 coronavirus pandemic was much less than the \$50m expected.

"Our China teams, in collaboration with our global emergency response and business continuity planning team, were able to bring all of our China facilities back to normal by the middle of March," notes Dr Vincent D. (Chuck) Mattera Jr.

"In this second full quarter of II–VI operations with Finisar included, we successfully continued our integration activities amid the COVID-19 pandemic," says Mattera. "Despite significant operating challenges, the extraordinary commitment of our employees allowed us to address the steep ramps requested by our customers, and to exceed the high end of our revenue and EPS guidance [of \$550–600m and \$0.02–0.32, respectively], with record bookings at 22% above our forecast."

"The performance is the result of growing and accelerating demand for the firm's products across key end-markets and continued success with our merger & acquisition (M&A) integration efforts that is, in many facets, at least 12 months ahead of plan," says Mattera. "Our substantial progress at integrating the Finisar acquisition after only two quarters is a result of our experience in assessing markets and acquiring complementary companies with great technology and potential," he adds.

"Our communications business [Datacoms and Telecoms] in the quarter was strong on all fronts," notes Dr Giovanni Barbarossa, chief strategy officer & president of the Compound Semiconductors segment.

In Datacoms, revenue for components rose 63% year-on-year and remained steady sequentially.

"As we execute on our acquisition strategy to penetrate the merchant market with our previously captive products, we're pleased to report that we have received our first production order for indium phosphide (InP) components, which we have already begun shipping this quarter," says Barbarossa. "As evidenced by the strength of the demand and the unfulfilled need for scalable indium phosphide and IC components, we accelerated the market introduction and qualification of our products, for which I'm pleased to report a very exciting pipeline of design-in activities," he adds.

Revenue for transceivers was flat year-on-year and fell 9% sequentially.

"100G remains the mainstay of the market today, representing almost 70% of the \$3bn high-speed transceiver market," notes Barbarossa.

We have received our first production order for InP components... We accelerated the market introduction and qualification of our products

"As the transceiver market leader, this is and will continue to be a large portion of our business, as we expect to see growth in 100G for at least the next five years... We were the fastest supply for 100G datacom transceivers to the industry and, as we continue to invest in that technology, we expect to secure a major portion of their market segment as it grows."

"The centerpieces of our Telecom revenue are ROADM [reconfigurable optical add/drop multiplexer] subsystems and components, which were also strong in the quarter," says Barbarossa. Telecom revenue fell only 10% sequentially due to COVID-19.

Revenue from silicon carbide (SiC) materials (for RF wireless applications) grew 75% year-on-year.

"Adoption is accelerating and, as an example, we are shipping under our large agreement (announced last quarter) at a faster rate than expected, driving a 5% growth sequentially," notes Mattera. "Our silicon carbide capacity expansion plans remain well on track for power applications, as we believe that the market is still in the early innings of a very long game."

II–VI had a second consecutive quarter of record 3D sensing shipments from its operations in Warren, NJ and Easton, PA. "We have clearly achieved the vertically integrated technology objectives we laid out at the time of our earlier acquisitions to address the emerging 3D sensing market, as we have demonstrated a sustained high degree of production efficiency based on our cumulative experience gained, while producing hundreds of millions of devices at very high yields and reliability," says Mattera. "Our top integration priority was to leverage our 3D sensing experience in our state-of-the-art Sherman, Texas compound semiconductor plant... We also successfully completed the qualification of our Sherman, TX facility as planned, and we have begun to ship produc-

tion units as we continue our manufacturing ramp," he adds. "With our qualified epitaxial growth and wafer fabrication capacity, we're now well-positioned as the only US-based vertically integrated supplier or big seller for 3D sensing on a 6-inch platform," says Barbarossa. "Moreover, we have adequate capacity to serve the majority of what we understand the market demand to be."

Industrial revenue remains steady sequentially. However, laser engines in particular grew 17% sequentially for new laser system builds.

Revenue for semiconductor capital equipment products continue to be in high demand, growing 12% sequentially, "driven by the global largest semiconductor market and undaunted by COVID," says Barbarossa.

Aerospace & defense (military) revenue grew 25% year-over-year and was steady sequentially. "Our advanced materials, electro-optical components and subsystem platforms, combined with semiconductor lasers, are essential to our growth strategy in our aerospace & defense segments, namely satellites, contested space, hypersonics, and directed energy," says Barbarossa.

On a non-GAAP basis, gross margin was 38.3% in fiscal Q3/2020, up from 36.2% last quarter and above II-VI's standalone gross margin of 37.4% a year ago, aided by a favorable product mix.

Operating expense (OpEx) has been cut from \$168m last quarter to \$154m, due mainly to internal R&D expenditure being cut from \$102.4m to \$90.6m.

Operating income has risen from \$73.6m last quarter to \$86.5m (operating margin of 13.8%, up from 11% last quarter, and level with a year ago when II-VI's pre-Finisar operating income was \$47.3m).

At the segment level, the adjusted operating margins were 13.4% for Photonics (benefitting from operating efficiencies and the richer product mix, including submarine pump sales more than doubling again year-on-year this quarter) and 14.6%

for Compound Semiconductors (up from just 4.9% last quarter, benefitting from strong sales of vertical-cavity surface-emitting laser (VCSEL) arrays, the qualification of the fab in Sherman, Texas, and the commencement of commercial shipments from Sherman).

Likewise, net income has risen from \$37.2m (\$0.40 per diluted share) last quarter to \$44.1m (\$0.47 per diluted share), i.e. an increase in return on sales from 5.6% to 7%.

Capital expenditure (CapEx) was \$28m (cut from \$55m last quarter). Free cash flow was \$36.5m. During the quarter, cash and cash equivalents rose from \$376.8m to \$388.1m. Availability on the firm's revolver is \$358m, including outstanding letters of credit. So, available liquidity is \$746m. Debt was reduced by \$21m with repayments during the quarter on the revolver and term loans. The firm's net debt position is now \$1.9bn (giving a net debt:leverage ratio of 3.8x).

"Regarding our work on synergies, we are tracking well against our target of \$150m in annual cost synergies within three years after the close of the [Finisar] transaction," comments chief financial officer Mary Jane Raymond. "We have realized \$43m compared to the expected \$35m halfway through the first year. Given the intensive focus on OpEx, we will likely deliver in the first year at least 50% more than the year-one target of \$35m."

Order bookings were a record \$840m in fiscal Q3/2020 (22% above the forecast). "Demand in the communications market accelerated considerably throughout the quarter... We experienced growth in demand in both telecom and data-com, driven by transceivers and optoelectronic components, ROADM modules and subsystems, combined with market share gains and the overall acceleration of legacy and 5G optical infrastructure buildout," says Mattera.

"This was most evident in our Transceiver business, where bookings far exceeded our expectations [by more than 40%] during the

quarter and customer enthusiasm remained high," says Mattera. "Our ramp of new products for 5G has accelerated, as over 80 carriers re-architect their networks to handle their 5 billion mobile subscribers who are quickly migrating to 5G."

In Telecoms, ROADM bookings grew 50% sequentially. "Demand was strong across the board for amplifiers, line-cards, and all enabling components including passive optics and wavelength-selective switches (WSS)," notes Barbarossa. In addition, 980nm pumps and wavelength-selective switches also saw extremely strong demand for undersea applications. "In fact, as we witnessed the acceleration of orders for our products for 5G applications in data-center infrastructure, most of these manufacturing lines continue to be sold out," he adds.

"That demand profile contains large orders placed for as long as a year, and the delivery of those bookings over a year's period of time suggest that this is the beginning of a long-term sustainable demand driven by an accelerated need to deploy new infrastructure worldwide," believes Mattera.

During the quarter, order backlog (of orders shipping over the next 12 months) rose from \$681m (\$346m in Photonics Solutions and \$335m in Compound Semiconductors) to a record \$893m (\$518m in Photonics Solutions and \$375m in Compound Semiconductors).

For fiscal fourth-quarter 2020 (to end-June), II-VI expects revenue of \$650-700m and earnings per diluted share on a non-GAAP basis of \$0.50-0.70. Gross margin is expected to range between 36% and 39% going forward.

For full-year fiscal 2020, CapEx is expected to be \$125-140m (reduced from the prior estimate of \$150-200m). "Our operating leaders have done a great job on yield and shift expansion to allow us to moderate new capital expenditures across the company," comments Raymond.

www.ii-vi.com

NeoPhotonics' Q1 revenue up a greater-than-expected 23% year-on-year to \$97.4m

For first-quarter 2020, NeoPhotonics of San Jose, CA, USA (a vertically integrated designer and maker of hybrid photonic integrated opto-electronic modules and subsystems for high-speed communications) has reported revenue of \$97.4m, down 6% on \$103.4m last quarter but up 23% on \$79.4m a year ago (exceeding the \$83–90m guidance). Growth was driven by a combination of strong end-customer demand in China as well as strong metro and data-center interconnect (DCI) markets in the West, where the firm's claimed continued leadership in 400G-and-faster solutions addresses the emerging needs for more network bandwidth capacity by both cloud players and carriers.

"The continued strength in our performance reflects our focus on high-speed products, including our unique ultra-pure-light tunable lasers, serving industry leaders in coherent telecom and data-center networks, and the transition of cloud and hyper-scale data-center networks to coherent technologies," says chairman & CEO Tim Jenks.

Largest customer Huawei comprised 52% of revenue (up from 41% last quarter) as demand in China has returned following the onset of the COVID-19 coronavirus pandemic. The next four customers comprised 33% of revenue (including one that exceeded 10%), up 10% year-on-year in dollars terms but down sequentially as expected in the first quarter and lower in percentage terms due to the strength of China (which totaled 60% of revenue, up on 55% last quarter). The Americas contributed 19% of revenue, and rest of world 21%.

High-speed products (for data rates of 100G-and-above) comprised 92% of revenue, level with last quarter and up from 88% a year ago.

Despite normal seasonality, the extended Chinese New Year shut-down, and supply chain issues due to the COVID-19 pandemic that were expected to impact revenue by

\$10m, non-GAAP gross margin has risen further, from 22.4% a year ago and 30.9% last quarter to 31.2% (above the midpoint of the 28–32% guidance range), driven by an increase in volume and improved product mix. Specifically, product margin was 35.8%, down by just one percentage point from 36.8% last quarter due to annual pricing reductions offset by a favorable product mix. Moreover, this was up nearly nine points from 27% a year ago, driven by the increasing leadership of the firm's lasers, it is claimed. Other cost of sales charges of about 4.5 points improved sequentially and consisted of 2 points of under-utilization charges (mostly related to the extended Chinese New Year shut down), just under 2 points of inventory reserves, and just over 0.5 points of sales charges on product shipping from the firm's US fabs into China (lower than last quarter, as tariffs on most products were eliminated in March).

Operating expense (OpEx) has been cut from \$24.3m (30.5% of revenue) last quarter to \$20.3m (20.9% of revenue), better the targeted \$22–23m. Of the \$4m reduction, \$1.5m was an expected one-time license fee as a credit to R&D; the remainder is related to COVID-19 impacts in terms of lower travel, fewer marketing events, and a temporary push-out of R&D projects (as some teams were not in the lab). The R&D spending reductions from Q1 will be added to future quarters.

Compared with a loss

of \$9m (\$0.19 per diluted share) a year ago, net income increased from \$5.3m (\$0.10 per diluted share) last quarter to \$9.1m (\$0.17 per diluted share, above the \$0.00–0.10 guidance), reflecting "increased value-add products and continued strong execution".

"We are pleased to deliver another profitable quarter, notably through our seasonally low first quarter, in spite of supply chain risks related to the pandemic," says Jenks.

Cash generated from operations has risen further, from \$8.7m a year ago and \$16.3m last quarter to \$24.9m. Likewise, free cash flow has grown further, from \$5m a year ago and \$13m last quarter to \$22m.

During the quarter, cash and cash equivalents, short-term investments and restricted cash hence rose by \$20.4m to \$109.5m. Restricted cash was \$10.9m. "Over the last couple of years, we have put a heavy emphasis on cash, cash flow and paying down debt," notes chief financial officer Beth Eby. Long-term debt was paid down to \$41m.

Inventory has been increased from 59 days last quarter to 61 days. "We are taking steps to ensure that we can withstand a variety of potential scenarios that may emerge through the rest of the year, both positive and negative. As part of this, we are working to build inventory to buffer supply chain volatility," notes Eby.

"As we look forward, the industry continues to move in our direction with higher and higher speed over distance requirements, which are satisfied by our ultra-narrow-linewidth lasers, high-baud-rate coherent components and our coherent pluggable DCO modules utilizing these leading optical components," says Jenks.

For second-quarter 2020, NeoPhotonics expects revenue of \$94–102m, gross margin of 30–34%, OpEx of \$24–25m, and diluted

Inventory has been increased from 59 days last quarter to 61 days. We are taking steps to ensure that we can withstand a variety of potential scenarios that may emerge through the rest of the year

earnings per share of \$0.05–0.15.

This outlook includes about \$10m of COVID-19-related impact to Q2 revenue, reflecting identified supply chain risks (such as shut downs, as they comply with their local public health orders). "It [the \$10m] is a little bit higher risk than I would say that we saw in the first quarter, because what we saw in the first

quarter was just waiting for companies to start up in China. Now we're dealing with a much broader set of suppliers that are potentially impacted by COVID-19... some of them have periods of shutdown," Eby says. "In the first quarter, it was just risk, and that played out over time in the second quarter... we've seen some of them actually

impact," notes Jenks. "Even when those plants sometimes come back up, if they come up at 20–30% capacity, you have a problem. We've seen that play out a number of times over the last two months," he adds. "We expect the supply chain risk to continue into the second half of the year," concludes Eby.

www.neophotonics.com

Q2 guidance reaffirmed despite US export restrictions Department of Commerce Entity List may impact FiberHome exports

Regarding the US Department of Commerce's Bureau of Industry and Security (BIS) on 22 May announcing the impending addition of certain Chinese companies to the Export Administration Regulations (EAR) Entity List, NeoPhotonics says that the action will potentially restrict the export of items subject

to the EAR to its customer FiberHome Technologies Group. NeoPhotonics says that it will continue to monitor BIS guidance to assess the final ruling and any changes that may be required, and will remain in full compliance.

The firm says that it does not anticipate any material impact on

its near-term financial prospects and currently expects second-quarter 2020 results to be within the upper half of its guidance ranges (given on 30 April) of revenue of \$94–102m, gross margin of 30–34%, operating expenses of \$24–25m, and diluted earnings per share of \$0.05–0.15.

Infinera leverages Tower's SiGe BiCMOS in 800Gbs optical engine

Specialty foundry Tower Semiconductor Ltd (which has fabrication plants in Migdal Haemek, Israel, and at its US subsidiaries in Newport Beach, CA and San Antonio, TX, and at TowerJazz Japan Ltd) says that its Terabit silicon-germanium (SiGe) BiCMOS platform has been selected for use in the 800G sixth-generation Infinite Capacity Engine (ICE6) of Infinera Corp of Sunnyvale, CA, USA, a vertically integrated manufacturer of digital optical network systems incorporating its own indium phosphide (InP)-based photonic integrated circuits (PICs).

ICE6's 800Gb/s single wavelength provides what is claimed to be significant cost, power and fiber capacity advantages to network operators, enabling them to cost-effectively address the ever-increasing bandwidth demand on their networks.

"Infinera always leverages best-in-class technologies to achieve industry-leading system performance.

This includes Infinera's industry-leading indium phosphide (InP) photonic integrated circuits (PICs) and Tower's advanced silicon germanium (SiGe) for high-bandwidth driver and receiver circuitry," says Dr Ray Milano, senior VP, Optical Module Development at Infinera.

The latest innovation from Infinera's Optical Innovation Center, the ICE6 optical engine is designed in a compact digital coherent optical (DCO) package that can be easily integrated into a variety of networking platforms. Supporting two 800G wavelengths, it is claimed that the 1.6Tbs optical engine has demonstrated significantly superior performance than competing solutions, providing incremental value to network operators.

Tower's SBC18 Terabit SiGe BiCMOS platform is optimized for high-speed networking applications, providing transistors with speeds exceeding 300GHz, and is a work-horse for those designing high-performance telecom and datacom

optical networks with speeds of 100Gbps, 400Gbps and now 800Gbps. The SiGe platform is also tailored to deliver the highest performance for high-frequency wireless communications such as automotive radar, satellite communications and 5G for both sub-6GHz and millimeter-wave bands.

"Our collaboration with Infinera's team has allowed both companies to achieve an important milestone in the optical transmission market segment," says Dr Marco Racanelli, senior VP & general manager of Tower's Analog IC business unit. "Tower continues to bring to market cutting-edge technologies and corresponding high-volume manufacturing capabilities to serve the rapidly growing data transport market and enable industry-leading companies such as Infinera to deliver differentiated, high-value solutions."

www.infinera.com

www.towersemi.com/technology/rf-and-hpa/sige-bicmos-platform

Emcore's cost cutting limits quarterly loss

June-quarter CATV product revenue growth driven by increased bandwidth demand at MSOs

For fiscal second-quarter 2020 (to end-March), Emcore Corp of Alhambra, CA, USA — which provides mixed-signal products for the aerospace & defense and broadband communications markets — has reported revenue of \$23.8m, down 6% on \$25.5m last quarter but up 9.7% on 21.7m a year ago.

“Revenue was largely impacted by the typical March quarter seasonality of our two largest product lines: our Quartz MEMS [micro-electro-mechanical system] navigation products [acquired through buying Systron Donner Inertial (SDI) of Concord, CA, last June] within the Aerospace & Defense (A&D) segment; and our cable TV transmitters and components within the Broadband segment,” says chief financial officer Tom Minichiello.

“Despite the global impact of COVID-19, the Emcore team came together to deliver quarterly revenue that was in-line with our guidance [of \$23–25m],” adds CEO Jeff Rittichier.

“As the pandemic spread throughout the globe in our second fiscal quarter, we encountered disruptions to our manufacturing operations in Beijing and California, as well as shortages in supply chain and air freight capacity, affecting revenue and costs,” continues Rittichier. “Within China, we were able to re-establish 75% of operations by 10 February, and were at planned capacity by the end of February. Office staff worked on the line to bolster output while manufacturing engineers who are in quarantine guided them with webcams and by video conference. By March, we saw activity return to normalized levels in Beijing. Prior to the COVID-19 problem, nearly half of our equipment had already been transferred to [electronics manufacturing services (EMS) provider] Hytera in Thailand and was unavailable to offset production shortfalls

as we were still awaiting customer Product Change Notification (PCN) approvals before beginning production in Bangkok,” he adds.

“Although our Beijing facility was up and running by the end of February, all three of our California factories were subsequently impacted in mid-March,” says Rittichier.

“When shelter-in-place orders were first implemented, they created labor and key component shortages at a critical juncture in our normally back-end-loaded March quarter. These initial disruptions ultimately gave way to a determination that Emcore was an essential business that serves defense, commercial aviation and telecommunications industries. Thus, our facilities were able to remain open, albeit at reduced capacity. As such, while demand from Aerospace & Defense customers remained as expected during the quarter, supplies to certain critical components were impacted, which caused delays in being able to ship product at the end of the quarter.”

Aerospace & Defense (A&D) segment revenue fell only slightly by 5% from \$13.7m last quarter to \$13m (54.6% of total revenue). “We expected a seasonally soft Q2,” says Rittichier. “The mid-March shelter-in-place orders in California presented additional challenges to completing our revenue plan. Not only did our Concord and Alhambra facilities experience disruptions but our contract manufacturing partner in Orange County was also impacted.” However, the lower Quartz MEMS revenue (which was additionally affected by COVID-19-related supply-chain headwinds) was partly offset by double-digit percentage increases for fiber-optic gyroscope (FOG) navigation and defense optoelectronics product lines.

Broadband segment revenue fell by 8.5% from \$11.8m to \$10.8m

(45.4% of total revenue), driven mainly by decreased sales in CATV and chips. However, the typical cable TV demand softness early in the quarter and the impact of the extended Chinese New Year was somewhat mitigated by a stronger-than-expected rebound in CATV towards the end of the quarter. This additional demand created unplanned complications in securing airfreight capacity in time to recognize revenue, notes the firm. “Getting products through customs in time also proved problematic, preventing us from recognizing the full value of our shipments as revenue in the second quarter,” says Rittichier.

On a non-GAAP basis, gross margin fell 30% last quarter to 28%, including decreases of about 1.5 percentage point from the lower revenue and another 1.5 percentage point from lower A&D production yields, offset by a 1 percentage point improvement from cost reductions in broadband.

Also, while swings in overhead cost absorption at the consolidated level were not a significant factor, it did have a meaningful impact on the product segments. Specifically, A&D gross margin fell from 33% to 23%, impacted by lower absorption due to decreased production output (driven by lower Quartz MEMS and fiber-optic gyroscope margins, partially offset by an increase in defense optoelectronic margin). Broadband gross margin grew from 26% to 34%, driven by a more favorable mix and reduced under-absorption, largely as a result of lower costs in China.

Operating expenses were \$10.4m, cut by \$2m (15%) from just two quarters ago following recent cost-cutting actions. During fiscal Q2, Emcore implemented a workforce reduction, redesigned its wafer fab workflow, and optimized other R&D functions around the smaller staff. ➤

▶ Despite this, net loss increased from \$1.8m (\$0.06 per share) last quarter to \$3.8m (\$0.13 per share).

During the quarter, cash and cash equivalents rose by \$6.7m from \$15.4m to \$22.1m. Compared with borrowings of \$4.5m from its credit facility during last quarter, the firm had no debt as of end-March.

The net cash increase of \$11.2m is attributable to the following factors: \$12.8m received from the 10 February sale and leaseback transaction of the firm's Quartz MEMS facility in Concord, CA; \$100,000 received from a previous-quarter shipment of CATV equipment as part of a production asset sale agreement with Hytera; offset by \$1.7m used during the quarter (of which \$900,000 funded routine operating activities and \$200,000 was for employee severance). The balance covered previous-period CapEx and legal matters.

"As evidenced by our first-half results, improved operational performance, combined with expense reductions and actions to improve our cash balance and liquidity levels, have placed us in a much improved financial footing even at the current revenue levels," believes Rittichier.

Also, on 5 May (after the quarter-end), Emcore reported that it had secured a loan of \$6,448,000 under the US Small Business Administration's Paycheck Protection Program (PPP), to be used primarily for payroll expenses.

"We see no reductions in defense programs currently in production but have seen delays in qualification testing for new programs. We continue to meet important milestones for our manufacturing transition and completed the ERP [enterprise resource planning] project in Concord on schedule, enabling us to reduce our operating expenses. These actions, when taken together with our improved cash position following the Concord facility sale and PPP loan funding, give us the necessary resources to navigate through these unprecedented times," believes Rittichier.

"Looking forward, we're seeing an

increase in customer demand for the third fiscal quarter as the MSOs work to break network bottlenecks," says Rittichier.

For fiscal third quarter 2020 (to end-June), Emcore expects revenue to grow by about \$2m to \$25-27m. OpEx should remain at about \$10m.

"As we move into the June quarter, labor shortages due to COVID-19 remain our biggest concern," says Rittichier. "Beyond that, we expect the general amount of friction in the supply chain will continue to present a changing set of obstacles for us to overcome. We have plans in place to deal with shortages of airfreight, custom staffing as well as sourcing of certain limited components."

"Related to the strategic initiatives we outlined in our last call and despite the obstacles within China during the [March] quarter, we completed all of the transmitter qualifications from Hytera's Bangkok facility and received the necessary PCNs on schedule. These customer approvals authorized Emcore to build production transmitters at Hytera SDI during the June quarter," says Rittichier.

"We expect to complete the PCN for all of the laser and linear EML modules, enabling us to completely switch manufacturing to Thailand

We expect the smaller wireless and chip components in the broadband business to maintain their contribution, but we are seeing strength in our cable TV products.

Recent comments from the MSOs have pointed to significant bandwidth demand from workers complying with work-from-home initiatives

during the September quarter. The exact timing of the cutover remains somewhat fluid because it's crucial that our engineers be able to travel to support the production processes in the new facility. Travel to Thailand remains difficult with mandatory quarantine periods in effect," he adds.

"We're also being cautious with this transition, so as not to concentrate our geographic risk during the COVID-19 pandemic," Rittichier continues. "By building across Chinese and Thai facilities in the current quarter, we will hedge the risk of labor shortages at the cost of lower total capacity in our operations and some additional costs. We see this as the right bet given the circumstances."

Emcore also expects further revenue growth from the June quarter into the September quarter (fiscal Q4/2020). "We expect the smaller wireless and chip components in the broadband business to maintain their contribution, but we are seeing strength in our cable TV products," says Rittichier. "Recent comments from the MSOs have pointed to significant bandwidth demand from workers complying with work-from-home initiatives. In one particular case, a leading MSO stated that a whole year's worth of bandwidth growth concentrated itself into a single month. The MSOs are now reacting strongly to improve capacity and response to their networks, which has resulted in a full order book for Emcore's cable TV business going out into Q4," he adds. "MSOs are relying on proven technology to meet their needs... Remote PHY shelf products, which incorporate linear optics built by Emcore, continue to gain traction in the longer-term planning of the MSOs. Although it's impossible to say with any degree of certainty how long this upgrade cycle will last, Emcore is very well positioned to meet these demands as it works to complete its EMS transfer by the end of the fiscal year," Rittichier concludes.

www.emcore.com

Lumentum's quarterly revenue falls 12% as COVID-19 exacerbates supply constraints

June quarter to be impacted by over 20%, cutting revenue by \$90m

For fiscal third-quarter 2020 (ended 28 March), Lumentum Holdings Inc of San Jose, CA, USA (which designs and makes photonics products for optical networks and lasers for industrial and consumer markets) has reported revenue of \$402.8m, down 12% on \$457.8m last quarter and 7% on \$432.9m a year ago.

"Results were impacted by the COVID-19 pandemic due to limitations on our ability to supply products to our customers," notes president & CEO Alan Lowe. Initial guidance (given in early February) assumed that COVID-19 would impact revenue by \$15–20m, reducing it to \$400–425m, revenue came in at the lower end of this guidance. "We had a larger impact [by more than \$10m] than we assumed, due to the spread of the virus beyond China late in the third quarter," he adds.

"In China, because we had a large number of employees working through the Lunar New Year holiday due to strong demand for our products, we were able to quickly ramp up production from our Shenzhen factory after the extended Lunar New Year holiday. However, our Shenzhen factory was impacted in the third quarter by challenges in obtaining components from third-party suppliers inside and outside of China," says Lowe.

"In nearly all of our locations around the world, local governments have mandated social distancing measures including shelter-in-place orders. We are deemed an essential business by these local governments due to the key role we play in the global supply chains of critical communications and healthcare systems. As such, we have been encouraged and permitted to continue operations regarding our factories in Asia which perform assembly & test operations," continues Lowe.

"In Thailand, we rapidly implemented employee protective measures in the third quarter. These measures have not limited output so far, but production in Thailand has been impacted by the same challenges that our Shenzhen factory is experiencing with sourcing components," notes Lowe.

In Malaysia, Lumentum uses a contract-manufacturing partner for most of its telecom transmission revenue. Output was significantly impacted late in fiscal Q3 due to the government's movement control order issued on 16 March. "We had no production for several weeks after this," says Lowe.

"As we provide an essential service under the order, we have been able to slowly increase production in Malaysia from zero when the movement control order was issued and expect to reach near 100% production levels in the coming weeks."

Optical Communications segment revenue already supply constrained before COVID-19

Commercial Laser segment revenue was \$43.5m (10.8% of total revenue) in fiscal Q3, down 10.8% on \$48.4m last quarter and 20.9% on \$55m a year ago due primarily to lower fiber-laser sales.

Optical Communications segment revenue was \$359.3m (89.2% of total revenue), down 12.2% on \$409.2m last quarter (due primarily to 3D sensing seasonality and COVID-19-related supply limitations) and down 4.9% on \$377.9m a year ago (from exiting the datacom transceiver module business, and the COVID-19 supply limitations more than offsetting higher 3D sensing revenue). Revenue from the remaining discontinued datacom transceiver module products was about \$5m (and will decline to zero in the next quarter or two, as planned). In April 2019, Lumentum completed the divestiture of several datacom transceiver product lines

(manufactured by subsidiary Oclaro Japan Inc) to Shanghai-based Cambridge Industries Group (CIG) in exchange for a long-term strategic supply agreement for Lumentum's photonic chips.

"On our telecom and datacom product lines, before COVID-19 demand was very strong and accelerating, driven by global telecom infrastructure upgrades, the start of 5G deployments and significant cloud data-center expansion. We were already supply-constrained on most key product lines," notes Lowe. Despite COVID-19, demand was strong throughout the quarter across telecom transmission, transport and datacom chips. Bookings for these products grew more than 10% sequentially, driving book-to-bill to over 1.3 (up from 1.1 last quarter). However, the COVID-19 outbreak exacerbated existing supply challenges.

Telecom transmission product supply from China and Malaysia was significantly negatively impacted late in fiscal Q3. Telecom and datacom revenue hence fell 6% sequentially. "Despite these supply challenges, we continue to grow our DCO [digital coherent optics] module revenue and our next-generation indium phosphide (InP) high-bandwidth components for 600G and 800G systems," says Lowe.

Telecom transport revenue was roughly flat quarter-on-quarter. "These product lines are more reliant on Thailand than China for manufacturing operations, but growth was limited by the supply of key components from third parties in China and elsewhere within Asia," notes Lowe.

Datacom chip revenue continues to grow strongly, rising more than 20% sequentially as data-center and 5G demand was robust.

Industrial & Consumer product revenue was down seasonally by

24% sequentially, but up 40% year-on-year driven by customers incorporating 3D sensing in a higher percentage of their products plus increased consumer demand for 3D-sensing-enabled products. "We steeply ramped volume production of lasers for world-facing cameras or LiDAR for consumer applications," says Lowe.

Lumentum's top two customers comprised about 37% of total revenue, with the largest contributing more than \$90m per quarter. Huawei contributed \$60m. "That's a supply-constrained number, given the constraints we're having on ability to provide telecom transport, for that matter, as well as transmission," notes Lowe. "The demand is higher than that."

About \$100m of targeted \$110m annual expense synergies completed during quarter

On a non-GAAP basis, gross margin was 45.5%, down from 47.4% last quarter but up from 39% a year ago. By segment, Optical Communications gross margin was 45%, down from 48% last quarter due to the lower revenue (particularly in Industrial & Consumer) and a less favorable product mix, but up from 38% a year ago aided by improved telecom and datacom margins as well as acquisition synergies. Commercial Lasers gross margin was 49.7%, up from 42.1% last quarter due to a better product mix and lower manufacturing costs.

Operating expenses have been cut further, from \$91.8m a year ago and \$84.8m last quarter to \$82.7m (falling from 21.2% to 20.5% of revenue). Selling, general & administrative (SG&A) expenses were steady at \$38.4m. R&D expenses have been cut from \$52.8m a year ago and \$46.8m last quarter to \$44.3m, driven by reduced tradeshow and travel expenses and the realization of additional acquisition synergies (and cutting investment in underperforming product lines). During the quarter, Lumentum completed actions that will result in annual expense synergies of about \$100m (of its targeted

\$110m, with the remaining \$10m to be attained over the next few quarters.)

Operating income was \$100.7m (operating margin of 25% of revenue), down from \$132m (28.8% margin) last quarter but up from \$77m (17.8% margin) a year ago (and above the expected margin of 21–23%).

Despite falling from \$119.4m (\$1.53 per diluted share) last quarter, net income is still up on \$70.9m (\$0.92 per diluted share) a year ago at \$98m (\$1.26 per diluted share, above the expected \$1.00–1.17).

During fiscal Q3, Lumentum closed the sale of its lithium niobate (LiNbO₃)-based optical component wafer fab in San Donato, Italy to China-based Advanced Fiber Resources (Zhuhai) Ltd (AFR) — in fiscal Q3 Lumentum recorded a gain of \$13.8m on the sale of product lines — and it continues to ramp down its US-based lithium niobate production. Lithium niobate revenue was about \$10m in fiscal Q3 and is expected to fall to almost zero over the next two quarters.

Total cash and short-term investments rose by \$135.8m during the quarter, from \$1315.6 to \$1451.4m. Lumentum has \$1.5bn in aggregate principal convertible notes and no term debt. Of these convertible notes, \$450m is due in 2024 and \$1.05bn is due in 2026. The total cash interest expense associated with these notes is about \$6m per year.

Also during fiscal Q3, Lumentum introduced key new tele-

com datacom products. "These new products leveraged our highly differentiated indium phosphide and gallium arsenide capabilities and included 50G PAM4 vertical-cavity surface-emitting lasers [VCSELs] and directly modulated lasers (DMLs) to enable higher bandwidths, uncooled 100G PAM 4 externally modulated lasers (EMLs) to reduce data-center power consumption, and a wide set of new pump laser products that increase efficiency and power while lowering cost. These address the full range of optical amplifier applications," says Lowe.

COVID-19 to suppress June-quarter revenue by more than 29% (over \$90m)

For fiscal fourth-quarter 2020, Lumentum expects revenue to fall to \$325–365m (down 14.7% year-on-year). "We are providing a wider-than-normal revenue range to incorporate uncertainty around our assumptions on the impact of COVID-19. This includes on-going component supply challenges and limited production in Malaysia in the first half of the quarter," says Lowe. "COVID-19 will impact fourth-quarter revenue by more than \$90m at the midpoint of our guidance. This is more than 20% below what we were anticipating for the fourth-quarter before the brunt of our challenges from COVID-19 began," he adds. "A little more than half of this \$90m [\$50m] is a result of our inability to supply communication products due to both component sourcing and production limitations, and the balance is from reduced Industrial & Consumer market demand."

Industrial & Consumer revenue (3D sensing) is expected to fall by more than 40% due to expectations around consumer spending trends in a macro slowdown, the potential for smartphone supply-chain challenges impacting demand for the firm's products, and potential risk around the timing of new customer programs. "We have a range of new products we are readying to ramp in the second half

COVID-19 will impact fourth-quarter revenue by more than \$90m at the midpoint of our guidance. This is more than 20% below what we were anticipating for the fourth-quarter before the brunt of our challenges from COVID-19 began

► of the calendar year, including additional world-facing designs that we expect will increase the penetration of world-facing 3D sensing or LiDAR-enabled cameras," says Lowe. "It is too early to quantify with confidence any impact to consumer volumes or the timing of new programs due to COVID-19... We believe the 3D sensing market will continue to grow over the long term," he adds. "Mobile device manufacturers continue to make progress on their plans to incorporate front-facing and world-facing capabilities into a wider range of models. We are engaged with a broad range of customers focused on the consumer, industrial and automotive end-markets looking to add 3D sensing or LiDAR capabilities to enable their applications," Lowe continues. "Our focus is making sure we're there for our customer when they need us, especially on the new products."

Telecom and datacom demand remains robust and strong bookings continue, but revenue is expected to be roughly flat due to declines from discontinued products of \$6–8m and limitations from the continuing COVID-19-related supply constraints.

Telecom transport revenue is expected to rise sequentially due to progress on relieving supply challenges and new product momentum in the market. "Supply constraints in telecom transmission in Malaysia are improving, but we are not at 100% output yet. We won't be able to satisfy more than \$100m of current backlog we have for these products until the second half of the calendar year," says Lowe. "Historic transmission business is usually \$100–120m per quarter and growing. We're continuing to get bookings. So, we're going to end the fiscal year with a very strong backlog."

Datacom chip revenue is expected to grow, again due to continued strong cloud and 5G market demand, but is still gated by capacity in the firm's wafer fab.

Commercial Lasers segment rev-

enue should fall by about 20% due to end-market demand, caused by the slowdown in industrial production globally, with declines for fiber lasers exceeding growth in solid-state lasers. "Our solid-state laser revenue expanded nicely quarter-on-quarter and attained levels not seen in nearly two years. This was due to strength in certain semiconductor manufacturing end-markets, including 5G antenna fabrication," says Lowe. "We expect over the next several quarters that our fiber-lasers business will soften further, as it is tied to growth in global manufacturing," he adds. "We think it's several quarters until the global manufacturing infrastructure comes back to normal. We're at a new lower level for lasers, probably through the calendar year."

Operating expenses should be reduced by \$2–3m. "There will be some travel that starts up again as June rolls around," notes chief financial officer Wajid Ali. "There certainly is an itch from our sales team as well as our operations team to get back into normal, especially with the number of capital deployments that we've got going on specifically at our UK facility as well as Caswell."

Operating margin is expected to fall to 18–21%, but this is still up on 17.8% a year previously. "Our model improvement is seen in the improving margins in our guidance for the fourth quarter, even with a substantially lower top line and a less rich revenue mix, relative to the prior year," notes Ali.

"The COVID-19-related revenue reduction lowers projected fourth-quarter earnings by more than \$0.50 per share [by more than 35%, from \$1.26 in fiscal Q3 to \$0.70–0.90 in fiscal Q4]," says Lowe.

Adding staff and capital equipment to restore fab capacity post-COVID-19

Lumentum has received the go-ahead to re-engage its employees in Malaysia, but social distancing limitations prevent it from getting all the way back to 100% with the

current headcount. "So, we're hiring, we're adding capital equipment," says Lowe. By the end of May, it should be close to where it was in February.

Lumentum's wafer fabs in the USA (chips for telecom transport and commercial lasers products), Japan (datacom chips) and the UK (chips for telecom transmission products) are all operating, with some at lower efficiencies than before due to implementing social distancing and other protocols to protect the health of employees. "The lower efficiency in our Japan and UK fabs is limiting our ability to grow to meet strong and increasing customer demand. We need to be able to get more wafers out and improve the yields and drive the cost and things like that," says Lowe. "We are hiring and adding capital equipment to increase our capacity, but this takes time. As we enter into July and August, we should be back to near-normal," he reckons.

"We use third-party fabs in Taiwan, the USA and the UK for 3D sensing and have not seen any impact in our ability to meet customer demand for these products," notes Lowe.

"While the COVID-19 pandemic is currently impacting our ability to satisfy strong customer demand for our communications products, we believe the world's experience with COVID-19 will accelerate the shift to increasingly digital and virtual approaches to work, education, healthcare, entertainment, social interaction and commerce around the world," says Lowe. "This accelerating shift will stress the world's communications and cloud networks and should, therefore, drive the need for higher volumes of high-performance optical devices. This will favorably impact our communication business, as well as our laser and 3D sensing lines of business over the long run, as more secure devices and other hardware that are easier to interact with and more autonomous will be needed to consume, produce and communicate digital and virtual content.

www.lumentum.com

DOD announces Defense Production Act Title 3 COVID-19 projects to support space defense industrial base

\$12.45m for 5N Plus to improve semiconductor production and \$6m for SolAero to expand satellite solar panel production

As part of the national response to COVID-19, the US Department of Defense (DoD) has signed a \$12.45m contract award with 5N Plus Semiconductor Corp of St George, Utah - the US-based subsidiary of engineered materials and specialty chemicals producer 5N Plus Inc of Montreal, Quebec, Canada - for a project (to be performed over 39 months) to improve semiconductor production processes to "support long-term business viability and maintain the sole domestic source of critical semiconductor technologies for space programs," says DoD spokesman Lt. Col. Mike Andrews.

The agreement will support 5N Plus Semiconductors' product and process capability integration with US space satellite suppliers to complete development and qualification

of next-generation semiconductor products and technologies.

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

The Department of Defense has also signed a \$6m contract with SolAero Technologies of Albuquerque, NM, USA (formerly the Space Photovoltaics business of Emcore, making high-efficiency solar cells and panels) to sustain critical domestic industrial base capability for satellite solar array panels during the COVID-19

pandemic. SolAero will expand its domestic production capability and capacity for advanced satellite solar cells and panels.

SolAero aims to accomplish this by addressing critical capabilities and capacity to integrate advanced solar cells into covered inter-connected cells (CICs) and photovoltaic assemblies (PVAs). This should enable SolAero to retain critical workforce capabilities throughout the disruption caused by COVID-19 and to restore some jobs lost because of the pandemic.

Both Defense Production Act Title 3 contracts support the space defense industrial base, and use funds authorized and appropriated under the CARES Act.

www.solaerotech.com

www.5nplus.com

www.defense.gov

First Solar supplying 415MW of Series 6 PVs to Geronimo

First Solar Inc of Tempe, AZ, USA has entered into a framework supply agreement to supply 415MW_{DC} of its Series 6 cadmium telluride (CdTe) photovoltaic (PV) modules in 2022 to Geronimo Energy. This latest deal has grown the relationship between the two companies to over 1.4GW_{DC} of both systems and module technology sales.

Headquartered in Minneapolis, MN, Geronimo is a North American renewable energy firm with over 2.4GW of wind and solar operational or under construction, and a multi-gigawatt development pipeline. It was acquired in July 2019 by National Grid, one of the world's largest publicly owned utilities.

"Geronimo sees value in optimizing our solar projects with the Series 6 module. Its benchmark-setting degradation rate and lifetime energy yields make it the right choice to support our mission to help repower

America's grid with clean, renewable electricity," says Nathan Franzen, VP of development. "First Solar and Geronimo have deep roots in the US Midwest and a shared commitment to a sustainable future. A strategic partnership like this helps Geronimo continue its mission to re-power rural American communities with renewable energy projects through farmer-friendly development and local economic benefits," he adds.

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

"Geronimo and First Solar have a longstanding relationship," says Darin Green, senior director, business development, First Solar. "Geronimo's evolution into one of the country's largest and most respected independent power producers is an American success story."

First Solar recently expanded its capacity to meet the demand for Series 6 modules, starting production at its new module manufacturing facility in Lake Township, Ohio, in October 2019. Representing over \$1bn in cumulative investment, the new facility expanded First Solar's annualized manufacturing capacity in the USA to 1.9GW_{DC}, making it the largest solar manufacturer in the Western Hemisphere. The firm also operates manufacturing facilities in Vietnam and Malaysia, with a global annualized Series 6 manufacturing capacity of 5.5GW_{DC}.

www.firstsolar.com

University of Tokyo makes record-mobility tin dioxide thin films with transparent properties

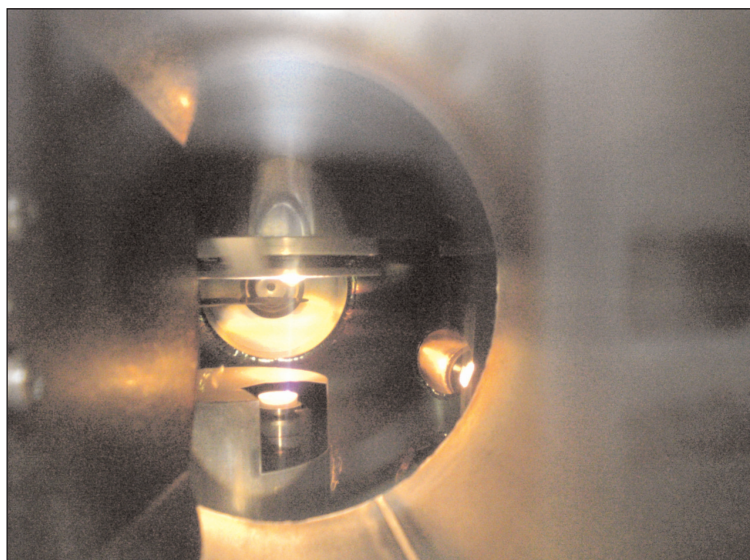
Researchers at the University of Tokyo have achieved the highest mobility among thin films of tin dioxide ever reported (Michitaka Fukumoto et al, 'High mobility approaching the intrinsic limit in Ta-doped SnO₂ films epitaxially grown on TiO₂ (001) substrates', Scientific Reports 10, article no. 6844). This high mobility could allow the creation of thin and even transparent tin dioxide semiconductors for use in next-generation LED lights, photovoltaic solar panels or touch-sensitive display technologies, it is reckoned.

When tin and oxygen are combined in a certain way to become tin dioxide (SnO₂), the material can be made into a wide-bandgap oxide semiconductor. Because of its high mobility, since the 1960s tin dioxide has found effective use in industrial applications like gas sensors and transparent electrodes for solar devices, as well as field-effect transistors. However, the high mobility of tin oxide only existed in large bulk crystals, until now.

Nakao and his team made lightly tantalum (Ta)-doped SnO₂ (Sn_{1-x}Ta_xO₂, TTO) thin films epitaxially grown on titanium dioxide TiO₂ (001) substrates by pulsed laser deposition (PLD) and investigated the transport properties. The carrier density (n_e) of the TTO films was systematically controlled by x . Optimized TTO ($x=3 \times 10^{-3}$) films with $n_e \sim 10^{20} \text{cm}^{-3}$ exhibited a very high Hall mobility (μ_H) of $130 \text{cm}^2 \text{V}^{-1} \text{s}^{-1}$ at room temperature.

"We demonstrated the highest mobility in a thin film of tin oxide ever achieved," says Shoichiro Nakao, a researcher in the University of Tokyo's Department of Chemistry.

The μ_H value coincided well with the intrinsic limit of μ_H calculated on the assumption that only phonon and ionized impurities contribute to the



Laser deposition: a focused laser is used to create thin films of tin dioxide. © 2020 Nakao et al.

carrier scattering. The suppressed grain-boundary scattering might be explained by the reduced density of the {101} crystallographic shear planes.

"Our method of production was key to creating a substance with these properties. We used a highly focused laser to evaporate pellets of pure tin dioxide and deposit or grow material exactly how we wanted it," says Nakao. "Such a process allows us to explore different growth conditions as well as how to incorporate additional substances. This means we can endow tin dioxide semiconductors with high mobility and useful functional-

ity," he adds.

"Improved mobility not only enhances the conductivity but also the transparency of the material," notes Nakao.

"Generally, transparency and conductivity cannot coexist in a material.

Typical transparent materials such as glass or plastic

are insulating, whereas conducting materials like metals are opaque. Few materials exhibit transparent conductivity."

The tin oxide thin film allows visible light and near-infrared light to pass. This is a great benefit to the power conversion efficiency of photovoltaic solar panels, but other uses could include enhanced touch-screen displays with even better accuracy and responsiveness, or more efficient LED lights, it is reckoned.

www.nature.com/articles/s41598-020-63800-3

www.chem.s.u-tokyo.ac.jp/users/sschem/en



Final SnO₂ thin film grown on glass to make efficient PVs. © 2020 Nakao et al.

NREL co-founds consortium to speed commercialization of perovskite solar cells

Working with leading domestic solar companies, the US National Renewable Energy Laboratory (NREL), the Washington Clean Energy Testbeds at the University of Washington, the University of North Carolina at Chapel Hill, and the University of Toledo have formed the US Manufacturing of Advanced Perovskites Consortium (US-MAP), which will work to accelerate the commercialization of perovskite technologies.

Perovskite solar cells are a type of thin-film solar cell that have proven to be highly efficient at harnessing sunlight. Perovskites have also shown tremendous promise in a range of other technologies, including solid-state lighting, advanced radiation detection, dynamic sensing and actuation, photo-catalysis, and quantum information science. Early investments by the US Department of Energy's Solar Energy Technologies Office and its Office of Science into perovskite research have enabled the USA to engage at the forefront of many of these technology areas and fostered a vibrant community of domestic industrial leaders.

"Perovskites have the potential to become a game-changer for solar and many other fields," reckons NREL director Martin Keller. "By combining our research efforts, this new consortium will bring this technology to market sooner than if we were all operating alone."

While perovskite cells have shown promise in the lab, more work remains to be done to ensure that the technology is ready for commercial success. Manufacturing, durability and sustainability remain challenges and will be the consortium's research focus. Members of US-MAP will share R&D, validation and pilot manufacturing, which will reduce development costs and technology risks for potential investors.

US-MAP has six major US-based industry players as founding members: BlueDot Photonics, Energy Materials Corporation, First Solar, Hunt Perovskites Technologies, Swift Solar, and Tandem PV. Representatives from each company, as well as new US startups and other established companies, will form an industry advisory board that will inform and guide the efforts per-

formed at the research institutions. The founding organizers (NREL, Washington Clean Energy Testbeds, UNC-Chapel Hill, and the University of Toledo) will form the executive board that will oversee delivery on projects.

The organizers and members of US-MAP have already begun expanding this network to include the University of Colorado at Boulder and the SLAC National Accelerator Laboratory.

The founding organizers of the US-MAP consortium will explore funding from a variety of sources including industrial members and the federal government. Leadership of the consortium will be provided at NREL by Joseph J. Berry and Jao van de Lagemaat, who will work with the key points of contact of the other founding organizers and industrial advisory board.

"Forming this collective will enable innovation in the US that will strengthen our position in these important materials and associated technologies," reckons consortium director Berry, senior scientist and perovskite team lead for NREL.

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Excitonic complexes in 2D semiconductors exploited to achieve optical gain

The prospect of low-power nanolasers using two-dimensional materials targets high-speed communications in supercomputing and data-center applications.

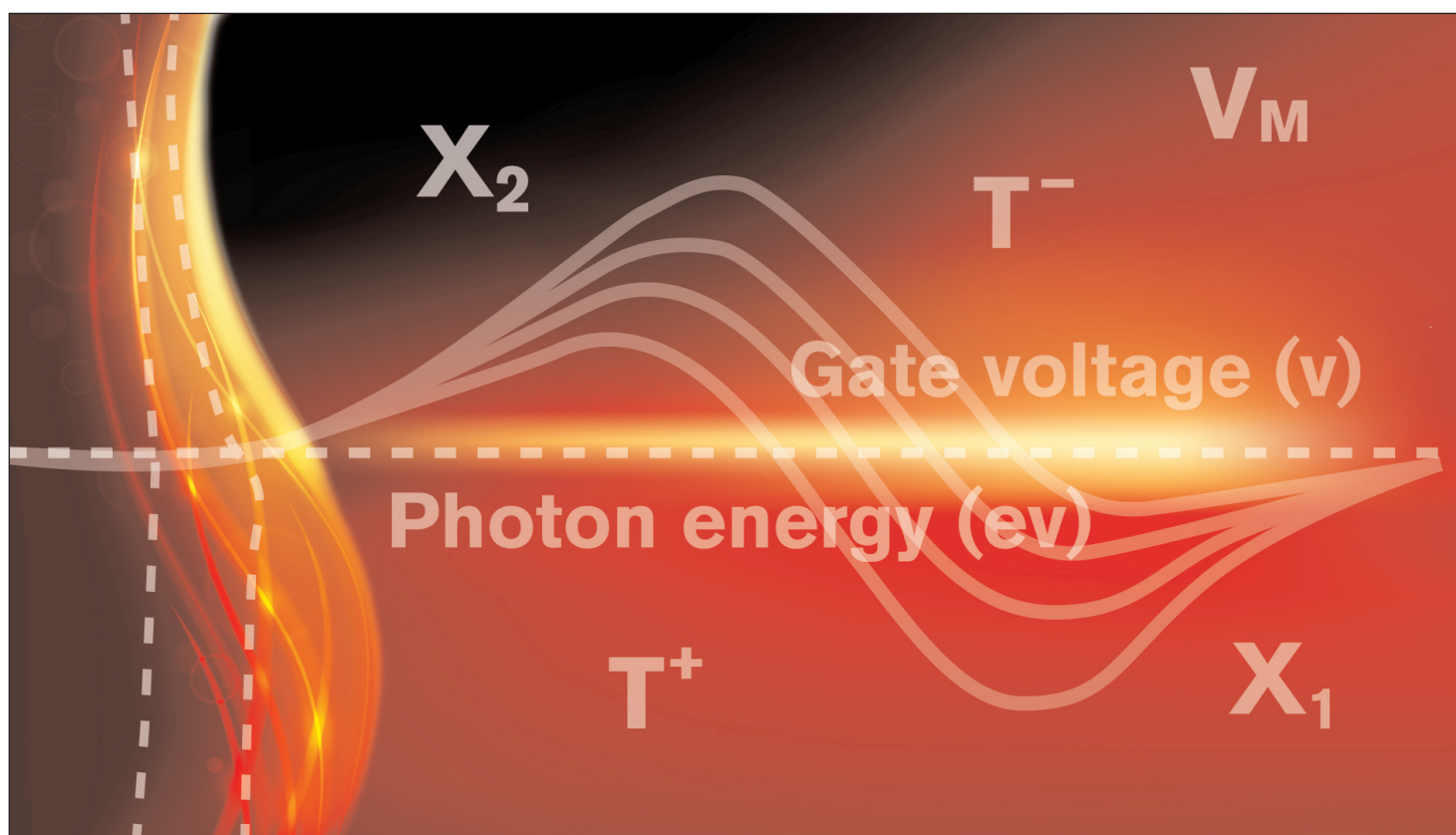
Led by associate professor Hao Sun of China's Tsinghua University, Cun-Zheng Ning, a professor of electrical engineering in the Ira A. Fulton Schools of Engineering at Arizona State University (ASU), and his peers have explored the intricate balance of physics that governs how electrons, holes, excitons and trions coexist and mutually convert into each other to produce optical gain (Zhen Wang et al, 'Excitonic complexes and optical gain in two-dimensional molybdenum ditelluride well below the Mott transition', *Light: Science and Applications*, 9, article no.39 (10 March 2020)).

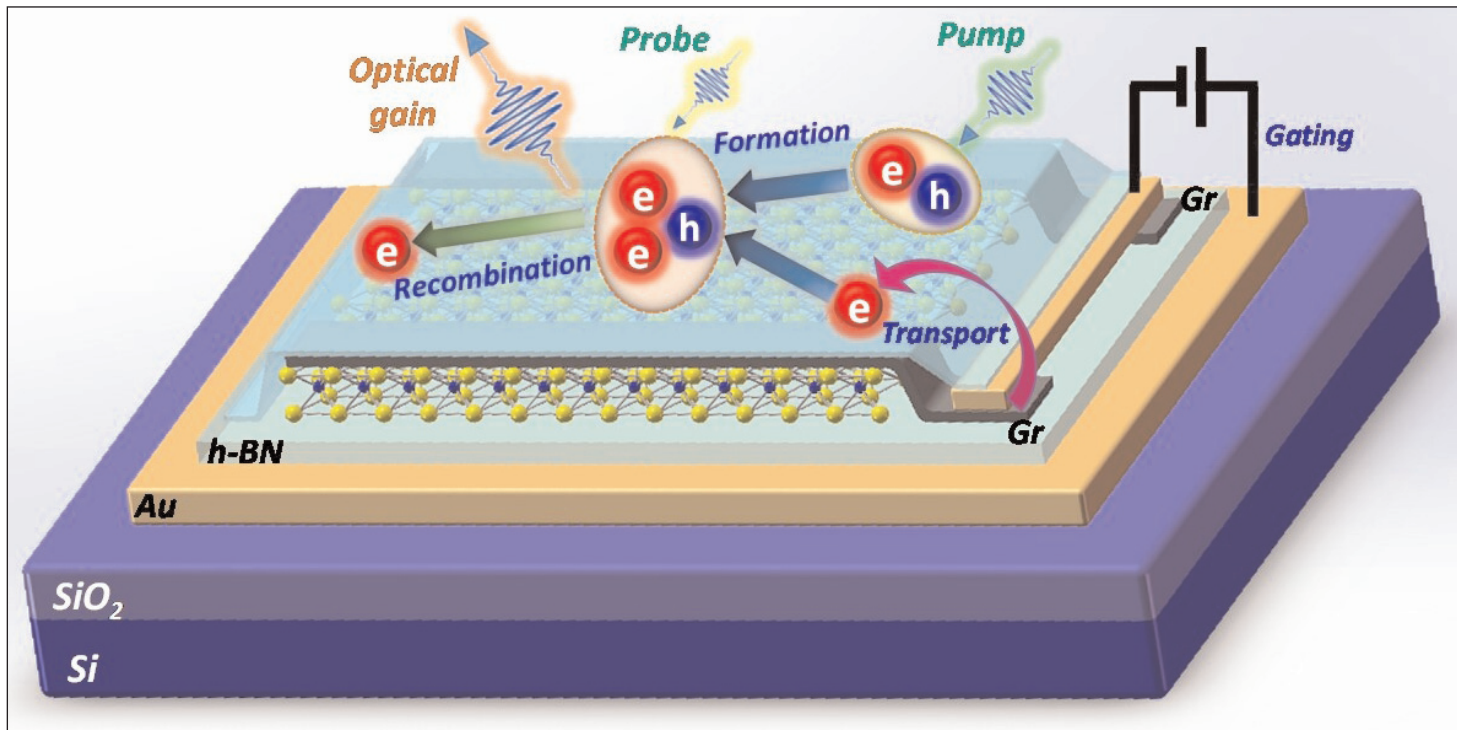
"While studying the fundamental optical processes of how a trion can emit a photon or absorb a photon, we discovered that optical gain can exist when we have sufficient trion population," Ning says. "Furthermore, the threshold value for the existence of such optical gain can be arbitrarily small, only limited by our measurement system."

In Ning's experiment, the team measured optical gain at density levels four to five orders of magnitude smaller than those in conventional semiconductors.

Ning was driven to make such a discovery by his interest in the phenomenon of Mott transitions, an unresolved mystery in physics about how excitons form trions and conduct electricity in semiconductor materials to the point that they reach the Mott density (the point at which a semiconductor changes from an insulator to a conductor and optical gain first occurs). But the electrical power needed to achieve Mott transition and density is far more than what is desirable for the future of efficient computing. Without new low-power nanolaser capabilities like those he is researching, Ning says it would take a small power station to operate one supercomputer.

"If optical gain can be achieved with excitonic complexes below the Mott transition, at low levels of





A single layer of 2D material was placed on a substrate with gold as a back-gate to control the number of electrons in the material. Another laser pumps the 2D material to create excitons, some of which form trions with the pre-existing electrons. Reflected light is monitored to find the signature of amplification. Graphic courtesy of Cun-Zheng Ning.

power input, future amplifiers and lasers could be made that would require a small amount of driving power," Ning says.

It is reckoned that this development could be game-changing for energy-efficient photonics, or light-based devices, and provide an alternative to conventional semiconductors, which are limited in their ability to create and maintain enough excitons.

As Ning observed in previous experiments with 2D materials, it is possible to achieve optical gain earlier than previously believed. Now he and his team have uncovered a mechanism that could make it work.

"Because of the thinness of the materials, electrons and holes attract each other hundreds of times stronger than in conventional semiconductors," Ning says. "Such strong charge interactions make excitons and trions very stable even at room temperatures."

This means that the research team could explore the balance of the electrons, holes, excitons and trions as well as control their conversion to achieve optical gain at very low levels of density.

When more electrons are in the trion state than their original electron state, then population inversion occurs. "More photons can be emitted than absorbed, leading to a process called stimulated emission and optical amplification, or gain," says Ning.

Design of practical 2D nanolasers targeted

While this new discovery added a piece to the puzzle of Mott transitions — uncovering a new mechanism that researchers can exploit to create low-power 2D semi-

conductor nanolasers — Ning says that they are not yet sure if this is the same mechanism that led to the production of their 2017 nanolasers.

Similar trion experiments were conducted in the 1990s with conventional semiconductors, "but the excitons and trions were so unstable, both experimental observation and, especially, utilization of this optical gain mechanism for real devices is extremely difficult," Ning says. "Since the excitons and trions are much more stable in the 2D materials, there are new opportunities to make real-world devices out of these observations."

Ning's team has more work left to do to study how this new mechanism of optical gain works at different temperatures — and how to use it to create the nanolasers purposefully. "The next step is to design lasers that can operate specifically using the new mechanisms of optical gain," Ning says.

With the physics foundations laid, they could eventually be applied to create new nanolasers that could change the future of supercomputing and data centers, it is reckoned. "The long-term dream is to combine lasers and electronic devices in a single integrated platform, to enable a supercomputer or data center on a chip," Ning says. "For such future applications, our present semiconductor lasers are still too large to be integrated with electronic devices." ■

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Green VCSEL enabled by curved mirror process

Room-temperature, continuous-wave operation demonstrated, along with incorporation in a white-light combination with blue and red VCSELs.

Japan's Sony Corp has extended its curved-mirror vertical-cavity surface-emitting laser (VCSEL) process to $\sim 515\text{--}518\text{nm}$ green wavelengths [Tatsushi Hamaguchi et al, Appl. Phys. Express, vol13, p041002, 2020]. In previous work, Sony produced low-threshold 445nm blue VCSELs with curved-mirror back reflectors [www.semiconductor-today.com/news_items/2019/apr/sony_030419.shtml].

The curved mirror allows longer cavity lengths through the reduction of diffraction effects. The longer lengths are desired to take advantage of the higher thermal conductivity of GaN relative to distributed Bragg reflectors (DBRs) for heat management.

The researchers combined their device with existing blue and red VCSELs to produce white light, claimed as a first such demonstration (Figure 1). The team comments: "This is the first example of a VCSEL-based full-color light source, which will have a great impact on the industry."

The Sony researchers point out that smartphones, tablets, laptops, smartwatches and other devices with displays emit light over a wide range of wavelength, only a small fraction of which is visible, wasting much of the input power. They suggest that highly directive, low-power VCSELs would be able to deliver sufficient power with lower losses in applications such as retinal scanning displays.

The team also hopes that its curved-mirror technique could be applied to III-arsenide and III-phosphide VCSELs, enabling emission wavelengths from ultraviolet, through visible, and down to the infrared regions of the electromagnetic spectrum.

The epitaxial material for the green VCSEL consisted of metal-organic chemical vapor deposition (MOCVD) III-N layers on (20 $\bar{2}$ 1) n-GaN substrate. The active region consisted of four indium gallium nitride (InGaN) quantum wells separated by GaN barrier layers. The use of the (20 $\bar{2}$ 1) crystal orientation avoids unwanted piezoelectric fields inhibiting low laser threshold currents due to strain in the high-indium-content InGaN layers needed for green emissions.

The p-side fabrication created a 30nm indium tin oxide (ITO) transparent conductor contact and a 11.5-pair tantalum oxide (Ta₂O₅)/silicon dioxide (SiO₂) distributed Bragg reflector with a designed reflectivity peak wavelength of 515nm. The n-contact was made through a hole etched into the top-side layers to the n-GaN sub-

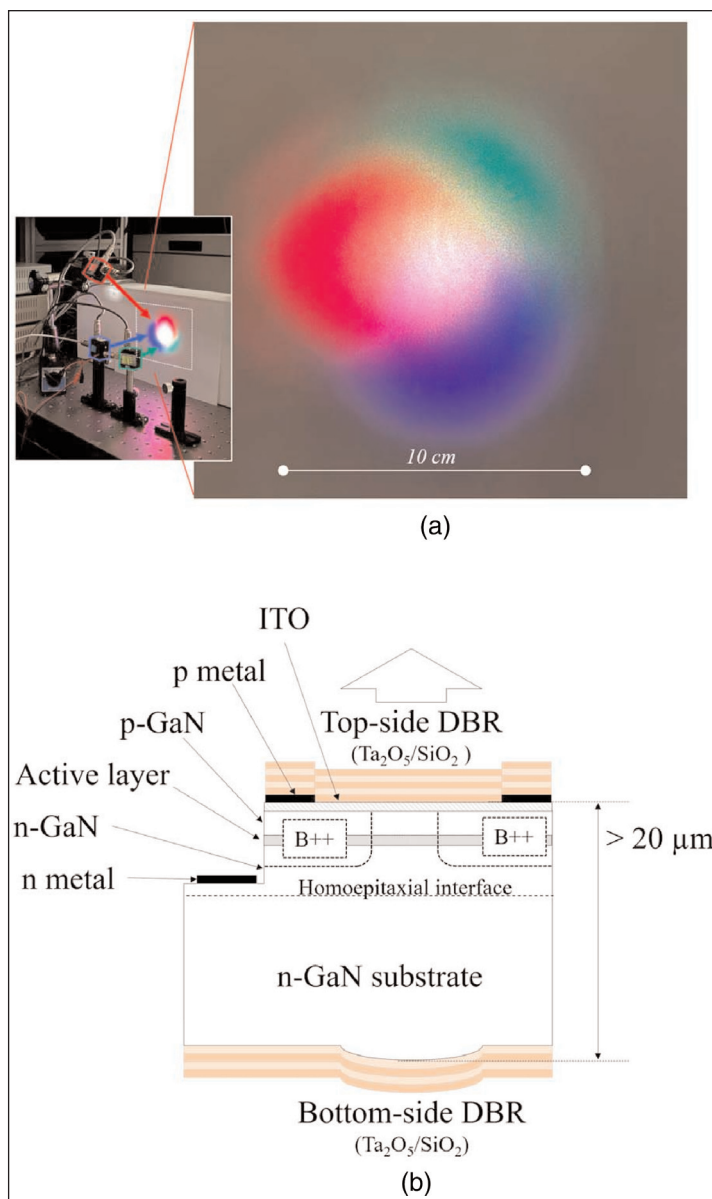


Figure 1. (a) Screen irradiated by three VCSEL outputs, red, blue and green. Inset: measurement set up. (b) Schematics of green VCSELs with curved bottom mirror.

strate. The metal contacts for both the ITO and n-GaN were titanium/platinum/gold. A 4μm-diameter circular current aperture was defined by a boron (B) implant.

The bottom curved mirror was fabricated by thinning the wafer to 20μm, applying a 26μm-diameter resin disks, heating to 200° to convert the disks to droplets, and performing reactive-ion etch. The resin droplets acted as a sacrificial mask for the etch, resulting in a

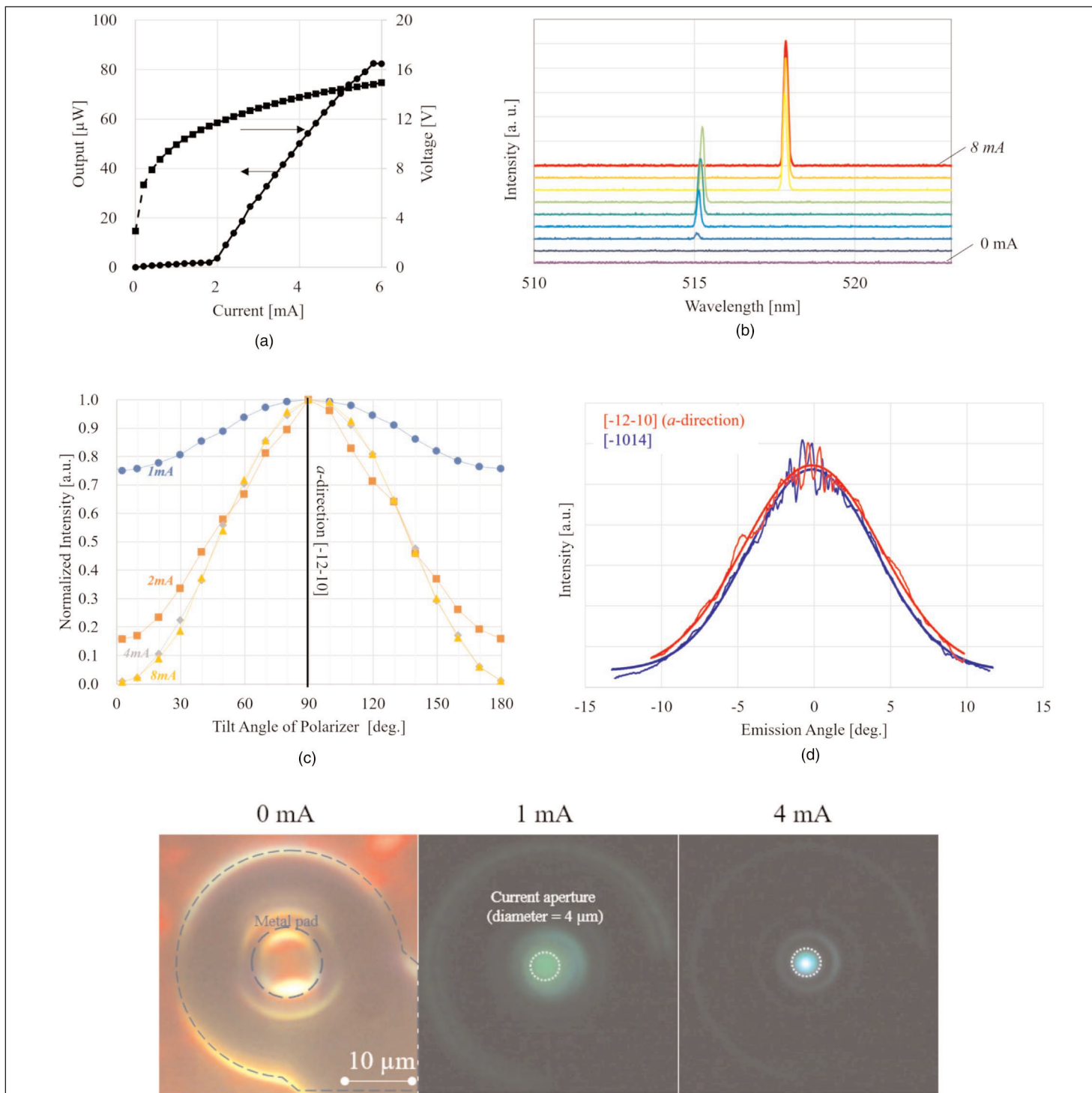


Figure 2. (a) Current–voltage and current–light output power (I–V and I–L) curves. (b) Emission spectra for 0–8 mA. (c) Polarization angle measured across threshold current. (d) Far-field pattern (FFP) at 6 mA. (e) Near-field image below and above threshold.

lens-shaped curved surface. The bottom mirror was completed with 14 pairs of $\text{Ta}_2\text{O}_5/\text{SiO}_2$.

The VCSEL was finally diced and mounted p-side up in a 5.6 mm TO-CAN package without a submount. Testing was in continuous wave mode with the VCSEL on a Peltier cooler at 25°C. The laser threshold current was 1.8 mA, corresponding to 14.4 kA/cm², with a wall-plug efficiency less than 0.1%.

The initial emission peak was at 515.2 nm, which hopped to 517.9 nm when the current was in the

5–6 mA range. The 2.7 nm hop suggested an effective cavity length of 18.6 μm . The output light became more polarized as the injected current increased: 0.14 at 1 mA, and 0.93 at 8 mA. The polarization angle was fixed relative to the III-nitride crystal structure and was in the a-direction ($[\bar{1}2\bar{1}0]$). The far-field emission pattern was approximately Gaussian with a full-width at half maximum divergence of about 9°. ■

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Author: Mike Cooke

High-index-contrast gratings for III-nitride vertical-cavity surface-emitting laser diodes

Researchers hope to enable device thickness reduction, polarization-pinning, and easier setting of the resonance wavelength.

Researchers based in Taiwan and Sweden claim the first demonstration of high-index-contrast grating (HCG) as the top mirror for III-nitride (III-N) vertical-cavity surface-emitting laser (VCSEL) diodes [Tsu-Chi Chang et al, ACS Photonics, published online 26 February 2020]. The team from National Chiao Tung University and Chalmers University of Technology hope that the development will lead to “substantial thickness reduction, polarization-pinning, and setting of the resonance wavelength by the grating parameters”.

The VCSEL used epitaxial III-N material flipped onto a silicon substrate. The epitaxial source material consisted of patterned sapphire substrate (PSS), gallium nitride (GaN) nucleation, 2µm undoped GaN, 5µm n-GaN contact, 10 pairs of indium gallium nitride ($\text{In}_{0.1}\text{Ga}_{0.9}\text{N}$)/GaN (3nm/8nm) multiple quantum well (MQWs) for an

active region, a 10nm p-type aluminium gallium nitride ($\text{Al}_{0.2}\text{Ga}_{0.8}\text{N}$) electron-blocking layer, and a 170nm p-GaN contact layer.

VCSEL fabrication began with atomic layer deposition (ALD) of 30nm silicon dioxide (SiO_2) on the p-GaN. A 10µm-diameter current aperture was opened before applying 10nm sputtered indium tin oxide (ITO) transparent conductor. The final part of the p-side of the device consisted of electron-beam evaporation of a distributed Bragg reflector (DBR) composed of 12-pairs of SiO_2 and tantalum oxide (Ta_2O_5) dielectric layers. Typical GaN-based VCSELs use top and bottom DBRs.

The next stage of processing consisted of thermo-compressive flip-chip bonding to a silicon substrate. Laser lift-off removed the sapphire substrate and further GaN material was also removed using chemical-mechanical polishing (CMP), giving a 5µm thickness

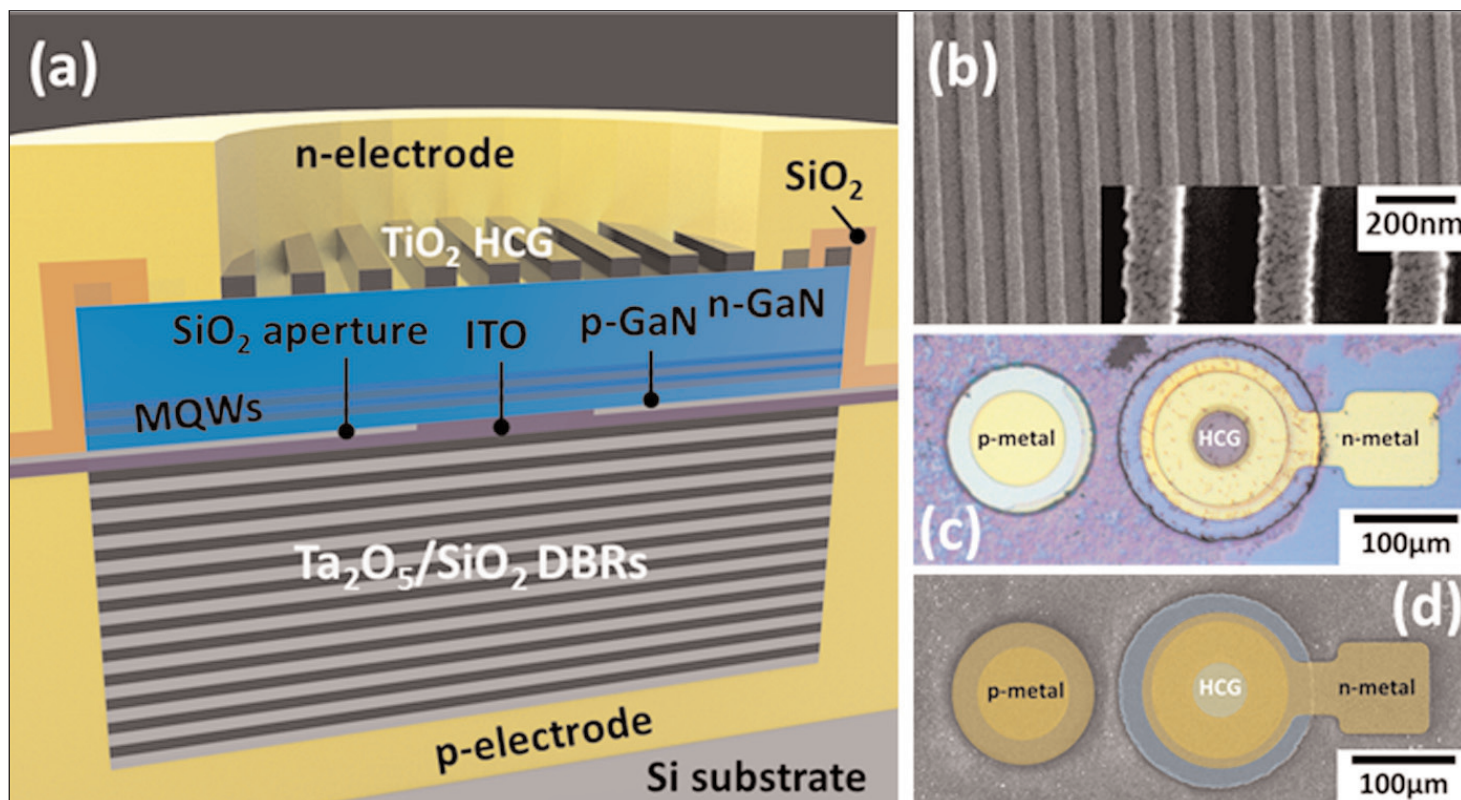


Figure 1. (a) Three-dimensional illustration of GaN VCSELs. (b) Top-view scanning electron microscope (SEM) image of TiO_2 HCG. Top-view (c) optical microscopy and (d) SEM images of VCSELs.

with an n-GaN surface.

The HCG grating was fabricated using sputtering of titanium dioxide (TiO_2) and SiO_2 , followed by lift-off patterning, using the SiO_2 and nickel as hard masks. The etching used inductively coupled plasma reactive ions. The grating consisted of strips of TiO_2 with 344.5nm pitch. The strip height and base width were 112.3nm and 177.8nm, respectively.

The device was completed with electrical isolation and deposition of the n- and p-contact metals.

The VCSEL was tested in pulsed mode with 0.1 μs width and 0.3% duty cycle (Figure 2). The lasing threshold was 25mA, equivalent to 31.8kA/cm² density. The turn-on voltage came at 6.9V. The researchers report: "Compared to our previously reported VCSELs with two dielectric DBRs, the HCG VCSEL (which has one of the DBRs replaced by an HCG) has a higher threshold current density, lower optical output power, and higher turn-on voltage."

The team explains the worse performance of the HCG by the thicker n-GaN layer ($\sim 5\mu\text{m}$) in the final device, compared with that of the previous DBR-only VCSEL ($\sim 940\text{nm}$). The researchers believe that some unintentionally doped GaN may have remained after the CMP, further increasing the contact and series resistance. The thicker n-GaN also absorbs more photons, increasing the threshold current and reducing optical output power.

The laser output was strongly polarized transverse electric, parallel to the grating bars above threshold. The highest peak came at 404.2nm. From the spacings between the multi-mode peaks ($\sim 4.2\text{nm}$), the researchers estimated the effective cavity length to be 5.1 μm . The line-width of the modes reduced from 2.5nm to 0.5nm as the current passed through threshold.

The beam divergence with 60mA drive current was 10° full-width at half-maximum (FWHM). ■

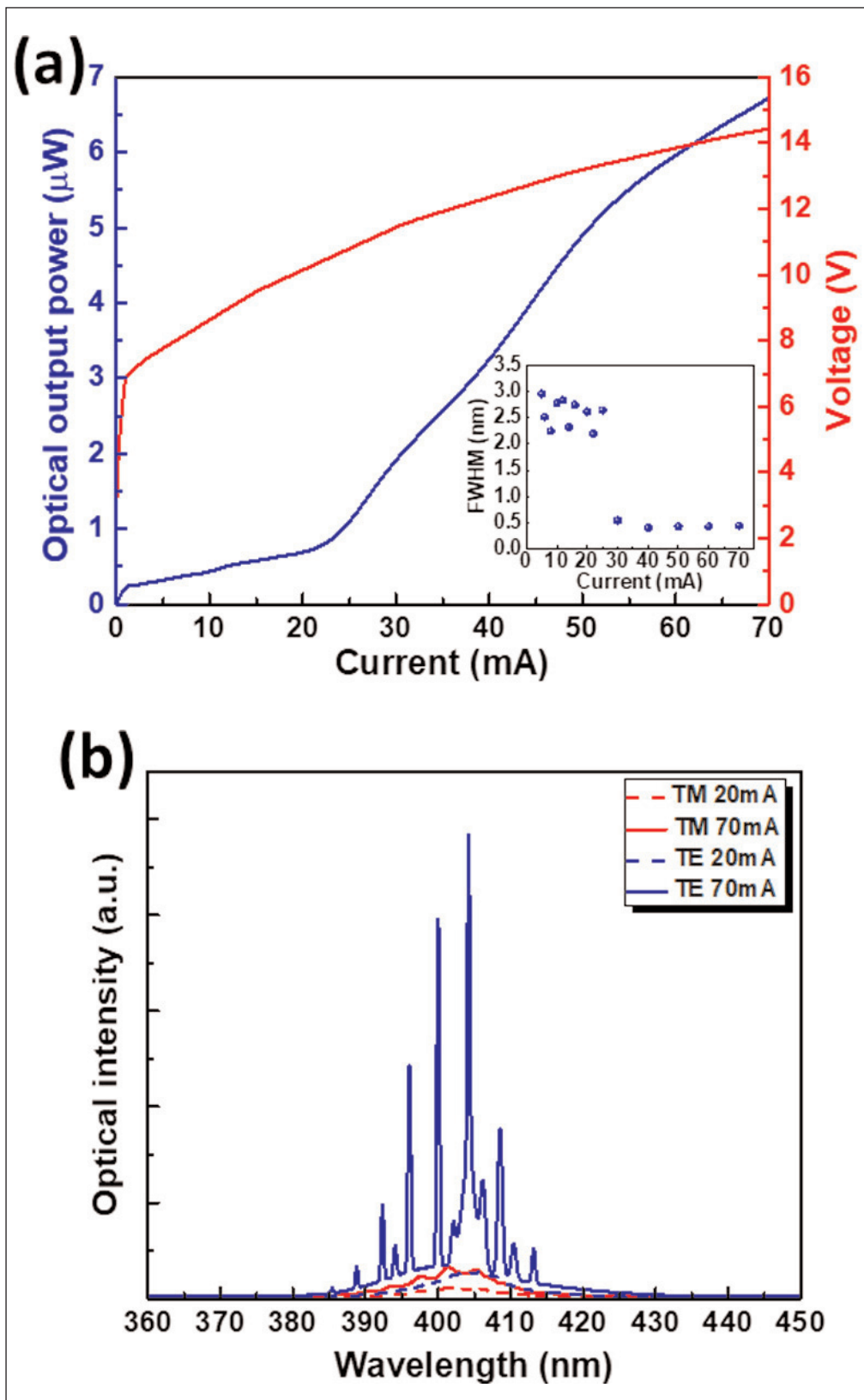


Figure 2. (a) Pulsed optical output power–current–voltage (L–I–V) characteristics of HCG GaN-based VCSEL. Inset: current-dependent line width. (b) Optical emission spectra in two orthogonal polarization directions with electric field parallel to grating bars (TE) and perpendicular to grating bars (TM) below and above threshold.

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Seeking lower-cost non- and semi-polar gallium nitride light-emitters

Researchers use cryogenic treatment to separate epitaxial layer overgrowth bars from growth substrate, allowing reuse of hyper-expensive material.

University of California Santa Barbara in the USA has been developing techniques to grow and separate gallium nitride (GaN) semi-polar and non-polar epitaxial layer overgrowth (ELO) bars on native substrates [Srinivas Gandrothula et al, *Appl. Phys. Express*, vol13, p041003, 2020]. Such material could lead to lower-cost manufacturing of

efficient light-emitting diodes (LEDs) and laser diodes, particularly for longer green and beyond wavelengths greater than 500nm.

The hope is that the process would lead to recycling of the prohibitively expensive GaN native growth substrates. The non/semi-polar crystal orientation can eliminate or even reverse spontaneous or strain-

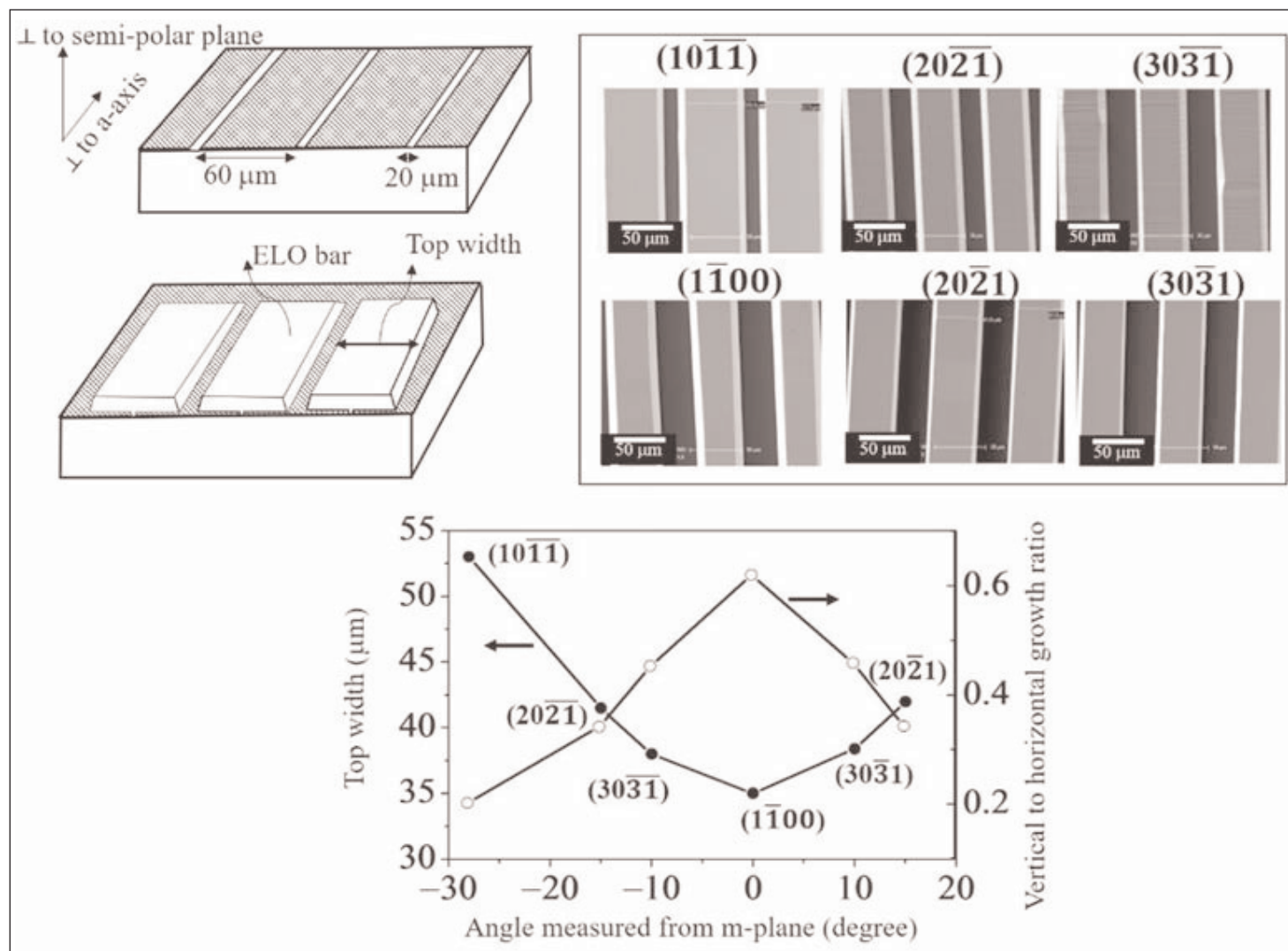


Figure 1. (a) ELO mask design on native semi-polar GaN substrate, (b) schematic of grown ELO bars from open window, (c) magnified top-view scanning electron microscope images of ELO bars, (d) left and right vertical axis, respectively, indicate top width and vertical to horizontal growth of semi-polar ELO bars against angle measured from m-plane.

dependent electric fields in devices, which inhibit the recombination of electrons and holes into photons in the usual polar c-plane GaN and associated heterostructures. The researchers see potential for automotive headlights, specialty lighting, displays, augmented reality/virtual reality (AR/VR) and light fidelity communication.

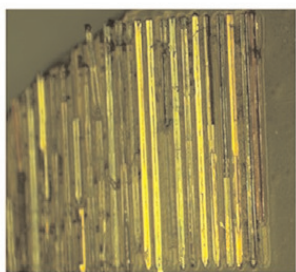
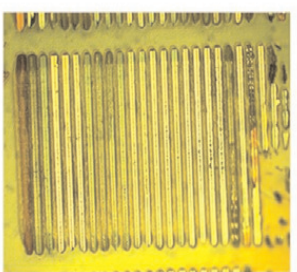
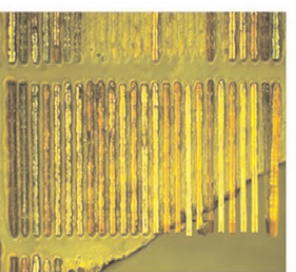
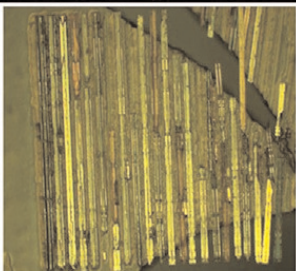
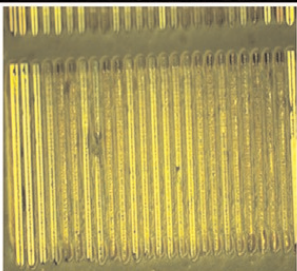
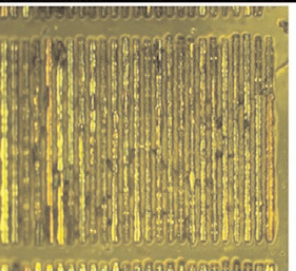
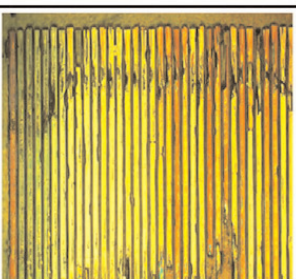
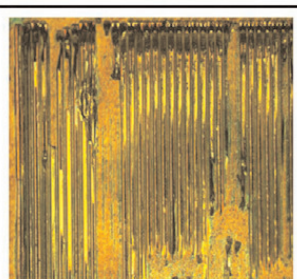
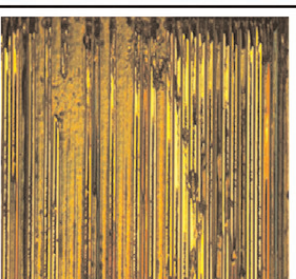
| ELO Window | ($1\bar{1}00$) | ($20\bar{2}1$) | ($20\bar{2}\bar{1}$) | Yield |
|------------------|--|---|--|---------------------------------------|
| 4 μm |  |  |  | 100% |
| 6 μm |  |  |  | 100% |
| 20 μm |  |  |  | ~60% Excluding ($1\bar{1}00$) |

Figure 2. Removed GaN ELO bars of ($1\bar{1}00$), ($20\bar{2}1$) and ($20\bar{2}\bar{1}$) on dicing tape.

Although the researchers have not produced functional devices on the bars, they comment: "We believe that the demonstrated top width of ELO bars on several semi-polar planes can comfortably accommodate micro-LEDs or edge-emitting lasers, including electrical pads." Also, last year, the UCSB group used a related technique to produce laser bars with a low threshold current density of $2.15\text{kA}/\text{cm}^2$ [Takeshi Kamikawa et al, *Optics Express*, vol27, p24717, 2019].

The process began with deposition of 200nm silicon dioxide (SiO_2) on the non- or semi-polar bulk GaN. The SiO_2 was patterned with $20\mu\text{m}\times 1.2\text{mm}$ rectangular stripes in an array of period $80\mu\text{m}$ and 1.3mm in the two dimensions, respectively (Figure 1). The stripes were oriented perpendicular to the a-direction of the GaN crystal structure. The SiO_2 was etched with buffered hydrochloric acid down to the GaN substrate.

The opened stripes were used as seeds for metal-organic chemical vapor deposition (MOCVD) of GaN, creating uncoalesced ELO bars. The GaN growth conditions were 1210°C , 100Torr, using ammonia and trimethyl-gallium precursors in hydrogen carrier gas. The growth resulted in $\sim 10\mu\text{m}$ thick bars after 4 hours.

The separation process began with removal of the SiO_2 mask by hydrofluoric acid. Dicing tape was placed on the GaN ELO bars, before plunging the material into

liquid nitrogen at 77K cryogenic temperatures for a minute or two. The GaN was returned to room temperature by blowing nitrogen gas on the structure. As the researchers slowly peeled the dicing tape from the GaN, the ELO bars separated from the main substrate. The separation did not occur without cryogenic treatment.

The researchers explain: "Our understanding is that, by rapidly reducing the temperature, cracks were induced at the weakest portion of the ELO bars, the interface between the open window of substrate and the MOCVD grown epitaxial layer, and that the cracks propagated along the easily cleavable m-plane lying near the substrate surface to separate the ELO bars."

Reducing the stripe width below $10\mu\text{m}$ resulted in a few broken bars being lifted away with the tape, but almost 100% yields (Figure 2). For $20\mu\text{m}$ wide window, the bar yield was around 60%. For semi-polar ELO bars, the surface presented a series of steps with non-polar m-plane facets.

Meanwhile, the growth substrate showed some cratering in the region where the bars were separated, up to around $3\mu\text{m}$. The researchers hope in future to control this growth substrate damage, enabling reuse. ■

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<https://doi.org/10.1364/OE.27.024717>

Author: Mike Cooke

Eta Research demonstrates GaN-on-GaN epitaxy of vertical power device structures

Other potential device structures include LEDs and lasers on n-type GaN wafers and HEMTs on semi-insulating GaN wafers, says **Eta Research**.

Vertical gallium nitride (GaN) power devices hold the potential to revolutionize the power device industry, notes Eta Research of Shanghai, China, which was founded in 2015 to develop free-standing GaN wafers. There is particular interest for higher-voltage applications (such as 600V and above) for vertical GaN devices. According to the physical properties of the materials, GaN devices have a lower specific on-resistance for a given breakdown voltage compared with traditional silicon power devices and newer native silicon carbide (SiC) power devices. As proof of the material benefits, horizontal GaN power devices — namely GaN-on-Si HEMTs — have seen success in competing with silicon in the low-voltage market.

It is expected that vertical GaN power devices will compete with native SiC power devices for the high-voltage market. In the last two years, SiC devices have been gaining market share for high-voltage applications and several companies have expanded the production of 6" and 8" SiC wafers. In contrast, vertical GaN power devices are not yet sold commercially, and GaN wafers are available in 4" diameter from only a handful of suppliers. The expanded supply and reliable quality of GaN wafers will be important for the development of vertical GaN power devices.

There are three potential advantages of GaN compared with SiC for high-voltage power devices. Firstly, for a given breakdown voltage, the theoretical specific on-resistance is about an order of magnitude less. Therefore, the power losses during forward bias could be reduced and the efficiency would be higher. Secondly, for a given breakdown voltage and on-resistance, the device size will be smaller. The smaller size means that many more devices can be made on a wafer, reducing the cost. Additionally, a smaller form factor is more desirable for most applications. Lastly, GaN holds an

Figure 1: X-ray diffraction data.

| Position | | XRD rocking curve FWHM (arcsec) | | | |
|----------------|-----|---------------------------------|-----------|----------------------|-----------|
| | | GaN substrate | | 20 μ m MOCVD epi | |
| x | y | (002) | (102) | (002) | (102) |
| 0 | 0 | 42 | 78 | 40 | 66 |
| 0 | 20 | 73 | 43 | 55 | 45 |
| -20 | 0 | 44 | 98 | 40 | 64 |
| 0 | -20 | 51 | 39 | 52 | 52 |
| 20 | 0 | 44 | 72 | 71 | 94 |
| 7 | 7 | 42 | 82 | 45 | 79 |
| -7 | 7 | 43 | 83 | 41 | 75 |
| -7 | -7 | 54 | 45 | 58 | 78 |
| 7 | -7 | 50 | 77 | 52 | 64 |
| Average | | 49 | 69 | 50 | 69 |

advantage in the maximum frequency at which a power device can operate, which is determined by both the materials properties and device design. Generally, for SiC the maximum frequency may be about 1MHz or less. GaN power devices will be able to operate at much higher frequencies, at least tens of MHz, which is a frequency range that is inaccessible to SiC. Higher-frequency operation is beneficial to reduce the size of passive components, and thereby reduce the size, weight and cost of the power conversion system.

Vertical GaN power devices are still in the R&D phase of development. There is no consensus within the GaN research community regarding the optimal device structure for GaN vertical power devices. The three leading potential device structures include the current-aperture vertical electron transistor, trench FET, and fin FET. All of the device structures include a lightly doped N-layer as the drift layer. This layer is important because the thickness of the drift

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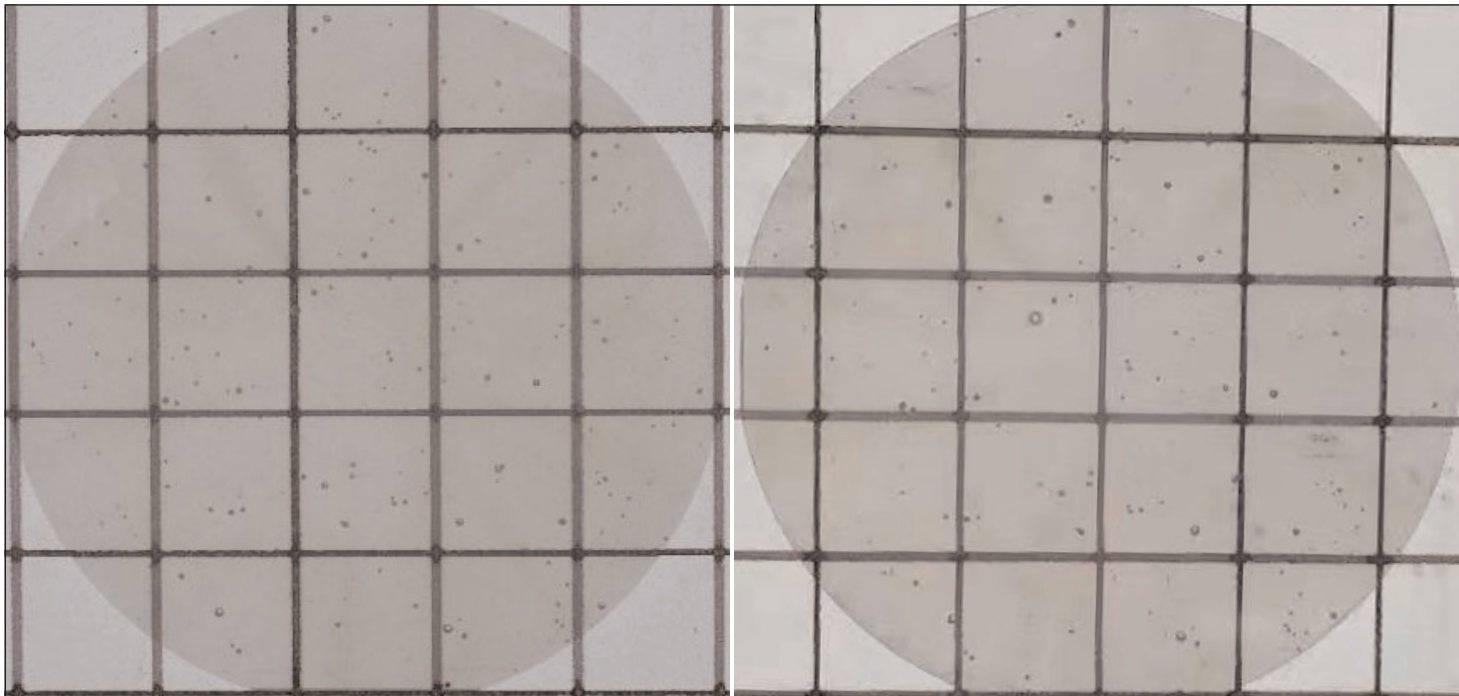


Figure 2: 2" GaN wafer before and after 20 μ m GaN epitaxy.

layer determines the breakdown voltage of the device and the electron concentration has an important role in achieving the theoretical lowest specific on-resistance.

Eta manufactures and sells 4" free-standing GaN wafers, which are available in both n-type conductivity and semi-insulating form. The company also offers metal-organic chemical vapor deposition (MOCVD)

epitaxy of GaN structures on GaN wafers. Customers developing vertical GaN power devices have similar requirements for their device structures, especially concerning the thickness and doping of the drift layer. First, the drift layer should have a thickness of about 10 μ m or more, which is required to ensure that the breakdown voltage is sufficient to meet the device design criteria. Next, the surface of the drift layer should be smooth enough to create planar interfaces for the subsequent device layers. Last, the drift layer must have a low elec-

tron concentration, typically in the range of 10^{16} – 5×10^{16} /cm³.

The firm has performed experiments for GaN-on-GaN epitaxy in the range of 10–20 μ m thickness. Figure 1 and Figure 2 show the x-ray diffraction (XRD) data and wafer pictures for 20 μ m of GaN grown by MOCVD on a 2" GaN wafer. A 9-point pattern was used for XRD

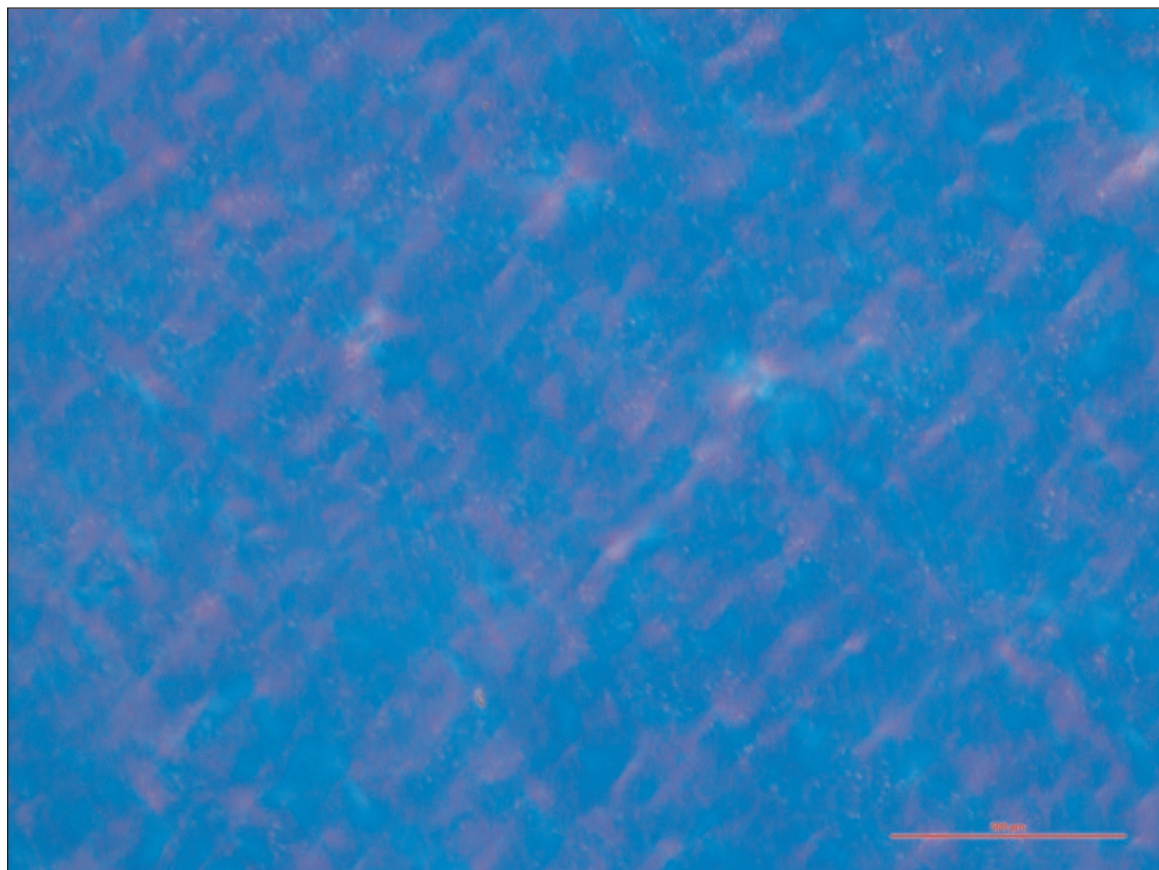


Figure 3: Nomarski optical microscope image, showing a relatively featureless surface.

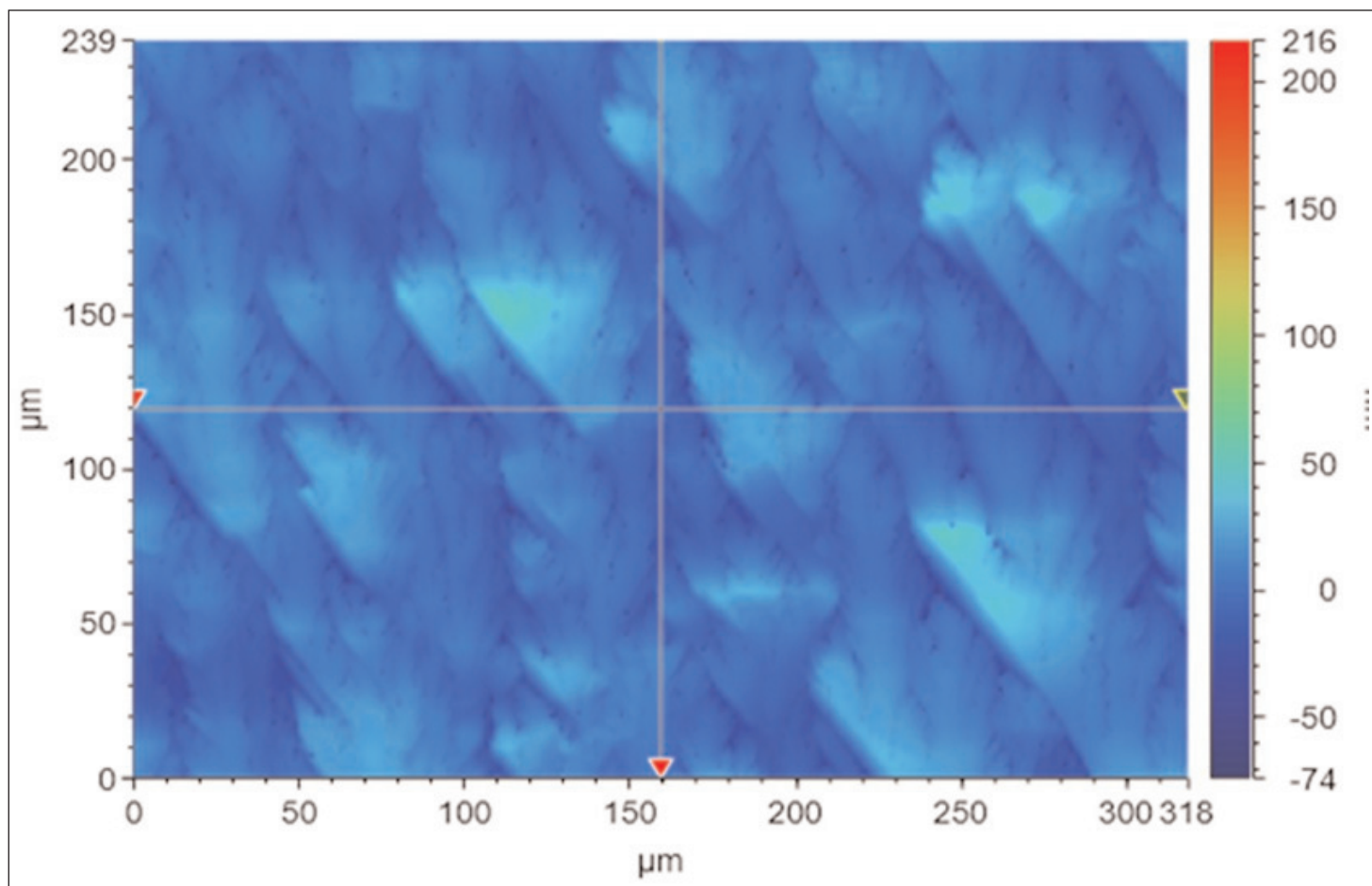


Figure 4: Bruker optical interferometer image of the epitaxy surface.

measurement of the rocking curve FWHMs of the 002 and 102 peaks. The average values of the rocking curve FWHMs before epitaxy were 49 arcsec and 69 arcsec for the 002 and 102 peaks, respectively. After the 20 μm epitaxy, the rocking curve FWHMs were nearly identical, with average values of 50 arcsec and 69 arcsec for the same two peaks. The bow of the wafer was slightly improved after epitaxy, starting at $-5.0\mu\text{m}$ before epitaxy and resulting in $-1.3\mu\text{m}$ after epitaxy.

A relatively smooth surface can be achieved by appropriate selection of the offcut. An offcut of 0.4° toward the m-plane was selected. For 10 μm film growth on the 0.4° -offcut GaN wafer, the average surface roughness was

Eta is now able to offer GaN-on-GaN MOCVD epitaxy layers suitable for vertical GaN power devices. The gallium nitride homoepitaxy drift layers can be grown over 10mm thick with a relatively smooth surface and electron concentration in the 10^{15} – $10^{16}/\text{cm}^3$ range. Device structures can also be grown with multiple layers including InGaN, AlGaN, n-type doping and p-type doping

8–16nm, measured by Bruker optical interferometry over an area of $239\mu\text{m} \times 318\mu\text{m}$. Figure 3 shows an optical Nomarski image of a featureless surface and Figure 4 shows the optical interferometry image.

The low electron concentration of the drift layer may not be readily achievable under the typical MOCVD growth conditions used for LEDs. The drift layer must also have a growth rate that is sufficiently high to obtain a thick MOCVD layer within a reasonable time frame. The company has undertaken studies to achieve a low-electron-concentration drift layer. The lowest electron concentration achieved has been $2 \times 10^{15}/\text{cm}^3$, measured using the capacitance–voltage (C–V) method. Additional silicon dopant can be added to the MOCVD growth to achieve higher electron concentrations.

Eta is now able to offer GaN-on-GaN MOCVD epitaxy layers suitable for vertical GaN power devices. The GaN homoepitaxy drift layers can be grown over 10 μm thick with a relatively smooth surface and electron concentration in the 10^{15} – $10^{16}/\text{cm}^3$ range. Device structures can also be grown with multiple layers including InGaN, AlGaN, n-type doping, and p-type doping. Other potential device structures include LEDs and lasers diodes grown on n-type GaN wafers and HEMTs grown on semi-insulating GaN wafers. ■

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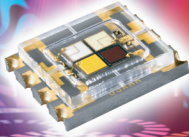


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GaN RF market growing at 12% CAGR to \$2bn in 2025

Coronavirus outbreak to have minor impact on GaN deployment for 5G in 2020, reckons Yole Développement.

The total gallium nitride (GaN) radio frequency (RF) market is rising at a compound annual growth rate (CAGR) of 12% from \$740m to more than \$2bn by 2025, forecasts market research and strategy consulting company Yole Développement in its annual report 'GaN RF market: applications, players, technology, and substrates 2020'.

"In the past few years, RF applications have received a boost from the implementation of GaN technology," says technology & market analyst Ezgi Dogmus PhD. "The main GaN RF market drivers remain telecom and defense applications."

In telecom infrastructure, the aftermath of US sanctions related to Huawei slowed the GaN-based remote radio head (RRH) market in 2019 and pushed original equipment manufacturers (OEMs) to restructure their supply chain for the coming years. Nevertheless, GaN deployment will remain the same for the long term. In active antenna systems (AAS), the increase in bandwidth will favor increasing GaN implementation. Also, small cells and backhaul connections will see impressive deployment of GaN in the coming years, reckons the report.

In military applications, with investments from governments to improve their national security by replacing travelling-wave

tube (TWT)-based systems, defense will remain one of the GaN RF market's main drivers, predicts the report.

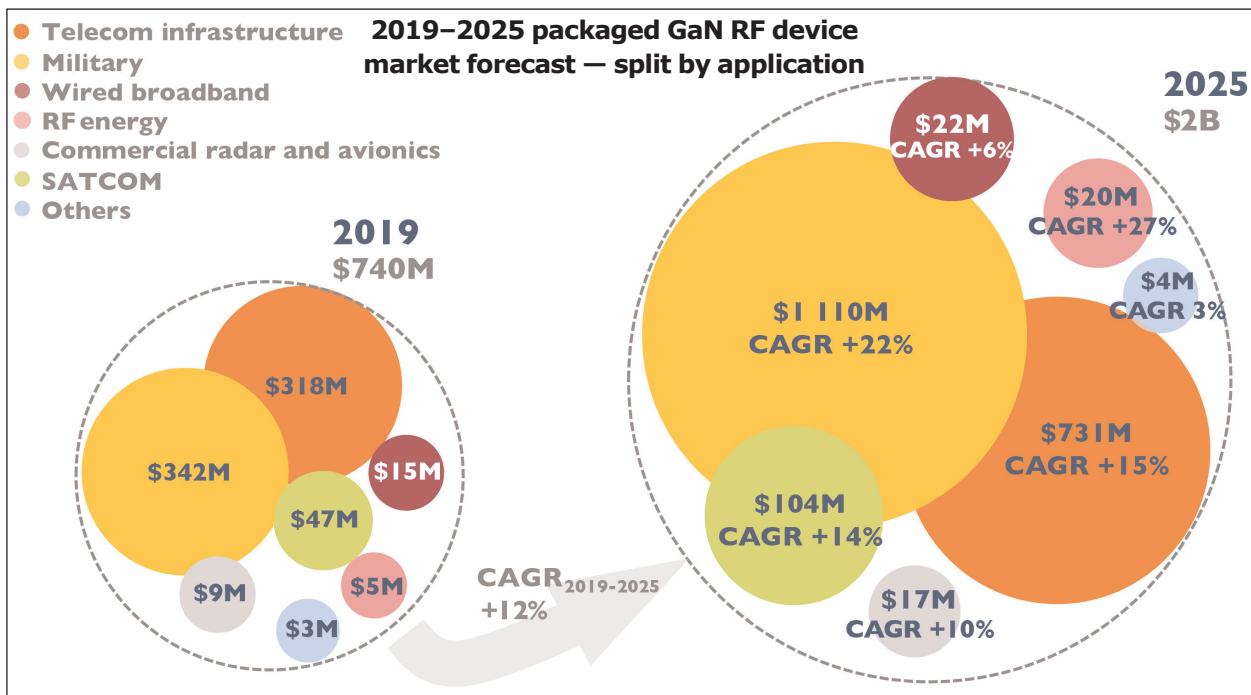
"Radar is the main driver in military applications, mainly due to the increase of transmit/receive (T/R) modules in new GaN-based AESA [active elec-

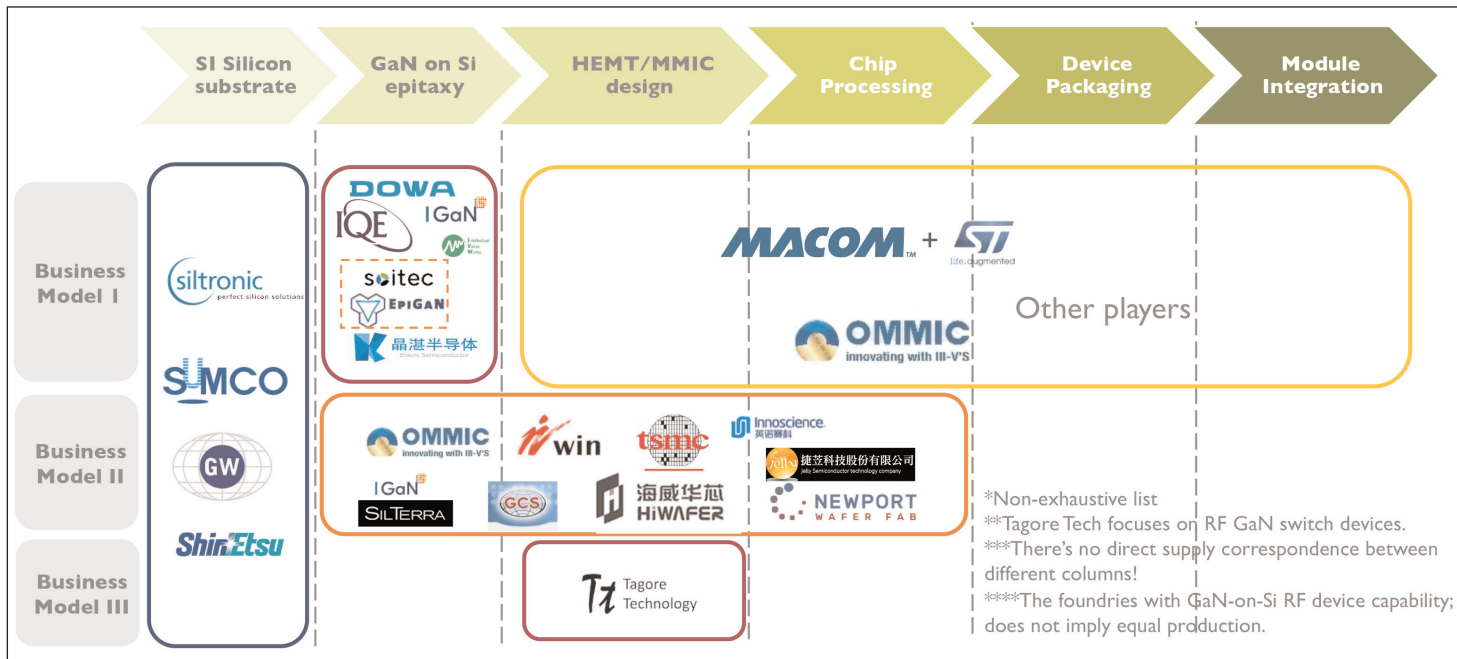
tronically scanned array] systems and stringent requirements for lightweight devices for airborne systems," says technology & market analyst Ahmed Ben Slimane PhD. "The total GaN RF military market will surpass \$1.1bn in 2025, at a 22% CAGR," he adds.

For handsets, GaN's high performance and small form factor could attract OEMs. The adoption of GaN power amplifiers (PAs) will depend on the evolution over the next five years of GaN's technology maturity, supply chain, and cost, as well as OEM strategies.

However, Yole says it is not possible today to give a comprehensive picture of the RF GaN industry without taking into account the US-China trade conflict and COVID-19 outbreak, since both events are having a significant impact on the landscape of the semiconductor industry.

China is the largest market for antenna systems and will remain so for the next several years. Due to US sanctions related to China-based Huawei, the OEM's supply chain has been restructured. As a consequence, Yole identifies a positive impact on Asian integrated device manufacturers (IDMs) and foundries, as well as European players. For example, the European foundry UMS doubled its GaN RF business in 2019, due mainly to the base transceiver station (BTS) market. The





Global industrial supply chain GaN-on-silicon capability.

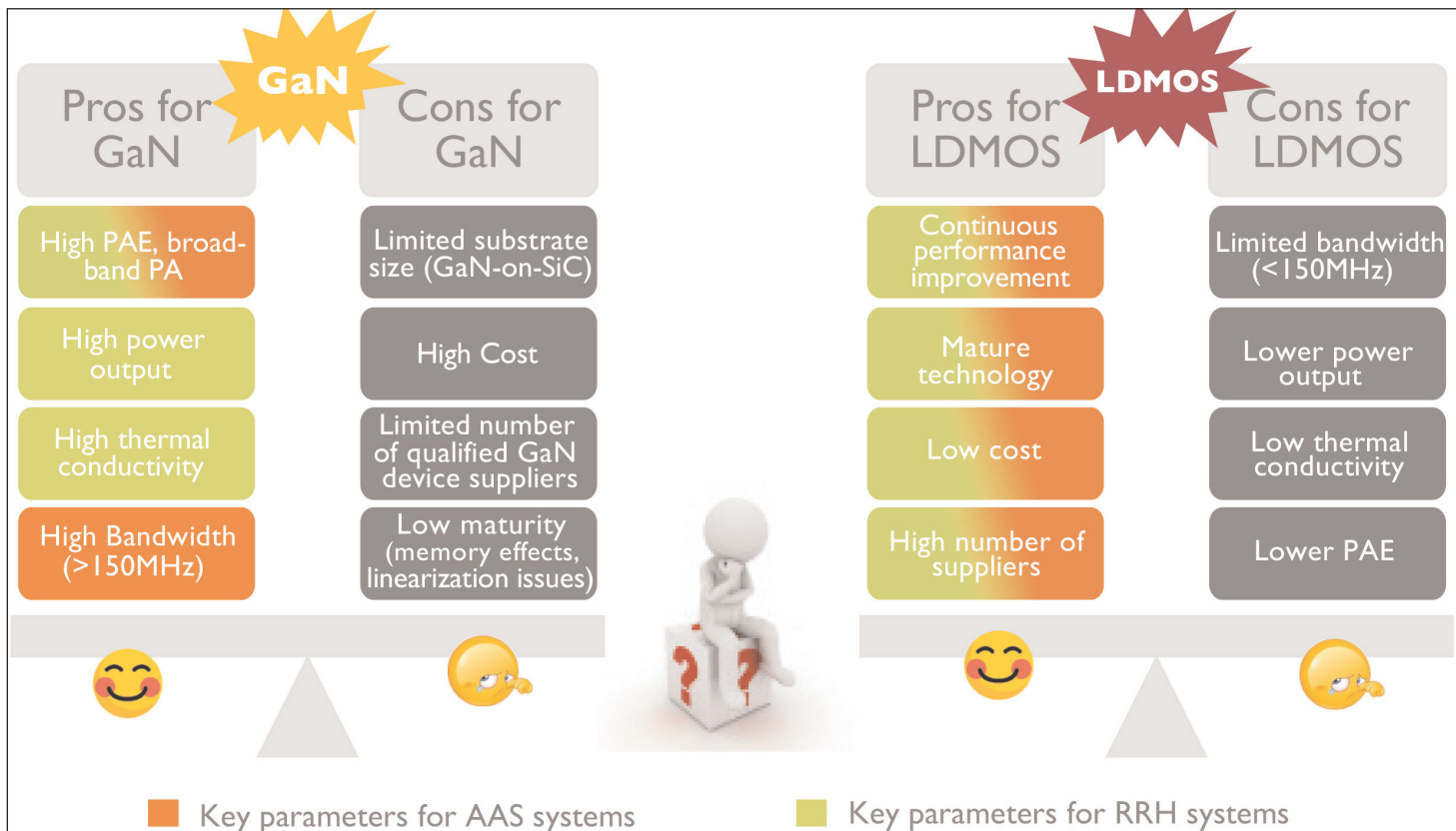
US-China trade war also makes it more urgent for Huawei and ZTE to have domestic suppliers.

"According to the industry feedback, despite the virus outbreak, leading Chinese telecom operators' 5G construction goals remain unchanged and development continues," notes Dogmus. The virus outbreak is therefore likely to have minor consequences for GaN deployment in 2020. "We could also expect a market adjustment starting from second-half 2020 in China as

well as the rest of the world," he concludes.

The GaN-based military market will likely follow the same trend, predicts Yole. The firm expects only minor changes in the long term, as the defense market is 'on demand'. However, in the short term, some disruptions to the supply chain may slow the global military market. ■

www.i-micronews.com/products/gan-rf-market-applications-players-technology-and-substrates-2020



Technology choice for macro sites: competitive analysis between GaN and LDMOS.

Dual-layer silicon nitride for threshold engineering gallium nitride transistors

A positive shift in threshold voltage has been achieved alongside reduced off-state leakage while maintaining on-current.

Researchers in China, Hong Kong, USA and Canada have used two silicon nitride (SiN_x) layers on gallium nitride (GaN) high-electron-mobility transistors (HEMTs) to push the threshold 1V in the positive direction, while reducing off-state leakage and maintaining on-current [Wei-Chih Cheng et al, *Semicond. Sci. Technol.*, vol35, p045010, 2020].

The dual-layer SiN_x acts as a stressor, depleting the two-dimensional electron gas (2-DEG) channel under the gate, and as passivation to reduce off-state leakage through the aluminium gallium nitride (AlGaN) barrier layer.

GaN HEMTs are being developed for high-voltage, high-density, high-frequency power switching and radio-frequency (RF) wireless transmission amplification. Although the presented devices were all normally-on (depletion-mode), more positive threshold voltages could eventually lead to normally-off (enhancement-mode) transistors, which reduce power consumption and allow fail-safe high-voltage operation.

The team involved researchers from Southern University of Science and Technology (SUSTech) in China, Hong Kong University of Science and Technology

(HKUST), Washington State University in the USA, University of British Columbia in Canada, GaN Device Engineering Technology Research Center of Guangdong in China, and Key Laboratory of the Third Generation Semi-conductor in China.

The researchers comment: "This V_{th} increase without recess etching processes or any observable compromises of the gate leakage, DC and RF amplification performance supports strain engineering as an effective approach in pursuing enhancement-mode AlGaN/GaN HEMTs for RF applications."

The epitaxial material used for the transistors was grown by metal-organic chemical vapor deposition (MOCVD) on 6-inch-diameter $\langle 111 \rangle$ silicon at Enkris Semiconductor. The devices (Figure 1) were electrically isolated using inductively couple plasma mesa etching. Annealed titanium/aluminium/titanium/gold formed the ohmic source-drain contacts. The gate consisted of patterned nickel/gold.

The two layers of silicon nitride (SiN_x) were deposited using dual-frequency plasma-enhanced chemical vapor deposition (PECVD). The low-stress passivation layer has an unintentional tensile stress of 0.3GPa.

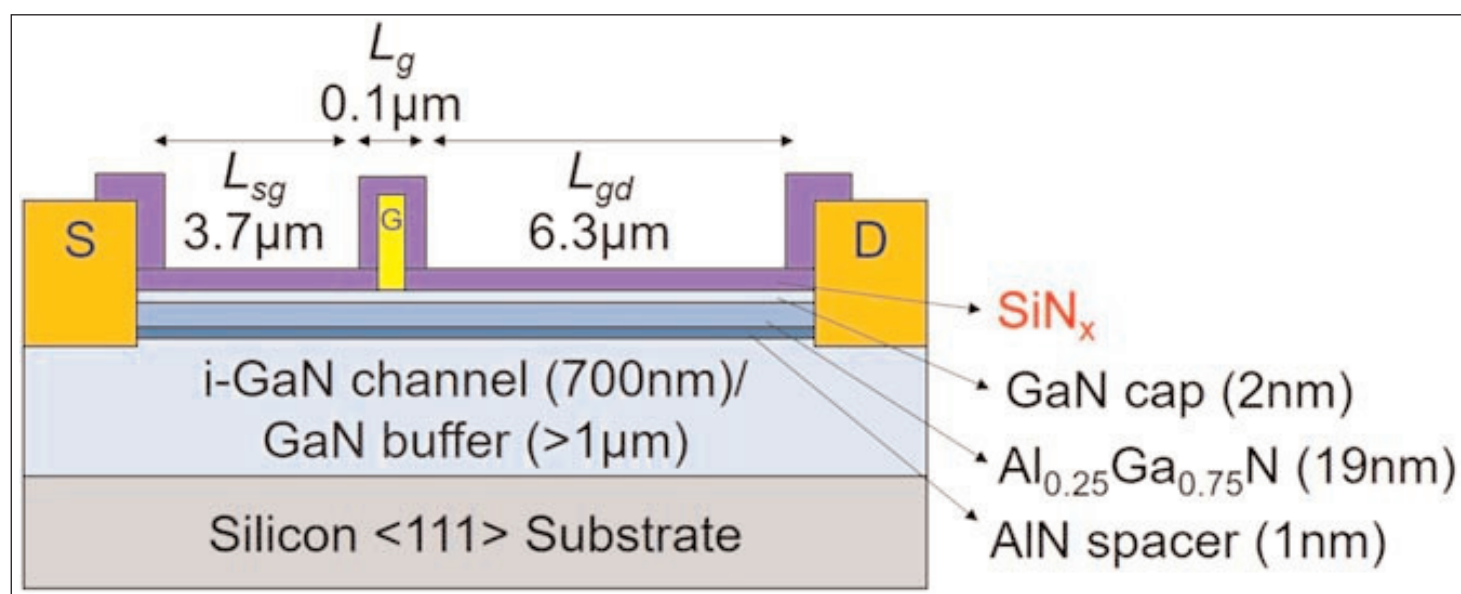


Figure 1. Device structure of AlGaN/GaN HEMT showing gate (L_g), source-to-gate (L_{sg}), and gate-to-drain (L_{gd}) lengths/spacings. Channel consisted of unintentionally doped GaN (i-GaN).

The layer used a process avoiding the low-frequency plasma excitation step, to reduce surface damage from nitrogen ion bombardment. The addition of low-frequency plasma excitation for the second layer produced a high-compressive-stress -1GPa film.

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

Simulations suggested that the increased threshold derived from electron depletion under the gate caused by the applied compressive stress counteracting the piezoelectric effects of the AlGaIn barrier. The tensile stress of the passivation layer only added a negligible amount of electron accumulation, according to the model.

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

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

The researchers attribute the good performance of the combined stressor/passivation HEMT process to the avoidance of surface damage in the first PECVD step. Surface damage also adversely affected the off-current (I_{off}) in the stressed devices without passivation. Adding passivation thicker than 7nm reduced the off-current leakage even below that of the BSL device.

The team summarizes: "From the above data, the devices with 14nm interlayers had the best performance (comparable DC and RF amplification performance,

one to three orders of magnitude lower I_{off} and 1V higher V_{th} compared with the baseline devices)."

The researchers also produced micron-scale devices, with $2\mu\text{m}$ gate and $10\mu\text{m}$ gate-drain, that were expected to have less effective stressing, which was confirmed by the performance being similar with respect to the BSL architecture in terms of off-current leakage. ■

<https://doi.org/10.1088/1361-6641/ab73ea>

<http://en.enkris.com>

Author: Mike Cooke

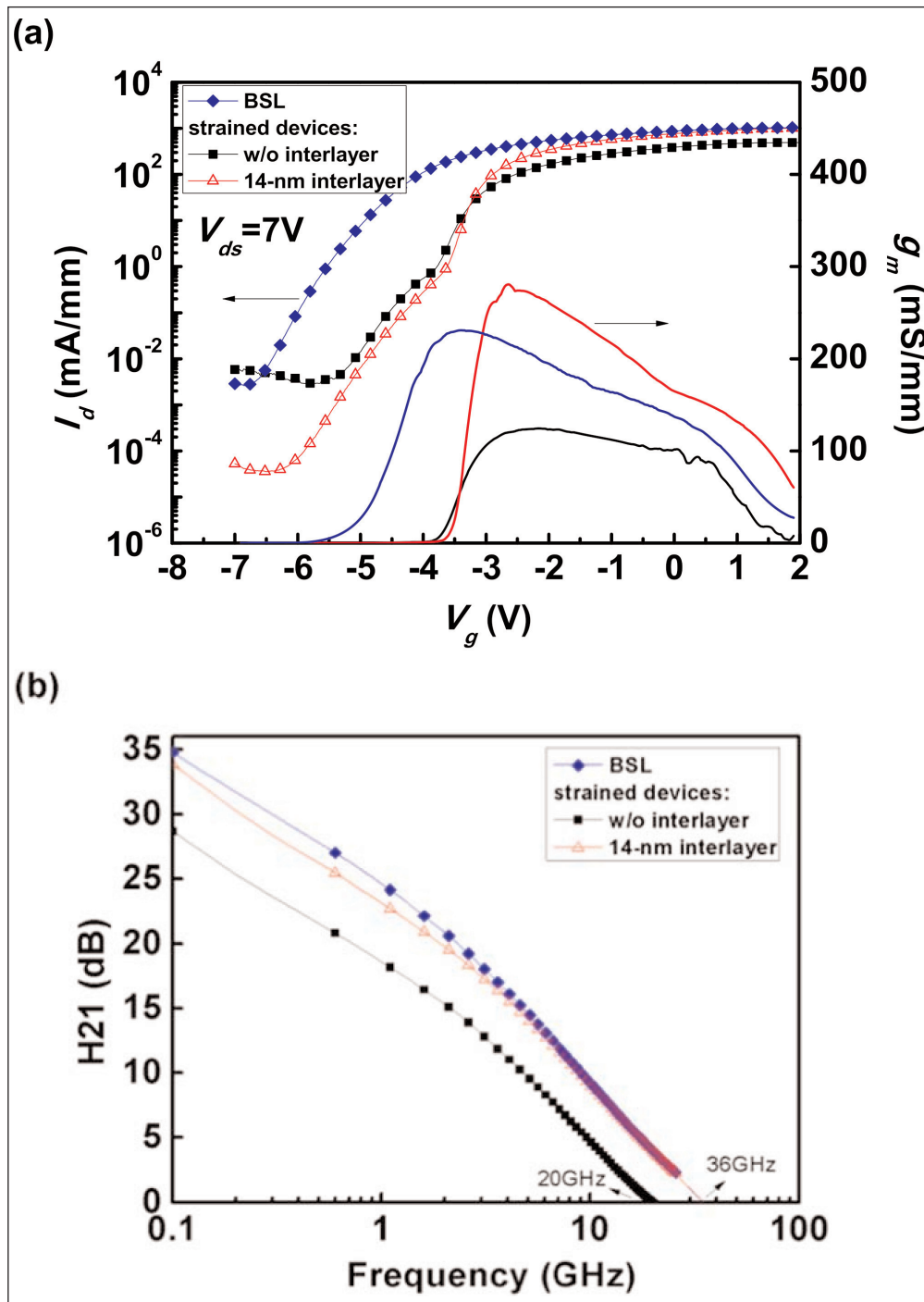


Figure 2. (a) Transfer characteristics of BSL and strained devices at 7V drain bias. (b) H21 current gain of BSL and strained devices biased to 7V drain and 1V above gate threshold.

Smartphone production falls 10% year-on-year in Q1 and to fall a record 16.5% in Q2

TrendForce has cut its forecast for global annual smartphone production to **1.24 billion units, down 11.3%, given the weakening end-product demand.**

The global COVID-19 pandemic in 2020 has brought about the greatest magnitude of declines in the smartphone market in recent years, according to market research firm TrendForce. Global smartphone production for first-quarter 2020 fell by 10% year-on-year to about 280 million units, the lowest in five years, due to pandemic-induced disruptions across the supply chain, such as delayed work resumption and labor/material shortages, which caused low factory capacity utilization rates.

There are now improvements to both the supply chain and the work resumption statuses of manufacturing and assembly lines, but the pandemic is now making its effects felt on the demand side of the smartphone market by tanking major economies worldwide. Global production for Q2/2020 is forecasted to see a year-on-year drop of 16.5% to 287 million units, the largest decline on record for a given quarter. TrendForce forecasts total annual production of 1.24 billion units, an 11.3% decrease year-on-year.

Vivo the only top-six brand to grow in Q1

Q1/2020 leader Samsung will experience constrained growth this year even without the emergence of COVID-19, says TrendForce. In addition to the market saturation, Chinese brands are exerting continuous pressure on Samsung's presence in the Southeast Asian and Indian markets by the day. Most of Samsung's smartphone assembly lines are located in Vietnam and India, and the firm has only about 2% of the market share for smartphones in China. Its production was thus not significantly affected by issues related to the disease during the initial phase of the outbreak in China. Nevertheless, the rapid spread of the disease across North America and Europe in the later part of Q1/2020 compelled Samsung to lower its device output even as its factories were running as usual. The brand's production volume for Q1 was 65.3 million units, down 9.9% year-on-year. India's smartphone assembly lines have been suspended since late March due to the imposition of a national lockdown. Furthermore, the global economy has gone into a recession. Samsung's smartphone production for Q2/2020 will hence fall

by 10.7% quarter-to-quarter to 58.3 million units, estimates TrendForce.

Ranked second by production volume in Q1/2020, Huawei was able to have its device assembly lines resume work soon after the Lunar New Year holiday. This brand has seen a steep decline in overseas sales due to its new devices being excluded from Google Mobile Services. Nevertheless, demand from China (its primary market) has started to recover. With the support of domestic demand, Huawei's smartphone production for Q1/2020 came to 46 million units, in line with TrendForce's earlier projection. If China's economy continues to improve, Huawei's production for Q2 may register quarter-on-quarter growth to about 48 million units. Huawei is sticking with its plan of making a push for its 5G smartphones this year, but 4G models will still account for most of its first-half 2020 smartphone output, and Huawei is also holding a significant inventory of 4G models. So, Huawei's greatest challenge at present is to simultaneously develop an effective campaign to promote the latest 5G smartphones and sell off the existing stock of 4G smartphones.

Prior to the onset of COVID-19, TrendForce had originally expected Apple to once again reach annual production of 200 million units, due to the release of five new models this year and the phasing out of the popular iPhone 6s series by the seasonal smartphone replacement cycle. However, Apple fell victim to the influence of the coronavirus pandemic, resulting in reduced production of its iPhone lineups this year. In Q1/2020, iPhone production fell by 8.7% year-on-year to 37.9 million units, due to labor and material shortages following the post-Lunar New Year work resumption, in turn ranking Apple in third place. As the firm releases the new iPhone SE with a consumer-friendly price tag in Q2, quarterly iPhone production is expected to stay relatively close to Q1 figures, reaching 36 million units. Apple is still planning to release four new 5G handsets in second-half 2020, but whether the pandemic's influence will weaken the demand for iPhones going forward remains a noteworthy concern, since iPhones sell at a relatively high retail price, and the iPhone's primary sales regions are the European and US markets, which

are in the midst of dealing with COVID-19.

For fourth-ranked Xiaomi, overseas markets account for over 70% of its sales. As these markets were unaffected by the Lunar New Year, Xiaomi rapidly expanded production capacity, following its domestic work resumption, to meet demand from overseas channels. But Xiaomi also had to contend with industry-wide issues of labor and material shortages, resulting in lower-than-expected capacity utilization of its production lines. The firm registered Q1/2020 production of 24.5 million units, flat with Q1/2019. TrendForce expects the Q2/2020 acceleration of COVID-19 in India and Indonesia, both of which are major sales regions for Xiaomi, to impact their quarterly smartphone demand and lead to a 10.7% decrease year-on-year in Xiaomi's Q2 production, to 27.5 million units. The pandemic is projected to have a greater impact on Xiaomi relative to other Chinese brands that rely primarily on domestic sales. In response, Xiaomi will aim to gain a competitive advantage by pricing its 5G handsets for low gross margins, in an effort to capture a greater share of the Chinese market, in turn making up for the shortfall in overseas sales.

OPPO (including OnePlus, OPPO, and Realme) and Vivo, ranked fifth and sixth respectively, benefitted from increased overseas orders, but their capacity utilization rates have been sluggish following post-Lunar New Year work resumption. OPPO posted Q1 production volume of 24 million units, a 10.4% drop year-on-year. On the other hand, Vivo had traditionally maintained conservative production plans during past first quarters, so the base period for year-on-year comparisons with Q1/2020 is relatively low. Vivo's production volume in Q1/2020 grew by 5.5% year-on-year to 23 million units, making it the only smartphone brand in the top six exhibiting year-on-year growth, against the overall trend of declines. TrendForce has lowered its production forecast for Q2 in light of national lockdowns in Southeast Asia and India starting in March: 30 million and 24.5 million units for OPPO and Vivo, respectively, with each brand seeing year-on-year declines of more than 14%.

Q1/2020–Q2/2020 market share/production volume forecast for top six smartphone brands.

| Company | Q1/2020 | | Q2/2020(e) | |
|-------------------------------|---------|--------------|------------|--------------|
| | Rank | Market share | Rank | Market share |
| Samsung | 1 | 23.3% | 1 | 20.3% |
| Huawei | 2 | 16.4% | 2 | 16.7% |
| Apple | 3 | 13.5% | 3 | 12.6% |
| Xiaomi | 4 | 8.8% | 5 | 9.6% |
| OPPO | 5 | 8.6% | 4 | 10.5% |
| Vivo | 6 | 8.2% | 6 | 8.5% |
| Total units (millions) | | 279.9 | | 286.8 |

Annual 5G smartphone production to reach 200 million, depending on Chinese market

The pandemic's impact prompted governments to prioritize disease prevention and stabilization. Furthermore, consumers generally have a speculative attitude towards purchasing 5G handsets. These two factors diminished the smartphone market's momentum of transitioning from 4G into 5G in first-half 2020.

In second-half 2020, if the Chinese government stays the course in commercializing 5G and mid-range 5G chips are successfully supplied to the market, the Chinese smartphone market will then see increased incentive to transition into 5G, while also resulting in consumer-friendly retail prices for 5G handsets.

At the moment, as brands fight over 5G market shares, the forecasted annual 5G smartphone production volume remains about 200 million units, with a 16% penetration rate into the overall smartphone market. In particular, Chinese brands have over 60% of 5G smartphone market share, with the domestic Chinese market as their primary sales region. This means that the penetration rate of 5G handsets into the overall smartphone market will depend heavily on feedback from the Chinese market. However, the penetration rate of 5G smartphones does not absolutely reflect the availability of 5G networks, which will depend on the construction of 5G base stations. ■

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7 Wafer processing materials

Air Products and Chemicals Inc

7201 Hamilton Blvd.,
Allentown, PA 18195, USA
Tel: +1 610 481 4911
www.airproducts.com/compound

Praxair Electronics

(see section 5 for full contact details)

8 Wafer processing equipment

EV Group

DI Erich Thallner Strasse 1,
St. Florian/Inn, 4782,
Austria
Tel: +43 7712 5311 0
Fax: +43 7712 5311 4600
www.EVGroup.com

Logitech Ltd

Erskine Ferry Road,
Old Kilpatrick,
near Glasgow G60 5EU,
Scotland, UK
Tel: +44 (0) 1389 875 444
Fax: +44 (0) 1389 879 042
www.logitech.uk.com

Plasma-Therm LLC

(see section 6 for full contact details)

SAMCO International Inc

532 Weddell Drive,
Sunnyvale, CA,
USA
Tel: +1 408 734 0459
Fax: +1 408 734 0961
www.samcointl.com

SPTS Technology Ltd

Ringland Way, Newport NP18 2TA,
UK

Tel: +44 (0)1633 414000

Fax: +44 (0)1633 414141

www.spts.com

SUSS MicroTec AG

Schleißheimer Strasse 90,
85748 Garching,

Germany

Tel: +49 89 32007 0

Fax: +49 89 32007 162

www.suss.com

Veeco Instruments Inc

(see section 6 for full contact details)

9 Materials & metals

Goodfellow Cambridge Ltd

Ermine Business Park,
Huntingdon,
Cambridgeshire PE29 6WR,
UK

Tel: +44 (0) 1480 424800

Fax: +44 (0) 1480 424900

www.goodfellow.com

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Goodfellow supplies small quantities of metals and materials for research, development, prototyping and specialised manufacturing operations.

10 Gas and liquid handling equipment

Air Products and Chemicals Inc

(see section 7 for full contact details)

Cambridge Fluid Systems

12 Trafalgar Way, Bar Hill,
Cambridge CB3 8SQ,
UK

Tel: +44 (0)1954 786800

Fax: +44 (0)1954 786818

www.cambridge-fluid.com

CS CLEAN SOLUTIONS AG

Fraunhoferstrasse 4,
Ismaning, 85737,
Germany

Tel: +49 89 96 24000

Fax: +49 89 96 2400122

www.csclean.com

SAES Pure Gas Inc

4175 Santa Fe Road,
San Luis Obispo, CA 93401,
USA

Tel: +1 805 541 9299

Fax: +1 805 541 9399

www.saesgetters.com

11 Process monitoring and control

Conax Technologies

2300 Walden Avenue,
Buffalo, NY 14225,
USA

Tel: +1 800 223 2389

Tel: +1 716 684 4500

E-mail: conax@conaxtechnologies.com

www.conaxtechnologies.com



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k-Space Associates Inc

2182 Bishop Circle
East, Dexter, MI 48130,
USA

Tel: +1 734 426 7977

Fax: +1 734 426 7955

www.k-space.com

KLA-Tencor

One Technology Dr,
1-2221I, Milpitas,
CA 95035,
USA

Tel: +1 408 875 3000

Fax: +1 408 875 4144

www.kla-tencor.com

LayTec AG

Seesener Str.
10-13,
10709 Berlin,
Germany

Tel: +49 30 89 00 55 0

Fax: +49 30 89 00 180

www.laytec.de



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WEP (Ingenieurbüro Wolff für Elektronik- und Programmentwicklungen)

Bregstrasse 90,
D-78120 Furtwangen im
Schwarzwald, Germany

Tel: +49 7723 9197 0

Fax: +49 7723 9197 22

www.wepcontrol.com

12 Inspection equipment

Bruker AXS GmbH

Oestliche Rheinbrueckenstrasse 49,
Karlsruhe, 76187, Germany

Tel: +49 (0)721 595 2888

Fax: +49 (0)721 595 4587

www.bruker-axs.de

13 Characterization equipment

J.A. Woollam Co. Inc.

645 M Street Suite 102,
Lincoln, NE 68508, USA

Tel: +1 402 477 7501

Fax: +1 402 477 8214

www.jawoollam.com

Lake Shore Cryotronics Inc

575 McCorkle Boulevard,
Westerville, OH 43082, USA

Tel: +1 614 891 2244

Fax: +1 614 818 1600

www.lakeshore.com

14 Chip test equipment

Keithley Instruments Inc

28775 Aurora Road,
Cleveland, OH 44139, USA

Tel: +1 440.248.0400

Fax: +1 440.248.6168

www.keithley.com

15 Assembly/packaging materials

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

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

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

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

16 Assembly/packaging equipment

Ismeca Europe Semiconductor SA
Helvetie 283, La Chaux-de-Fonds,
2301, Switzerland
Tel: +41 329257111
Fax: +41 329257115
www.ismeca.com

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

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

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

17 Assembly/packaging foundry

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

18 Chip foundry

Compound Semiconductor Technologies Ltd
Block 7, Kelvin Campus,
West of Scotland, Glasgow,
Scotland G20 0TH, UK
Tel: +44 141 579 3000
Fax: +44 141 579 3040
www.compoundsemi.co.uk

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

19 Facility equipment

MEI, LLC
3474 18th Avenue SE,
Albany, OR 97322-7014,
USA
Tel: +1 541 917 3626
Fax: +1 541 917 3623
www.marlerenterprises.net

20 Facility consumables

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

21 Computer hardware & software

Ansoft Corp
4 Station Square,
Suite 200,
Pittsburgh, PA 15219,
USA
Tel: +1 412 261 3200
Fax: +1 412 471 9427
www.ansoft.com

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

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

22 Used equipment

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

23 Services

Henry Butcher International
Brownlow House, 50-51
High Holborn, London WC1V 6EG,
UK
Tel: +44 (0)20 7405 8411
Fax: +44 (0)20 7405 9772
www.henrybutcher.com

M+W Zander Holding AG
Lotterbergstrasse 30,
Stuttgart,
Germany
Tel: +49 711 8804 1141
Fax: +49 711 8804 1950
www.mw-zander.com

24 Consulting

Fishbone Consulting SARL

8 Rue de la Grange aux Moines,
78460 Choisel,
France
Tel: + 33 (0)1 30 47 29 03
E-mail: jean-luc.ledys@neuf.fr

25 Resources

Al Shultz Advertising Marketing for Advanced Technology Companies

1346 The Alameda, 7140 San Jose,
CA 95126, USA
Tel: +1 408 289 9555
www.alshultz.com

SEMI Global Headquarters

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

Yole Développement

69006 Lyon, France
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www.yole.fr

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14–19 June 2020

(postponed to 4–9 July 2021)

ICMOVPE XX:

20th International Conference on Metal Organic Vapor Phase Epitaxy

Stuttgart/Ulm, Germany

E-mail: info@icmovpexx.eu

www.icmovpexx.eu

14–19 June 2020

2020 Symposia on VLSI Technology & Circuits – 'The Next 40 Years of VLSI for Ubiquitous Intelligence'

To be held as a virtual conference

E-mail: d.artis@ieee.org

www.vlisisymposium.org

21–26 June 2020

(postponed to August – now a virtual event)

Microwave Week, including:

IEEE MTT-S International Microwave Symposium (IMS 2020)

Radio Frequency Integrated Circuits Symposium (RFIC 2020)

Automatic Radio-Frequency Techniques Group Conference (ARFTG)

Los Angeles, CA, USA

E-mail: e.niehenke@ieee.org

www.ims-ieee.org

27–29 June 2020

SEMICON China 2020

Shanghai New International Expo Centre (SNIEC) and Kerry Hotel, Shanghai, China

E-mail: semichina@semi.org

www.semiconchina.org/en

21–23 July 2020

SEMICON West 2020 – now a virtual event

Moscone Center, San Francisco, CA, USA

E-mail: semiconwest@semi.org

www.semiconwest.org

22–25 July 2020

International Congress on Advanced Materials Sciences & Engineering (AMSE-2020)

Vienna, Austria

E-mail: eve@istci.org

www.istci.org/amse2020

28–30 July 2020 (postponed from 5–7 May)

PCIM Europe 2020

(Power Conversion and Intelligent Motion)

Nuremberg Exhibition Centre (Messe Nürnberg), Germany

E-mail: pcim@mesago.com

<https://pcim.mesago.com/nuernberg/en.html>

23–27 August 2020

SPIE Optics + Photonics 2020

San Diego Convention Center, San Diego, CA, USA

E-mail: customerservice@spie.org

https://spie.org/Optics_Photonics

23–28 August 2020

International Workshop on Nitride Semiconductors (IWN 2020)

Maritim Hotel Berlin, Germany

E-mail: iwn2020@conventus.de

www.iwn2020.org

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23–28 August 2020

9th International Conference on Optical, Optoelectronic and Photonic Materials and Applications (ICOOPMA)

University of Pardubice, Czech Republic

E-mail: info@icoopma.com

www.icoopma.com

24–25 August 2020

TSMC North America Technology Symposium and Open Innovation Platform Forum

Santa Clara Convention Center, Santa Clara, CA, USA

E-mail: press@tsmc.com

www.tsmc.com/english/newsEvents/events.htm

3–6 September 2020 (postponed from 17–21 May)

32nd International Symposium on Power Semiconductor Devices and ICs (ISPSD 2020)

Hofburg Palace, Vienna, Austria

E-mail: ispsd2020@guarant.cz

www.ispsd2020.com

7–11 September 2020

22nd European Conference on Power Electronics and Applications (EPE 2020 ECCE Europe)

Lyon, France

E-mail: info@epe2020.com

www.epe2020.com

9–11 September 2020

22nd China International Optoelectronic Exposition (CIOE 2020)

Shenzhen World Exhibition & Convention Center, China

E-mail: cioe@cioe.cn

www.cioe.cn/en

13–17 September 2020

(postponed to 24–28 October 2021)

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

13–18 September 2020

23rd European Microwave Week (EuMW 2020)

Utrecht, The Netherlands

E-mail: eumwreg@itnint.com

www.eumweek.com

10–13 November 2020

SEMICON Europa 2020

Munich, Germany

E-mail: SEMICONEuropa@semi.org

www.semiconeuropa.org

6–8 December 2020

2020 IEEE 51st Semiconductor Interface Specialists Conference (SISC)

San Diego, CA, USA

E-mail: mpasslack@ieeesisc.org

www.ieeesisc.org

6–10 December 2020

(postponed from 20–24 September)

46th European Conference on Optical Communication (ECOC 2020)

Brussels Expo, Brussels, Belgium

E-mail: info@ecoc2020.org

www.ecoco2020.org

14–16 December 2020

IEEE International Electron Devices Meeting (IEDM 2020)

Hilton San Francisco and Towers, San Francisco, CA, USA

Paper submission deadline: 24 July

E-mail: info@ieee-iedm.org

www.ieee.org/conference/iedm

17–19 December 2020

SEMICON Japan 2020

Tokyo Big Sight, Tokyo, Japan

E-mail: semicon@sakurain.co.jp

www.semiconjapan.org/en

21–25 March 2021

IEEE Applied Power Electronics Conference and Exposition (APEC 2021)

Phoenix, AZ USA

E-mail: registration@apec-conf.org

www.apec-conf.org

28 March – 1 April 2021

Optical Networking and Communication Conference & Exhibition (OFC 2021)

Moscone Center, San Francisco, CA, USA

E-mail: OFC@csreg.zohodesk.com

www.ofcconference.org

15–16 April 2021

EPIC Annual General Meeting 2021

Radisson Blu Hotel Lietuva, Vilnius, Lithuania

E-mail: neringa.norbutaite@epic-assoc.com

www.epic-assoc.com/epic-annual-general-meeting-2020

20–22 April 2021

Components for Military & Space Electronics Conference & Exhibition (CMSE 2021)

Four Points by Sheraton (LAX) Los Angeles, CA, USA

E-mail: info@tjgreenllc.com

www.tjgreenllc.com/cmse



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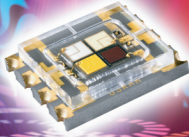


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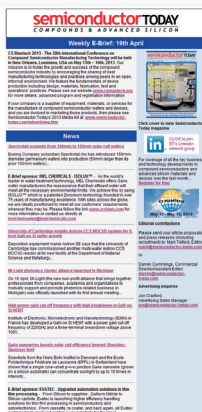


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