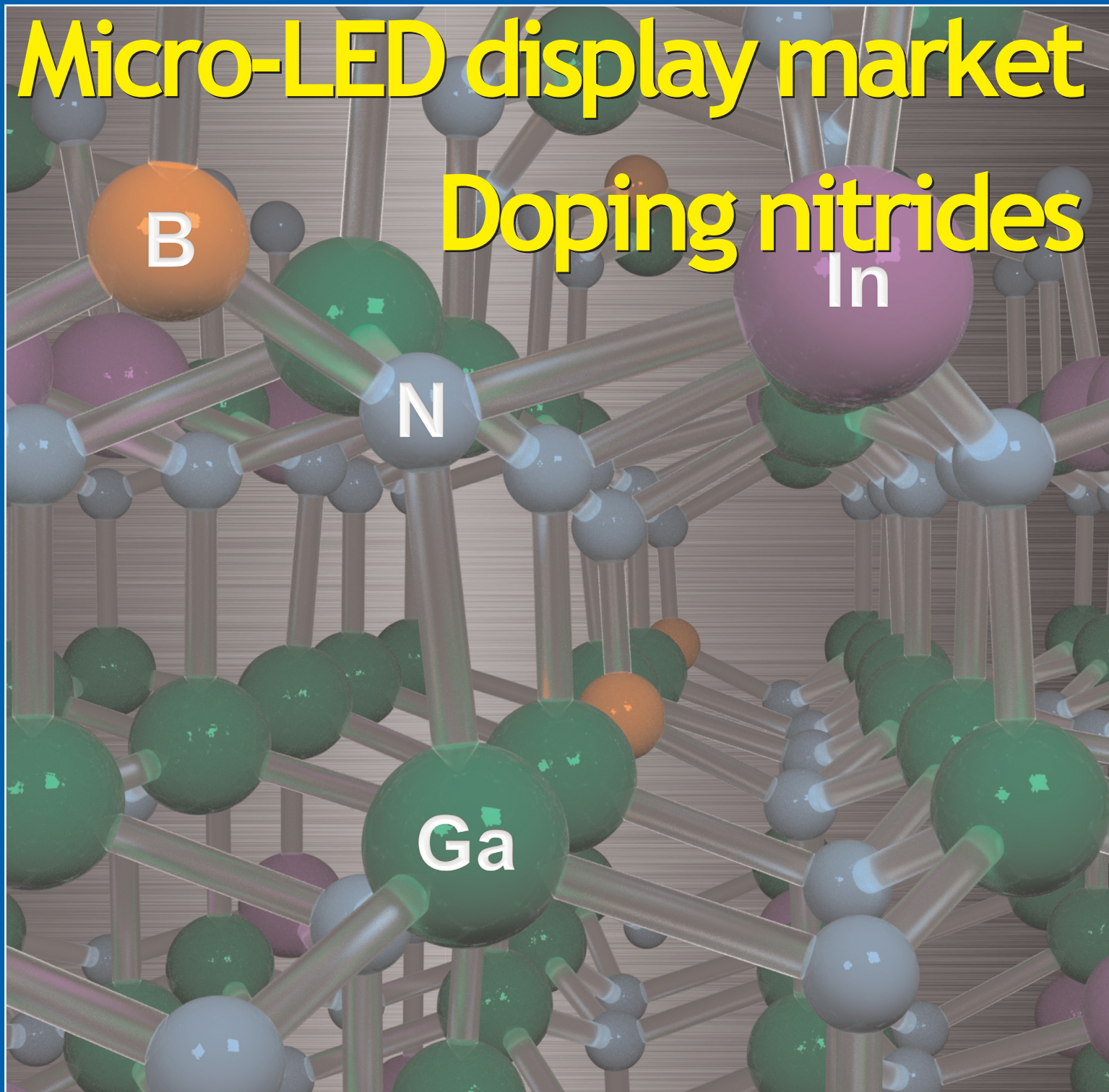


Micro-LED display market

Doping nitrides



IQE to buy 40-60 MOCVD systems • Lumileds opens Shanghai center
Osram's Malaysia LED chip fab begins operation



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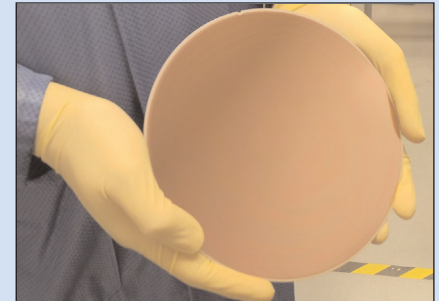
Contact us at www.veeco.com/EPIK700 to learn more.



Veeco's New TurboDisc EPIK700 GaN MOCVD System

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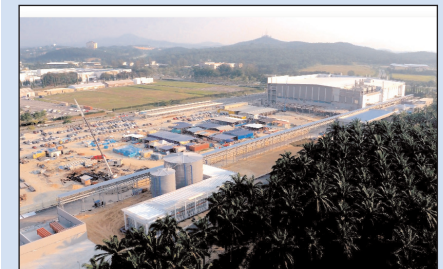
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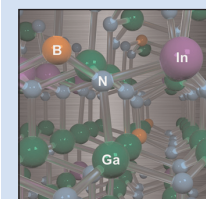
p28 Kyma has used its new K200 HVPE growth tool to produce 200mm HVPE GaN-on-QST templates.



p38 The opening of Lumileds' new office and innovation center in Shanghai.



p40 Osram's new LED chip factory in Kulim, Malaysia, which has now begun operation.



Cover: Crystal structure of BInGaN alloy. University of Michigan researchers predict that incorporating boron into the InGaN active region of nitride LEDs reduces or even eliminates the lattice mismatch with the underlying GaN layers while keeping the emission wavelength about the same. **p58**

Micro-LEDs display promise

On pages 60–63 we cover the topic of mini-LEDs and micro-LEDs, focusing on technical progress that has been made and the manufacturing challenges being faced that are impacting on which display applications are economically viable, made by whom, and when.

One firm driving demand is Samsung, which is set to unveil a 150-inch 'micro-LED TV' at January's Consumer Electronics Show in Las Vegas, for commercialization in 2018. However, the application of micro-LED displays in portable devices such as Apple smartphones will likely take longer, as the red-green-blue (RGB) LED chips must be definitively 'micro' (30µm or less, rather than the 100µm of mini-LEDs). Also, manufacturing processes need to be refined so they can separate epitaxial layers of RGB LEDs from their substrates and accurately transfer them en-masse onto a receiver substrate (e.g. glass or flexible polymer) at speeds that can compete with LCD display processing. Replacement of LCD technology by micro-LED-based displays is hence forecasted to be 3–5 years away.

A key enabler in economies of scale is a transition to larger-diameter substrates, e.g. from 4" to 6" wafers in the case of Taiwan's largest LED epiwafer and chip maker Epistar. Also, a strategic initiative has been completed in which the proprietary epitaxy technology of Germany's ALLOS has been transferred onto Veeco's Propel MOCVD system (launched in late 2014, targeting processing of GaN-based power electronic devices). The aim was to demonstrate how processing gallium nitride on silicon (GaN-on-Si) on 200mm-diameter wafers can enable blue/green micro-LED production on existing silicon production lines (see page 25).

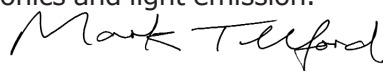
Also, presenting preliminary results for InGaN RGB LEDs applications at the Workshop on Ultra-Precision Processing for Wide Band-Gap Semiconductors (WUPP-2017) in early November was Australia's BluGlass, using its proprietary remote-plasma chemical vapor deposition (RPCVD) technology (see page 34). As well as accommodating 6" wafers, the firm's low-temperature technique targets deposition on substrates such as glass.

According to the University of Michigan, low temperature is also a benefit in incorporating boron into the InGaN active region of nitride LEDs, rather than the higher temperature required for incorporation into GaN (page 58). Compared with InGaN, BInGaN enables closer lattice matching to GaN substrate, allowing the growth of thicker active regions that are more efficient at emitting light at high power.

A method for growing thick layers rapidly is hydride vapor phase epitaxy (HVPE), which is one of the techniques (along with MOCVD and ALD) for which system maker SMI is recruiting scientists for product development (page 34). HVPE system maker Kyma has just demonstrated the growth of 10µm-thick GaN on MOCVD-grown QST (QROMIS Substrate Technology) template wafers, scaled up from the 150mm growth demonstrated in 2016 to Kyma's 200mm reactor commissioned this June (see page 28).

In addition to incorporating boron in InGaN LEDs, a team led by Finland's Aalto University has shown how doping GaN with beryllium (explored unsuccessfully in the late '90s as a better dopant than magnesium in LEDs) could increase GaN's efficiency in power electronics applications (page 16). Further, similarity to sodium and lithium doping in zinc oxide suggests this could be a universal property of light dopants substituting for heavy cations in compound semiconductors, possibly promising further avenues for efficiency improvement in both power electronics and light emission.

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GaN device market to grow at 4.6% CAGR to \$22.47bn in 2023

Opto to remain largest sector, but power devices growing fastest

The gallium nitride (GaN) device market will rise at a compound annual growth rate (CAGR) of 4.6% from \$16.5bn in 2016 to \$22.47bn in 2023, according to a report from MarketsandMarkets.

Major factors driving growth include the vast addressable market for GaN in consumer electronics and automotive, the wide-bandgap property of GaN material encouraging innovative applications, the success of GaN in RF power electronics, and growing adoption of GaN RF devices in military, defense and aerospace applications. However, the preference for silicon carbide (SiC) in high-voltage power semiconductor devices is expected to be a potential restraint for the overall GaN device market. This is expected to limit growth over the next few years.

The largest share of the GaN device market in 2016 comprised optoelectronic devices, due to their

wide application in consumer and enterprise, industrial, and automotive applications. GaN LEDs are widely used in laptop and notebook displays, mobile displays, projectors, TVs and monitors, signs and large displays, etc. The use of GaN-based LEDs for interior and exterior lighting such as headlights and signal lights, car interior lighting, fog lights, stop lights, and dome lights in the automotive industry has also contributed to the larger market size.

The market for GaN-based power devices is expected to grow significantly during the forecast period of 2017–2023 due to superior features such as minimum power loss, high-speed switching miniaturization, and high breakdown voltage compared with silicon-based power devices. Also, among the prime reasons for the faster growth are the large total addressable market (TAM) such as power distribution systems, indus-

trial systems, heavy electrical systems, turbines, heavy machinery, advanced industrial control systems, and electro-mechanical computing/computer systems, as well as several new clean-tech power applications — such as high-voltage direct current (HVDC), smart grid power systems, wind turbines, wind power systems, solar power systems, and electric vehicles and hybrid electric vehicles (EV/HEV).

The Asia-Pacific (APAC) region is expected to be the largest region in the GaN device market during the forecast period, due to rising demand for LEDs in various industries such as consumer and enterprise, industrial, and automotive applications. Further, electric vehicle charging and electric vehicle production markets, as well as increasing renewable energy generation, are driving the market in APAC.

www.marketsandmarkets.com

China LED lighting market to exceed \$24bn by end 2024

The China LED lighting market will exceed \$24bn by end 2024, forecasts Renub Research in a new report

Escalating urbanization, price cuts and local energy savings targets are making the technology more tempting. China's lighting industry has been on the rise, and the country has become a leading lighting consumer and producer.

Government backing

To promote high-efficiency LED lighting, the National Development and Reform Commission (NDRC) and China's Ministry of Finance (MOF) collaborated on interim measures concerning the administration of financial subsidies. Such initiatives are working, notes the report. In the current scenario, local govern-

ments are working more proactively than China's central government in implementing LED subsidies.

Guangdong Province comprises the largest part of China's LED industry and correspondingly receives the most subsidy. As of 2013, Foshan in Guangdong Province, Dongyuan, Zhongshan and many other cities have launched several projects to promote mass-market LED lighting products. In the meantime, the energy costs saved by LEDs are all being used to subsidize construction projects in Zhongshan city.

Since October 2012, China has banned the import and sale of all incandescent bulbs over 100W, and on 1 October 2016 it extended the ban to those over 15W.

Commercial segment dominant

The commercial segment dominates the China LED lighting market. Others such as residential, industrial and outdoor are also performing well. Moreover, the implementation of LED lighting standards in China should further shift lighting towards high-quality LED products.

Due to technology and innovation in LED lighting products, the average price of LED bulbs is gradually falling year-on-year and approaching that of conventional lightening products. So, demand for LED lighting products is expanding, particularly in the residential and commercial segments.

www.renub.com/china-led-lighting-market-size-volume-market-share-applications-companies-p.php



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Qorvo revenue grows a more-than-expected 28% quarter-to-quarter

Firm expects return to double-digit year-on-year growth in fiscal second-half year, and return to gross margin rise in March quarter

For fiscal second-quarter 2018 (to end-September 2017), Qorvo Inc of Greensboro, NC, USA (which provides core technologies and RF solutions for mobile, infrastructure and defense applications) has reported revenue of \$820.6m, down 5% on \$863.7m a year ago but up 28.2% on \$639.9m last quarter, and exceeding the expected 27% growth to \$800–820m.

Revenue for Mobile Products (MP) was \$630m, up 38% on \$456m last quarter, driven by growth at Qorvo's largest customer (which comprised 40% of revenue). Qorvo also supported the ramps of leading marquee smartphones and increased its dollar content on key customer programs. "We benefited from an improved demand environment in China with the launch of flagship devices at Huawei, Xiaomi, Oppo, Vivo and others," says president & CEO Bob Bruggeworth. "At Huawei, we supported the Mate 10 with BAW [bulk acoustic wave] filters, antenna tuners, RF front-end modules and our envelope tracking [ET] power management solution. At Xiaomi, we shipped more than \$9 of RF content, including our highly integrated RF Fusion products into their top-tier Mi Mix 2, and we were honored to receive their partnership award. We expect our design momentum at both accounts to continue in next-generation flagship models," he adds.

Revenue for Infrastructure & Defense Products (IDP) was a record \$190m, up 21% year-on-year, reflecting continued strength in defense (including advanced radars and other electronic warfare products) and in connectivity (including Wi-Fi and emerging Internet of Things applications). Specifically, IoT revenue grew by 50% year-on-year. In China, Qorvo saw strong demand supporting the deployment of

900MHz narrow-band IoT (NB-IoT) infrastructure with a broad product portfolio that optimizes performance and power consumption in high-volume low-power IoT applications. Meanwhile, gallium nitride (GaN) revenue doubled year-on-year.

On a non-GAAP basis, gross margin has grown further, from 42.8% a year ago and 47.3% last quarter to 47.4%, despite the negative impact of the after-effects of Hurricane Irma (which caused an isolated air contamination issue in the firm's Florida fab). "The operations team in Florida did a remarkable job to quickly identify the root cause and bring the fab back up without any customer impact," comments chief financial officer Mark Murphy. Excluding these costs, gross margin would have been above the 47.8% guidance. As expected, overall fab utilization weighed on margins, as well as an increase of low-band power amplifier duplexers (PAD) in the mix.

Operating expenses has been cut from \$172.9m a year ago and \$165.5m last quarter to \$158.2m (19.3% of sales), due to ongoing productivity efforts and spend timing. During the quarter, Qorvo took certain actions to reduce costs and improve operating efficiencies, including a head-count reduction program (involving about 300 people).

Gross margin has grown further... despite the negative impact of the after-effects of Hurricane Irma (which caused an isolated air contamination issue in the firm's Florida fab). The operations team in Florida did a remarkable job to quickly identify the root cause

Operating income was hence \$230.5m (28.1% of sales), up from \$137.4m last quarter and \$196.8m a year ago. Net income was \$198.4m (\$1.52 per diluted share, above the expected \$1.36–1.50), up from \$113.9m (\$0.87 per diluted share) last quarter and \$170.4m (\$1.29 per diluted share) a year ago.

Cash flow from operations more than doubled from \$104m last quarter to \$219.9m, while capital expenditure (CapEx) almost halved from \$124m to \$67.8m as Qorvo wrapped up recent expansions, tool conversions and other investments to support future growth. Free cash flow was hence \$152.1m. During the quarter, cash and cash equivalents therefore rose from \$512.6m to \$574.9m, despite repurchasing \$57m of stock.

"Our second quarter results exceeded expectations, driven by higher revenue and effective cost control," says chief financial officer Mark Murphy.

In IDP, in the September quarter Qorvo secured record design wins. In IoT specifically, these include an RF front-end module design win supporting the Tile tracker family, and multiple design wins for automotive IoT applications, supporting top automakers with content per car up to \$7.

In wireless infrastructure, Qorvo expanded its product portfolio to include a line of small-signal products that support the 600MHz band 71 (and secured design wins), making Qorvo the only supplier to address all 5G frequency bands from 600MHz through 39GHz.

Qorvo also secured multi-year design wins with a major defense contractor for high-power, high-efficiency GaAs components supporting several advanced radar applications. ➤

► “Qorvo’s technology portfolio and operating capabilities position us exceptionally well to address our customers’ LTE-Advanced and emerging 5G requirements as well as expanding IoT applications,” says Bruggeworth.

For fiscal third-quarter 2018 (to end-December 2017), Qorvo expects revenue to grow to \$830–850m, reflecting near-term demand for customers’ flagship models and continued strength in IDP. However, due to the effects of product mix, gross margin should rise only slightly to 47.5%. Nevertheless, operating expenses should remain flat at about \$158m. So, diluted EPS is expected to grow to \$1.60.

“Our outlook also reflects a recent event at a supplier. In mid-October, one of our laminate suppliers had a fire and shut down production,” notes Murphy. “We quickly launched a recovery plan to minimize the impact of the event. Thanks to close and collaborative

working relationships with customers and our other qualified suppliers and the exceptional efforts of our engineering, operations, quality and sales teams, we do not expect any major customer impacts,” he adds. Qorvo’s estimate of revenue and cost impacts of the event have been factored into the guidance.

For the remainder of fiscal 2018, Qorvo forecasts revenue to decline less than seasonally December to March (down only mid-single digits as a percentage). “In the second half, we expect a return to double-digit year-over-year growth, driven by the timing of flagship phone ramps and broad-based growth in IDP,” says Murphy. Specifically,

In the second half, we expect a return to double-digit year-over-year growth, driven by the timing of flagship phone ramps and broad-based growth in IDP

IDP is targeting double-digit year-on-year revenue growth across a broad set of customers in defense, base-station, automotive, smart home IoT, Wi-Fi and optical who require differentiated products with higher levels of integration, higher power, lower noise figure, better linearity and greater efficiency.

OpEx is forecast to be down in dollars from fiscal 2017, as Qorvo continues to drive towards its operating model of 20% of sales or lower. Also, CapEx should trend lower through the rest of the fiscal year, ending the full year below \$300m (less than 10% of sales). “Continued cost control and capital discipline will drive record second-half free cash flow,” Murphy believes.

“We expect gross margin expansion to resume in the March quarter and into next year, with improving mix, ongoing productivity efforts and increasing fab utilization,” concludes Murphy.

www.qorvo.com

Expanded 802.11ax portfolio for broader, faster, lower-cost Wi-Fi

Qorvo Inc of Greensboro, NC, USA (which provides core technologies and RF solutions for mobile, infrastructure and defense applications) has announced an expanded portfolio of 802.11ax products for Wi-Fi gateways, set-top boxes, routers and enterprise access points. The high-efficiency portfolio of integrated modules and advanced filters is said to improve Wi-Fi coverage, enables smaller end-products, and reduces costs for consumers, service providers and manufacturers.

“Qorvo’s advanced solutions are designed to help our customers maximize Wi-Fi capacity and data rates with 802.11ax, while reducing costs,” says Cees Links, general manager of Qorvo’s Wireless Connectivity business unit. “For manufacturers of high-performance Wi-Fi equipment, thermal issues can create significant design delays and additional expense due

to the need to add heat sinks and fans. Our high-efficiency portfolio reduces the need for thermal management, helping our customers design smaller, more attractive products without internal fans.”

Qorvo says that its bulk acoustic wave (BAW) filters allow full power output across all Wi-Fi channels, helping consumers receive reliable Wi-Fi service through the entire home. This helps to cut support costs. “About 40% of all operator service calls relate to poor Wi-Fi performance in the home,” Links says. “With improved coverage, operators can reduce expensive truck rolls and service calls, which cost an average of \$15–35 in addition to any repeater/extender hardware required,” he adds.

“Every operator is trying to get rid of Wi-Fi dead spots in the home and eliminate the associated customer care and helpdesk costs,” comments Peter White, CEO of

Rethink Technology Research. “Any technology that helps this is assured of a good reception in the market.”

802.11ax will greatly increase network capacity by supporting up to eight simultaneous data streams, each delivering up to 1.2Gbps, to connect many more devices at greater speeds. Qorvo’s broad 802.11ax portfolio includes 2.4GHz and 5GHz front-end modules (FEMs) and BAW filters. The portfolio’s high energy-efficiency FEMs reduce the thermal issues associated with supporting multiple-input multiple-output (MIMO) in Wi-Fi equipment, allowing manufacturers to reduce product size and cost. Qorvo says that its BAW band-edge and coexistence filters improve Wi-Fi quality of service and prevent interference with adjacent LTE frequencies.

www.qorvo.com/products/integrated-products/wifi

Skyworks' quarterly revenue grows 9% to record \$985m

For full-year fiscal 2017 (to 29 September), Skyworks Solutions Inc of Woburn, MA, USA has reported record revenue of \$3.65bn, up 11% on fiscal 2016's \$3.29bn.

For fiscal fourth-quarter 2017, revenue was a record \$984.6m (exceeding guidance of \$980m), up 9% on \$900.8m last quarter and up 18% on \$835.4m a year ago.

"Our market outperformance is being driven by new customers and content growth across an increasingly diverse set of end-market applications," says senior VP & chief financial officer Kris Sennesael.

Of total fiscal Q4 revenue, Broad Markets comprised 26% (exceeding \$250m), Integrated Mobile Systems comprised 64%, and Power Amplifiers 10%.

The three greater-than-10% customers were again Foxconn (approaching 40% of total revenue), Samsung (in the low teens) and Huawei (about 10%).

"Record results demonstrate our traction within the increasingly vibrant and profitable Mobile and IoT ecosystems," says president & CEO Liam K. Griffin. "We've significantly expanded the aperture of our design-win pipeline. Last quarter, we broadened our reach across all premier customers. Specifically, we powered Samsung's flagship Galaxy and Note LTE platforms with proprietary DRx and SkyOne solutions, while adding GPS and DC/DC converters. We enabled Huawei's newest premium smartphones with low-, mid- and high-band SkyOne, Wi-Fi, carrier aggregation, and proprietary SkyBlue power management solutions. We leveraged SkyLiTE and SkyOne across new platforms at Oppo, Vivo, Xiaomi, and Motorola."

"Across our broad markets, we delivered fully integrated Zigbee and ISM [industrial, scientific & medical] modules for Bosch's home security and Cisco's smart street-lighting systems," Griffin continues. "We commenced volume production of in-vehicle telematics at Hyundai, and launched wireless networking

engines within DirecTV's 4K Genie receivers. We also supported Sonos' latest hi-fi speaker featuring Amazon's Alexa virtual assistant technology," he adds. "We introduced next-generation 802.11ax Wi-Fi engines for home and commercial environments, enabling a fourfold increase in speed and supporting up to 50 simultaneous users. We secured connectivity wins at DJI for virtual reality and drone applications, supplied precision GPS and antenna tuning for Fitbit's newest smart watches, and we unveiled high-power solutions with leading base-station customers for 5G massive MIMO deployments."

On a non-GAAP basis, gross margin was 51%, level with a year ago but up from 50.7% last quarter, growing by 30 basis points for a second consecutive quarter. However, full-year gross margin of 50.8% is still down slightly on 2016's 51%.

Although up from \$107.5m a year ago, operating expenses of \$123m are level with last quarter while being cut from 13.7% to 12.5% of revenue.

Net income has risen further, from \$277.6m (\$1.47 per diluted share) a year ago and \$292.7m (\$1.57 per diluted share) last quarter to \$338.8m (\$1.82 per diluted share, better than the forecasted \$1.75). Full-year net income has risen from \$1.07bn (\$5.57 per diluted share) for 2016 to \$1.2bn (a record \$6.45 per diluted share) for 2017.

Although down on \$455m a year ago, cash flow from operations has risen from \$314.1m last quarter to \$425.4m for fiscal Q4/2017. CapEx (capital expenditure) was \$85m. Dividends paid were \$58.9m, and Skyworks repurchased 1 million shares of common stock for \$101.8m.

For the full year, cash flow from operations has risen from \$1.1bn for 2016 to \$1.47bn for 2017. CapEx has risen from \$189.3m to \$303.3m. So, free cash flow was \$1.2bn (32% free cash flow margin), above the \$1.1bn target. Skyworks returned 55% of the free cash flow to shareholders (exceeding the tar-

geted 40–50%), comprising \$214.6m in dividend payments and \$432m in repurchasing 4.6 million shares.

Overall, Skyworks' cash balance has hence risen from \$1.084bn at the end of fiscal 2016 and \$1.444bn at the end of fiscal Q3/2017 to \$1.617bn at the end of fiscal 2017, while the firm still has no debt.

Skyworks' board has declared a cash dividend of \$0.32 per share, payable on 12 December, to stockholders of record at the close of business on 21 November.

For fiscal Q1/2018 (to end-December 2017), Skyworks expects revenue to rise 7% sequentially and 15% year-on-year to \$1.05bn.

Gross margin should rise by 0–50 basis points to 51–51.5% (making progress towards the 53% target), driven by: (1) greater revenue (since more volume helps with size and scale and fixed-cost absorption); (2) continuing to drive operational efficiencies across all operations and with third-party suppliers; and (3) continuing to make good progress on filter insourcing (a quarter ago, about 50% of filters were produced in-house and 50% purchased from third parties, but Skyworks is making good progress towards a 75%/25% allocation in early 2018).

Despite expecting operating expenses to rise to \$127m (12.1% of revenue, maintaining the full-year target of 13%), diluted earnings per share should still grow to \$1.91 (up 19% year-on-year).

"The broad range of usage cases and expanding scope of newly connected platforms are crowding radio spectrum and stressing network capacity. These dynamics portend a digital traffic jam while creating a tremendous opportunity," says Griffin. "Given our strategic investments, technology breadth and differentiated system solutions, Skyworks is well positioned to empower revolutionary 5G applications, enabling up to 100x increases in speed and near-zero latency with expanding network capacity."

www.skyworksinc.com

Skyworks unveils new SkyOne WiFi family of front-end modules

Skyworks Solutions Inc of Woburn, MA, USA (which makes analog and mixed-signal semiconductors) has introduced a new family of highly integrated wireless networking solutions for mobile and Internet of Things (IoT) ecosystems.

The new SkyOne WiFi suite combines Skyworks' integration expertise and 802.11ac technology to provide a comprehensive front-end module in a single-placement, compact footprint. Specifically, the new products incorporate all key radio frequency blocks between the Wi-Fi system-on-chip (SOC) and the antenna, unburdening customers of complex RF design challenges, while reducing time to market, the firm claims. The platform is said to significantly improve Wi-Fi system performance compared with other standard SOC platforms and further mitigates interference with other radios, extending range and

increasing throughput.

The SKY85812-11, the first in the SkyOne WiFi series of products, is currently available for sampling and production (and already shipping in flagship platforms globally with a top-tier smartphone OEM).

"Today's mobile and IoT devices are now supporting up to 20 bands and require both seamless and robust Wi-Fi functionality to meet growing requirements from carrier offload, voice over IP and other bandwidth-intensive applications," says David Stasey, general manager & VP of Diversified Analog Solutions at Skyworks. "Building upon our highly successful SkyOne cellular platforms, Skyworks is now pleased to offer Wi-Fi solutions that deliver optimum levels of integration and performance," he adds.

According to ABI Research, more than 20 billion Wi-Fi chipsets are expected to be shipped between

2016 and 2021, particularly as Wi-Fi solutions expand beyond their traditional usage applications, frequency bands, device types and performance requirements. They also expect more than 95% of devices shipped in 2021 to support 5GHz Wi-Fi, signifying increased spectrum sharing with cellular technologies.

The SKY85812-11 is a dual-band front-end module incorporating a 5GHz bypass low-noise amplifier with single-pole, double-throw (SPDT) transmit/receive switch and a 2.4GHz bypass low-noise amplifier with single-pole, triple-throw (SP3T) switch with Bluetooth port that allows for Wi-Fi antenna sharing. The SKY85812-11 also includes a 2GHz LTE coexistence filter and diplexer — all designed into a compact, 16-pin 3mm x 3mm package.

www.skyworksinc.com/

[Product/3399/SKY85812-11](http://www.skyworksinc.com/Product/3399/SKY85812-11)

Skyworks' front-ends optimize battery life and extend range of 'nearable' tracking devices

Skyworks says that its connectivity solutions are enabling the new Internet of Things (IoT) application of next-generation tracking devices. Specifically, Skyworks' high-efficiency front-end systems have been adopted by 'nearable' technology firm XY Findables of San Diego, CA, USA to increase battery life and nearly double the range compared with other personal item finders.

XY4+ item finders are using Skyworks' highly integrated front-end modules designed for Bluetooth Low Energy (BLE) range extension devices operating in the 2.4–2.485GHz range. Applications include wearables, beacons, sensors, home automation and other IoT platforms.

"By leveraging Skyworks' fully integrated solutions, we were able to accelerate the introduction of

the most powerful Bluetooth item finder available," says XY's CEO Arie Trouw. "XY4+'s platform radically improves performance and extends battery life up to five years, supporting our goal of providing consumers both peace of mind and assistance when locating their most valuable items," he adds.

"Advancing Bluetooth wireless performance in premium products like XY4+ demonstrates our commitment

to pioneering breakthrough technologies and addressing demand for connectivity across a broad

Advancing Bluetooth wireless performance in premium products like XY4+ demonstrates our commitment to pioneering breakthrough technologies

array of IoT applications," says Skyworks' VP of product marketing John O'Neill. "As part of our ambitious vision to connect everyone and everything all the time, we are delighted to partner with innovative companies like XY Findables to offer our system-level expertise and broad product portfolio."

According to XY, the average person spends about 5 hours per month searching for misplaced items like TV remotes, keys, smartphones, eyewear, wallets and purses. In a recent report from the European Global Navigation Satellite Systems Agency, personal tracking devices are expected to become the fastest-growing market within the location-based services (LBS) sector, with an expected compounded annual growth rate of 18% over 2016–2025.

www.xyfindables.com

Guerrilla RF awarded ISO 9001:2015 certification

Guerrilla RF Inc of Greensboro, NC, USA — a provider of radio-frequency integrated circuits (RFICs) and monolithic microwave integrated circuits (MMICs) for consumer, commercial and military wireless applications — says that it has progressed from recommended status to final confirmation in being awarded ISO9001:2015 certification status by third-party registrar TUV Rheinland of North America.

ISO9001:2015 provides a process-based framework for taking a systematic approach to managing the organization's processes to enable consistent delivery of product that satisfies customers' expectations. As part of the ISO certification process, Guerrilla RF underwent a rigorous audit of its business and management processes, including the design, operations and sales processes.

"Guerrilla RF's achievement has received overwhelming positive feedback from our customers," says Steven Smith, VP of quality. "Achieving the final ISO9001:2015 award status illustrates our commitment as a company to customer satisfaction and strengthened performance through continual process improvement," he adds.

<http://guerrilla-rf.com/quality>

Samsung acknowledges Infineon for outstanding quality in supplying low-noise amplifiers

South Korea's Samsung Electronics has honored Infineon Technologies AG of Munich, Germany with its Quality Award in the semiconductor supplier category for second-quarter 2017, for delivering low-noise amplifiers (LNAs) of "outstanding quality" for the Galaxy smartphone series.

"Infineon has contributed for quality improvement and customer satisfaction throughout continuous effort and cooperation with Samsung," comments Kim Kyeongjun, executive VP of Samsung's Global CS (Customer Satisfaction) team.

Samsung Electronics' Mobile Division



Yoo Jaesang, manager of Infineon Korea's Quality Management team; Lee Seungsoo, managing director of Infineon Korea; and Kim Jongsu, director of Infineon Korea's Samsung Global Account team (from left).

assigns the Quality Award quarterly to its suppliers in four categories: Electricity, Instrument, Semiconductor and Application. Infineon supplies RF switches, LNA multiplexer modules (LMM), antenna tuners as well as LNA and security chips for Galaxy smartphones.

The award was accepted at Samsung by Lee Seung Soo, managing director of Infineon Technologies Korea, who adds that Infineon is contributing to Samsung's smartphones by enhancing the data rate, reducing power consumption and occupying less space.

www.infineon.com

Custom MMIC discusses latest in RF MMICs at EuMW

At European Microwave Week (EuMW 2017) in Nuremberg, Germany (8–13 October), monolithic microwave integrated circuit developer Custom MMIC of Westford, MA, USA discussed its latest developments in RF and microwave gallium arsenide (GaAs) and gallium nitride (GaN) MMICs, including ultra-wideband amplifiers, linear mixers, low-noise amplifiers (LNAs), low-phase-noise amplifiers (LPNAs), and switches.

As part of the 47th European Microwave Conference's EuMC28 sessions on amplifiers and receivers, lead engineer Nicholas Novaris presented a paper 'Understanding the Phenomenon of High

Power Pulse Recovery in GaN LNAs', exploring and detailing the high-power pulse recovery behavior of commercially available and overdriven GaN LNAs. This topic has become pertinent as GaN LNAs, with comparable noise figures to commonly installed GaAs LNAs, are capable of withstanding much higher input power levels than GaAs, and have the added benefit of not requiring additional and performance-degrading limiter circuitry, says Custom MMIC.

This input power-handling capability is attractive for defense applications, as military and aerospace receivers are often subject to jamming signals and may be in close proximity to

high-power transmitters, says the firm. However, it has been discovered that, even though GaN LNAs can withstand these high-power interfering signals, when the interference signal is quickly removed residual distortion occurs until the LNA recovers. So, advancing on past research, Custom MMIC engineers subjected GaN LNAs to a series of non-coherent jamming signals with varying duration and intensity. It was discovered that the recovery time exhibited a radical relationship to the input power. Moreover, the input action also significantly impacted the recovery time.

www.eumweek.com

www.custommmic.com

MACOM divests AppliedMicro's Compute business

MACOM Technology Solutions Holdings Inc of Lowell, MA, USA (which makes semiconductors, components and subassemblies for analog RF, microwave, millimeter-wave and photonic applications) has agreed to sell the Compute business — which it acquired in January when it bought Applied Micro Circuits Corp (AMCC) of Santa Clara, CA, USA — to Project Denver Holdings LLC (NewCo), a new company backed by The Carlyle Group.

MACOM will be issued with a minority equity ownership interest in NewCo.

In January, MACOM's president & CEO John Croteau said that the Compute part of AppliedMicro did not strategically align with MACOM's long-term product focus, and that it would be divested.

"The Carlyle Group is one of the world's largest and most successful global investment firms, with over \$170bn in assets under management," notes MACOM's president & CEO John Croteau. "NewCo's exceptional leadership team and Carlyle's backing combines the necessary elements to make the business a long-term success, and

through a minority equity ownership MACOM is positioned to participate in the company's long-term value creation," he adds.

Equity for Carlyle's investment came from Carlyle Partners VI, a \$13bn US buyout fund. The divestment became effective concurrently with the signing of the definitive agreement, with the exception of the transfer of certain assets and entities in jurisdictions outside of the USA, which will be transferred upon receipt of applicable foreign approvals.

www.macom.com

MACOM showcases GaN-on-Si portfolio and high-performance MMICs and diodes at COMCAS

At the IEEE Conference on Microwaves, Communications, Antennas, Electronic Systems and Bio-Medical Engineering (COMCAS 2017) in Tel Aviv, Israel (13–14 November), MACOM showcased its RF product and technology portfolio optimized for industrial, scientific, medical, point-to-point wireless and X-band radar, including:

- high-power GaN-on-Si;
- RF small-signal portfolio (featuring high-performance MMICs and basestation and mobile backhaul devices);
- high-performance diodes (diode design and application-specific solutions); and
- hi-rel and component devices (the latest screened products for

mission-critical aerospace applications).

MACOM staff also participated in various sessions, including:

- Tim Boles speaking on 'High Power mmW Switch Technologies'; and
- Frank Traut speaking on 'GaN-on-Si: Thermal Considerations'.

www.comcas.org

Saab using GaN-based AESA in new Arexis electronic warfare jammer pod for Gripen fighter aircraft

Sweden-based defence and security company Saab AB is in the final stages of development of a new family of electronic warfare (EW) self-protection systems called Arexis. One version of Arexis is the on-board EW suite in the new version of the Gripen fighter, Gripen E/F.

At the Defence and Security Equipment International (DSEI 2017) exhibition in London, UK (10–13 September), Saab expanded the Arexis product family by presenting the Arexis advanced electronic attack jammer pod. This has the capability to screen and hence protect the approach and departure of entire strike formations against low-frequency radars

by the smart utilization of DRFM-based jamming techniques such as smart noise, coherent false targets, and various saturation techniques.

The core technologies in Arexis are ultra-wideband digital receivers and DRFM (digital radio frequency memory) devices, gallium nitride (GaN)-based solid-state active electronically scanned array (AESA)

Core technologies in Arexis are ultra-wideband digital receivers and DRFM devices, GaN-based solid-state AESA jammer transmitters, and interferometric direction finding

jammer transmitters, and interferometric direction finding systems. For the advanced electronic attack application, these technologies are adapted to the lower-frequency ranges required to jam modern anti-stealth air defence systems, the output power is increased, and everything is repacked in a pod to make it a role-specific solution.

Saab EW systems are in use by customers worldwide. The firm can provide everything from electronic support measures, radar warning receivers and jammers to self-protection systems with missile approach warners and countermeasure dispenser systems.

www.saabgroup.com

Mitsubishi Electric US Inc to take over power device sales business from Powerex

Tokyo-based Mitsubishi Electric Corp has agreed to acquire the Mitsubishi Electric power device sales business currently handled by Powerex Inc of Youngwood, PA, USA (a 50:50 joint venture between Mitsubishi Electric and General Electric), which will be taken over in January by Mitsubishi Electric US Inc of Cypress, CA, USA.

Mitsubishi Electric power devices are sold in Japan, Europe, the Americas, China, Southeast Asia

and India. The Americas are a key region due to the projected growth of its automobile market. Putting the business in the hands of the subsidiary Mitsubishi Electric US will enable Mitsubishi Electric to focus more closely on its global customers, the firm reckons.

The specific benefits and synergies expected as a result of this new arrangement are as follows:

- stronger customer support for global manufacturing networks

based in the Americas;

- stronger collaboration and technical support for the automobile market and automobile manufacturers; and
- resources sharing among existing business units within Mitsubishi Electric US.

Following the acquisition, Mitsubishi Electric will continue to support Powerex's business development as a co-owner of the company.

www.MitsubishiElectric.com/semiconductors

Lockheed Martin completes critical design review on-schedule for GaN-based Long Range Discrimination Radar

Lockheed Martin has completed a rigorous critical design review (CDR) with the US Missile Defense Agency (MDA) for the Long Range Discrimination Radar (LRDR), demonstrating compliance to all technical performance measures and requirements. The radar system will support a layered ballistic missile defense strategy to protect the US homeland from attacks.

Similar to Lockheed Martin's Space Fence radar system, LRDR is a high-powered S-band radar incorporating solid-state gallium nitride components. It adds the capability of discriminating threats at extreme distances using the inherent wide-band capability of the hardware coupled with advanced software algorithms.

LRDR is a strategic national asset of the MDA's Ballistic Missile Defense System (BMDS) and will provide 24/7/365 acquisition, tracking and discrimination data to enable defense systems to lock on and engage ballistic missile threats, a capability that stems from Lockheed Martin's decades of experience in creating ballistic missile defense systems for the USA and allied governments.

The MDA awarded the \$784m contract to Lockheed Martin in 2015



Solid State Radar Integration Site.

to develop, build and test LRDR, and the firm is on track on an aggressive schedule to deliver the radar to Clear, Alaska in 2020. Teams from Lockheed Martin, MDA Sensors Directorate and the Command and Control, Battle Management, and Communications (C2BMC) have worked interfaces closely to ensure seamless integration.

Successfully executing CDR validates that the LRDR system is ready to proceed into fabrication, demonstration and test, and that the hardware and software component have achieved Technology Readiness Level (TRL) 7 and Manufacturing Readiness Level 7.

With the completion of CDR, the program now begins low-rate manufacturing, which began in October. In preparation for full-rate manufacturing starting in mid-2018, Lockheed Martin will be utilizing

production hardware in combination with prototype systems, tactical back-end processing equipment as well as tactical software to demonstrate system performance in an operational environment to achieve system TRL 7. Lockheed Martin will be performing a series of tests in the Solid State Radar Integration Site (SSRIS), including a closed-loop satellite track test.

"This team has achieved every milestone, including this CDR, on schedule since contract award in 2015," notes Lockheed Martin's LRDR program director Chandra Marshall. "With the success of CDR, LRDR is on track for initial operating capability (IOC) in 2020."

In addition to CDR, Lockheed Martin conducted a facilities design review in October for the LRDR equipment shelter design. The firm will run a full and open competition for the construction of the equipment shelter in Clear, Alaska and will begin construction of the shelter in first-half 2019. The MDA team is preparing the site for radar system installation and checkout mobilization, constructing the Mission Control Facility and starting the foundation for the LRDR equipment shelter.

www.lockheedmartin.com/lrdr

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Beryllium doping of gallium nitride shown to offer promise for higher efficiency in power electronics

Amphoteric behavior on heating or cooling switches beryllium between substitutional and interstitial lattice positions, between electron donor and acceptor

Working with scientists in Texas and Warsaw, researchers at Finland's Aalto University have made a breakthrough in revising methods largely discarded 15 years ago ('Amphoteric Be in GaN: Experimental Evidence for Switching between Substitutional and Interstitial Lattice Sites', *Physical Review Letters* (2017) volume 119, p196404).

Experiments with beryllium doping of gallium nitride were conducted in the late 1990s in the hope that beryllium would prove more efficient as a doping agent than the prevailing magnesium used in LED lights. However, the work proved unsuccessful, and research on beryllium was largely discarded.

The researchers have now discovered a microscopic mechanism that can allow GaN-based semiconductors to be used in electronic devices that distribute large amounts of electric power. To be useful in devices that need to process considerably more energy than in everyday home entertainment, gallium nitride needs to be manipulated in new ways on the atomic level, they add.

"There is growing demand for semiconducting gallium nitride in the power electronics industry," notes professor Filip Tuomisto of Aalto University. "To make electronic



Sample chamber of the positron accelerator. Photo: Hanna Koikkalainen.

devices that can process the amounts of power required in, say, electric cars, we need structures based on large-area semi-insulating semi-conductors with properties that allow minimizing power loss and can dissipate heat efficiently." To achieve this, doping gallium nitride with beryllium shows great promise, he adds.

Due to advances in computer modelling and experimental techniques, the researchers have managed to show that beryllium can actually perform useful functions in GaN. Depending on whether the material is heated or cooled, beryllium atoms exhibit amphoteric behavior in GaN, involving switching between substitutional and interstitial positions in the lattice, changing their nature of either donating or accepting electrons.

"Our results provide valuable knowledge for experimental scientists about the fundamentals of how beryllium changes its behaviour during the manufacturing process," says Tuomisto. "During it — while being subjected to high temperatures — the doped compound functions very differently than the end result."

If the beryllium-doped GaN structures and their electronic properties can be fully controlled, power electronics could move to a new realm of energy efficiency, it is reckoned.

"The magnitude of the change in energy efficiency could as be similar as when we moved to LED lights from traditional incandescent light bulbs," says Tuomisto.

"It could be possible to cut down the global power consumption by up to 10% by cutting the energy losses in power distribution systems," he concludes.

Moreover, the similarity of this behavior to that found for sodium (Na) and lithium (Li) dopants in zinc oxide (ZnO) suggests that this could be a universal property of light dopants substituting for heavy cations in compound semiconductors.

<https://journals.aps.org/prl/abstract/10.1103/PhysRevLett.119.196404>
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AKHAN issued Japan patent covering fabrication of diamond semiconductor materials

AKHAN Semiconductor Inc of Gurnee, IL, USA, which specializes in the fabrication and application of lab-grown, electronics-grade diamond, says that the Japan Patent Office has issued it patent JP6195831 (B2) covering a method for the fabrication of diamond semiconductor materials, core to applications including automotive, aerospace, consumer electronics, military, defense, and telecoms systems.

"Its issuance protects our proprietary interests in diamond semiconductor in one of the nations leading the globe in diamond research," says founder & CEO Adam Khan. "Following this year's issuances of a Taiwan diamond semiconductor patent, and a major US diamond transparent electronics patent, the Japan patent issuance is a further testament to AKHAN's leadership in the diamond semicon-

ductor space," he claims.

Japan, which has actively funded millions of dollars into diamond electronics research since 2002, earlier this year announced progress in the development of diamond semiconductor device performance. The AKHAN granted and issued patent is a foreign counterpart of other issued and pending patents that are used in the firm's Miraj Diamond Platform products. As a key patent, the claims protect uses far beyond the existing applications, including microprocessor applications. Covering the base materials common to nearly all semiconductor components, the intellectual property can be realized in everything from diodes, transistors, and power inverters, to fully functioning diamond chips such as integrated circuitry, says AKHAN.

Diamond-based technology is capable of increasing power density

as well as creating faster, lighter, and simpler devices for consumer use. Cheaper and thinner than its silicon counterparts, diamond-based electronics could become the industry standard for energy-efficient electronics, reckons the firm.

"This patent adds to the list of other key patents in the field of diamond semiconductor that are owned by the company, including the ability to fabricate transparent electronics, as well as the ability to form reliable metal contacts to diamond semiconductor systems," notes president & chief operating officer Carl Shurboff. "This patent bolsters the supporting evidence of AKHAN's leadership in manufacturing diamond semiconductor products, and supports ongoing efforts with our major defense, aerospace and space system development partners."

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InnovateUK awards project to CS MAGIC consortium Compound Semiconductor Centre, AHS, TWI, Renishaw and Swansea University to combine GaAs QW Hall-effect magneto-sensors with GaN-based magHEMTs

The Compound Semiconductor Centre (CSC) — a joint venture founded in 2015 between Cardiff University and epiwafer foundry and substrate maker IQE plc of Cardiff, Wales, UK — has been awarded a collaborative research & development grant by UK Government agency InnovateUK for the project CS MAGIC: (Compound Semiconductor MAGnetic Integrated Circuits), which will focus on the development of new ultra-sensitive magneto-sensors with integrated electronics.

The £367,153 project will leverage core technology based on GaAs quantum well Hall effect (QWHE) magnetic sensing technology developed by professor Mohamed Missous, the founder of Advanced Hall Sen-

sors Ltd (AHS), and a novel gallium nitride device based on a high-electron-mobility transistor (magHEMT) concept developed by Dr Petar Ijic at Swansea University.

Comprising CSC (in Cardiff), AHS Ltd (in Manchester), independent research and technology organization TWI (in Port Talbot), Renishaw (in Edinburgh) and Swansea University (in Wales), the project consortium will collaborate to deliver commercial-grade sensing solutions for a diverse range of challenging applications in automotive current sensing, high-resolution metrology, non-destructive inspection & test, and security screening applications.

"AHS has had considerable

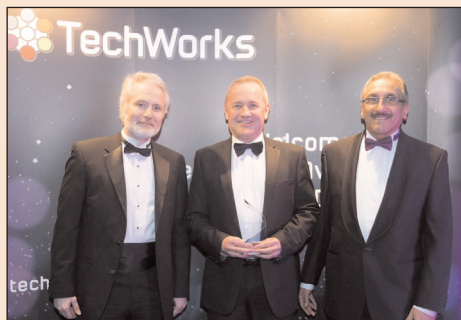
success in commercializing the core technology, with over 15 million discrete sensors shipped to date [to the industrial, medical, aerospace and oil & gas industries], and this project will extend the functionality of sensing platform for harsh-environment and ultra-wide dynamic range requirements to service a \$3bn market in magnetic sensing solutions," says Missous. "This project will deliver an 'all UK'-developed and -manufactured solution which leverages world-class compound semiconductor materials and device expertise in the consortium matched with the deep applications understanding of TWI and Renishaw," comments the CSC's director Dr Wyn Meredith.

CSC wins Research & Collaboration title at 2017 TechWorks Awards

The Compound Semiconductor Centre has won the Research and Collaboration title at the inaugural awards ceremony of TechWorks (the new UK industry association for 'deep tech', i.e. the underpinning technologies such as artificial intelligence, robotics, 5G, machine vision, Internet-of-Things, analytics and automation that are driving the new economy).

Sponsored by the Science & Technology Facilities Council (STFC), the award was presented by the BBC's technology correspondent Rory Cellan-Jones during a gala ceremony in London in recognition of the multiple collaborative R&D program wins, positioning South Wales as a location for the development, innovation and manufacture of compound semiconductor-related products.

Recent R&D programs include Project SUPER8 (a £1.1m collaborative R&D project under UK Government agency InnovateUK's recent Emerging and Enabling



Rob Harper of the Compound Semiconductor Centre receives the 2017 TechWorks Research and Collaboration Award.

Technologies Call) which focuses on the development of new ultra-high-speed transceiver platform to service the enormous growth market in optical data communications in hyper-scale Cloud data centers, and Project CS MAGIC (Compound Semiconductor MAGnetic Integrated Circuits), which is focusing on the development of new ultra-sensitive magneto-sensors with integrated electronics.

The STFC-sponsored category celebrates innovative R&D activity involving strong industry and academic collaboration and completed within the last two years. CSC has demonstrated "world beating" technology development, with very high potential of being adopted by industry, according to the citation.

"Collaboration is the DNA of the Compound Semiconductor Centre (CSC), enabling a wide range of business and academic partners to develop new compound semiconductor-based technologies from prototyping through to commercial realization," says CSC director Dr Wyn Meredith. "Recent collaborative R&D programs won by CSC demonstrate the high level of compound semiconductor technology activities in South Wales and provide an important milestone towards the establishment of the world's first CS Cluster, based in the region."

www.techworks.org.uk

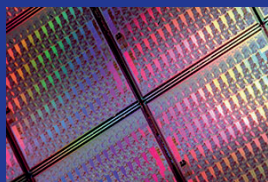
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IQE places new shares to raise £95m

Epi firm to buy 40–60 MOCVD systems over next 3–5 years for new foundry, driven by VCSEL wafers for 3D sensing

Pursuant to the authority granted at its annual general meeting on 13 June, epiwafer foundry and substrate maker IQE plc of Cardiff, Wales, UK has placed 67,941,581 new ordinary shares of 1 pence each at a price of 140 pence per share, to raise gross proceeds of about £95m.

The placing (to institutional investors only) represents about 9.9% of IQE's existing outstanding issued share capital. Application for admission of the placing shares to trading on the AIM market of the London Stock Exchange will be made in due course and they are expected to commence trading on 16 November, when the placing is expected to settle. IQE has agreed to a lock-up of 90 days following completion of the transaction.

Following the issue of the placing shares, the firm's enlarged issued ordinary share capital will be 754,756,394 voting ordinary shares.

Canaccord Genuity Ltd, Stifel Nicolaus Europe Ltd and Peel Hunt LLP acted as joint bookrunners in relation to the placing.

IQE says the rationale for the placing and use of proceeds is as follows:

- IQE is seeking funding to enable it to scale the business to capture multiple high-growth mass-market opportunities.
- The placing will allow the accelerated expansion of IQE's capital expenditure program in its new epi foundry in Newport, South Wales, UK, with the purchase of up to 40–60 new metal-organic chemical vapor deposition (MOCVD) systems over the next 3–5 years.
- The additional capacity should enable IQE to address multiple high-growth, mass-market opportunities, including its position in the production of vertical-cavity surface-emitting laser (VCSEL) wafers for 3D sensing consumer electronic applications as well as multiple other consumer applications and platforms.
- IQE is seeing material demand for its VCSEL wafers from a leading global consumer electronics firm for use in one of its mass-market consumer products. In conjunction with multiple other customer engagements, IQE expects this demand to rise as its technology is applied across multiple consumer applications and platforms.

● IQE should be able to accelerate the development of new products and technology, while protecting and enhancing its position in a fast-moving marketplace.

● The placing will allow the firm to de-gear and should enhance its financial strength and ability to supply global tier-1 OEMs (both existing and new customers).

● In conjunction with Cardiff City Deal, the placing should allow IQE to generate incremental sales.

On 20 October, IQE confirmed that a strong third-quarter 2017 saw continuing growth, driven largely by the ongoing VCSEL ramp for a mass-market 3D sensing technology. Should the VCSEL ramp continue along its current growth curve during Q4, then there is potential for full-year 2017 earnings to exceed current expectations, says IQE.

"Compound semiconductors are the fundamental enabler of innovations such as wireless connectivity, 3D sensing, biometric sensors, electric and autonomous vehicles, high-speed wireless and optical communications, and advanced manufacturing," notes CEO Drew Nelson.

www.iqep.com

IQE and Cardiff University win Economic Impact title at Business and Education Partnerships Awards

At the Marriott Hotel in Cardiff, Wales, the Economic Impact title at the 2017 Business and Education Partnerships Awards was presented to IQE and Cardiff University, in recognition of their close work to achieve key mile-stones in developing an advanced manufacturing capability with the vision of establishing the world's first Compound Semiconductor Cluster in Wales.

IQE and Cardiff established the Compound Semiconductor Centre (CSC), a 50/50 'for profit' enterprise for product, services and skills development in compound semi-

conductor technologies. Based in Cardiff, it provides facilities to help researchers and industry work together, aiming to position Cardiff as the European leader in compound semiconductor technology.

Also at the same awards ceremony, professor Peter Snowton, director of EPSRC Future Manufacturing Hub in Compound Semiconductors, won the title of Individual Impact. Snowton has been driving creation of the Hub, which aims to provide Europe-leading capability that will translate research into large-scale compound semiconductor growth

and device fabrication. Cardiff University leads the Hub with three key academic partners: UCL (University College London), the University of Manchester, and the University of Sheffield.

The EPSRC Manufacturing Hub in Future Compound Semiconductors and CSC work closely together for compound semiconductor manufacturing and applications development in Wales and have been key in driving establishment of the Compound Semiconductor Cluster.

www.epsrc.ac.uk/research/centres/manufacturinghubs



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Veeco wins preliminary injunction in patent infringement lawsuit against SGL Carbon

Ruling prohibits sale of wafer carriers for AMEC's MOCVD systems

The US District Court for the Eastern District of New York has granted a motion requested by epitaxial deposition and process equipment maker Veeco Instruments Inc of Plainview, NY, USA for a preliminary injunction against SGL Carbon LLC, a supplier of wafer carriers to Advanced Micro-Fabrication Equipment Inc (AMEC). The injunction prohibits SGL from shipping wafer carriers — for use in susceptorless metal-organic chemical vapor deposition (MOCVD) systems — that use Veeco's patented technology (including wafer carriers designed for AMEC MOCVD systems) without Veeco's express authorization.

The action for patent infringement was commenced by Veeco against SGL Carbon LLC and SGL Carbon SE on 12 April. Veeco "will not hesitate to protect its significant investment in research & development, including its patents in the US, Europe and Asia — particularly in China," says chairman & CEO John R. Peeler.

The court also ruled that Veeco showed a "clear likelihood of success" on its claim that its patent on wafer carriers for use in susceptorless MOCVD reactors is infringed by SGL and that the patent is valid. SGL had argued that its wafer carriers were based on AMEC's specifications. The ruling shows that AMEC does not respect its intellectual property rights, asserts Veeco.

Preliminary injunctions are rare in patent cases, since the legal requirements to issue such an injunction prohibiting sales prior to a jury verdict on patent infringement are very stringent, says Veeco, adding that the ruling shows the nature of SGL's and AMEC's violation of its IP.

SGL subsequently filed a motion requesting that the court suspend the preliminary injunction pending its appeal to the US Court of Appeals for the Federal Circuit (CAFC). However, on 16 November the court denied that motion. "We are confident that we will prevail before the appellate court in any appeal by

SGL, and will continue to take steps in the US and abroad to enforce Veeco's IP rights," says Veeco's chairman & CEO John R. Peeler.

The court's order means that the preliminary injunction will remain in place during the appeal by SGL. The appeal process at the CAFC usually takes over a year to complete. SGL will bear the burden of convincing the CAFC that the preliminary injunction should be overturned. Appeals of preliminary injunctions are evaluated by the CAFC under the highly deferential 'abuse of discretion' standard of review. As a result, Veeco believes that it is highly unlikely that the CAFC will overturn the preliminary injunction, especially in light of statistics showing that a substantial majority of preliminary injunctions are affirmed by the CAFC on appeal.

In addition to the preliminary injunction, Veeco is seeking a post-trial permanent injunction, monetary damages and other relief.

www.veeco.com

AMEC ships 100th Prismo A7 MOCVD tool chamber

Marking a milestone for its metal-organic chemical vapor deposition (MOCVD) business, Advanced Micro-Fabrication Equipment Inc (AMEC) of Shanghai, China has now shipped 100 Prismo A7 MOCVD tool chambers since the product's introduction last year. It is AMEC's second-generation MOCVD tool, and is used to manufacture gallium nitride (GaN)-based light-emitting diodes for solid-state lighting products and other applications. With up to four chambers contained in each Prismo A7 system (enabling it to process 136 x 4" wafers simultaneously), production throughput is more than twice as high as AMEC's first-generation MOCVD tool, the Prismo D-BLUE.

The systems are installed at cus-



AMEC's Prismo A7 MOCVD system.

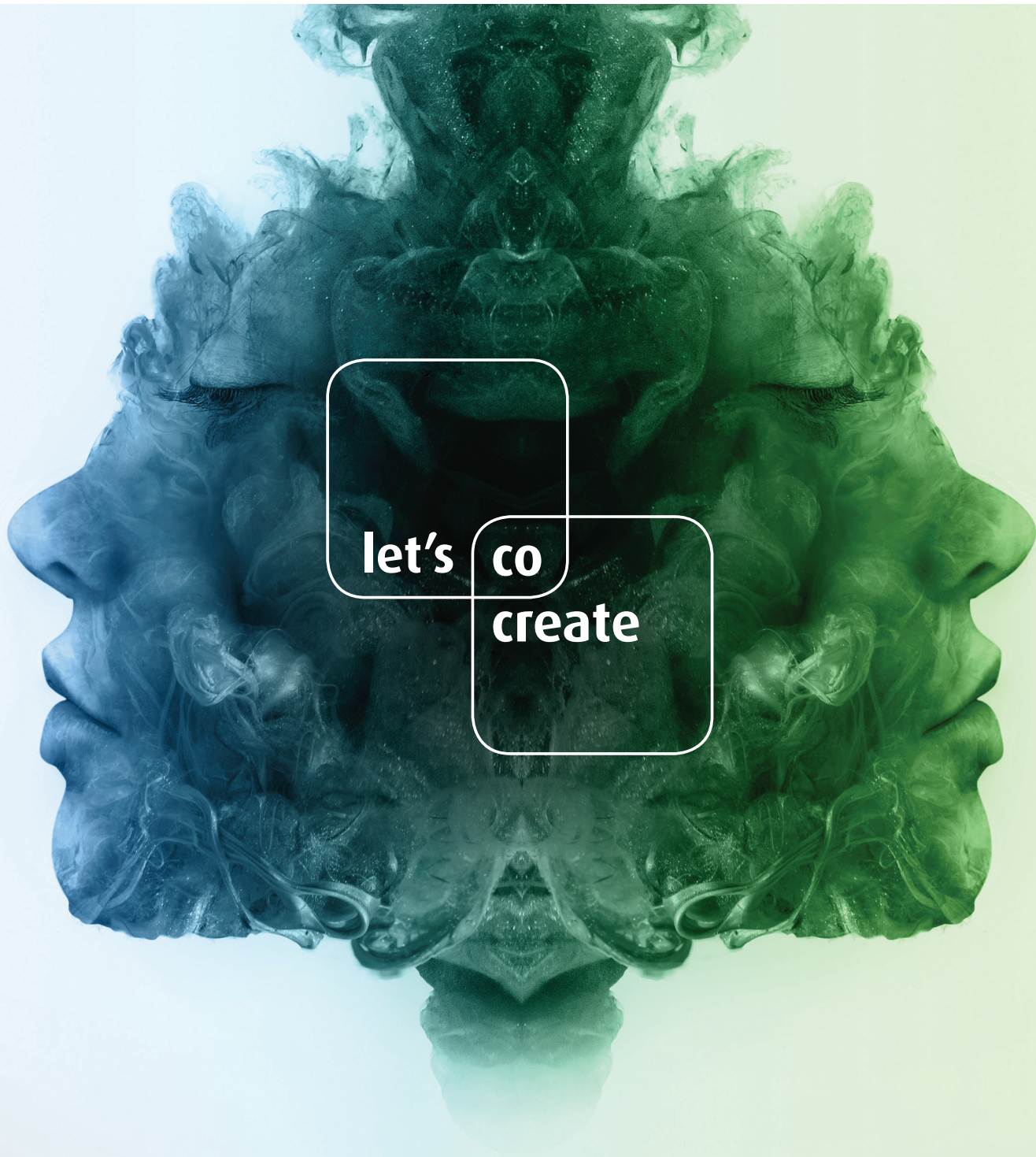
tomers facilities in China, including LED makers San'an Optoelectronics and HC SemiTek Corp. Since its introduction, AMEC has received multi-tool orders, as well as repeat orders for the system. By the end of 2017, the firm expects to record shipments of about 120 chambers.

"With AMEC, we have a partner

that can meet our advanced technical requirements with a tool that's engineered to deliver superior performance and very high throughput, at lower-than-average capital costs," comments San'an Optoelectronics' vice chairman & general manager Kechuang Lin. "We benefit from close proximity to AMEC's rich process expertise, as well as fast response times from the company's field support teams," he adds.

The technology embedded in the Prismo A7 system is protected by 155 patents (issued and pending), including filings in China, Korea, Japan, Taiwan, and the USA (as part of AMEC's intellectual property portfolio of more than 1000 patents issued and pending).

www.amec-inc.com



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Veeco's Q3 revenue growth driven by continued recovery in MOCVD market

Margins hit by increased competition in China, but new double-capacity EPIK 868 system to maintain competitiveness

For third-fiscal 2017, epitaxial deposition and process equipment maker Veeco Instruments Inc of Plainview, NY, USA has reported revenue of \$131.9m, up 15% on \$115.1m last quarter and up 54% on \$85.5m a year ago, marking the first full quarter of combined results for Veeco and Ultratech Inc of San Jose, CA, USA (which designs and makes lithogra-

phy, laser-processing and inspection systems for the advanced packaging, front-end semiconductor and LED markets), which was acquired on 26 May.

Sales into the LED Lighting, Display & Compound Semiconductor markets have grown from \$56.2m to \$60m (45% of overall revenue) — about half of which is for the China blue LED market — driven by continued roll-out of metal-organic chemical vapor deposition (MOCVD) and Precision Surface Processing (PSP) systems into Europe, China and South-East Asia.

Sales into the Advanced Packaging, MEMS & RF markets contributed 17% of overall revenue, driven by Ultratech and PSP system sales for advanced packaging applications and continued sales of PSP systems for MEMS applications.

Scientific & Industrial markets contributed 25% of overall revenue, supported by shipments of AVE systems for optical coding and data storage applications.

The Front-end Semiconductor segment (formerly part of the Scientific & Industrial segment, before the Ultratech acquisition) contributed 13% of overall revenue,

driven by the Ultratech laser annealing and AVE systems.

Geographically, 26% of revenue came from the USA (up from 18% last quarter), 13% from Europe, the Middle East & Africa (EMEA, down further, from 16%), and 49% from the rest of the world (up from 43%, driven mainly by sales into Malaysia and South Korea). Meanwhile, China fell from 23% to 12%. However, this excludes \$28.5m in shipments of Veeco's new TurboDisc EPIK 868 gallium nitride (GaN) MOCVD system for which revenue recognition has been deferred to Q1/2018.

On a non-GAAP basis, gross margin has risen further, from 40.3% a year ago and 40.6% last quarter to 42.3% (above the 39–41% guidance), driven by a favorable product mix across many of the firm's product lines.

Operating expenses (OpEx) were \$48.9m, up from \$37.2m last quarter (reflecting the full-quarter impact from Ultratech) but slightly better than the \$49–51m guidance.

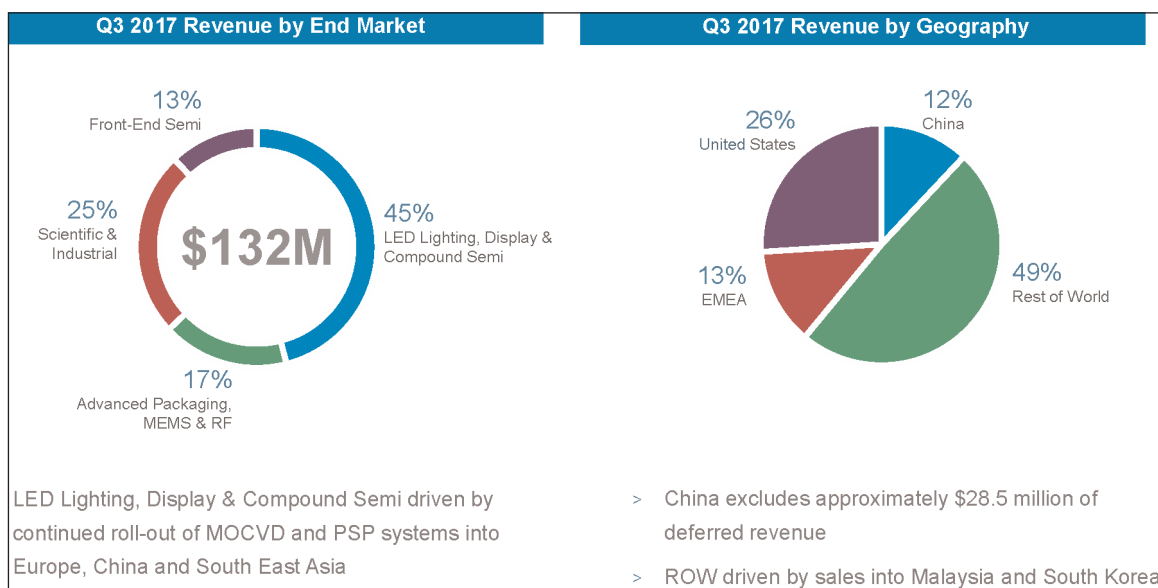
Net income was \$4.3m (\$0.09 per diluted share), down from \$6.4m (\$0.15 per diluted share) last quarter but an improvement from a loss

of \$1.8m (\$0.05 per diluted share) a year ago, and towards the top of the guidance range of between a loss of \$4m (\$0.09 per share) and a profit of \$5m (\$0.09 per share).

Cash flow from operations was \$24.9m (up from \$6.3m a year ago). During the quarter, cash and short-term investments rose by \$18m, from \$303m to \$321m.

Order bookings in Q3/2017 were \$162m, up 32% on \$123m last quarter and up 37% on \$118m a year ago. Growth was driven mainly by an increase in the LED lighting display and compound semiconductor markets, where Veeco received multiple system orders from LED makers in China, Korea and Europe for MOCVD systems in the EPIK, Propel and K475i family.

"We are seeing continued adoption of our K475i product into red, orange and yellow LEDs and photonics applications," says chairman & CEO John R. Peeler. "The photonics market, which includes VCSELs [vertical-cavity surface-emitting lasers] and lasers for optical communications, is growing rapidly and represents an exciting opportunity. We were engaged with multiple key



customers and have recently achieved sales to a leading photonics company for the development of next-generation VCSELs and other lasers," he adds.

Hence, during the quarter, order backlog rose by \$29m, from \$270m to \$299m.

"The integration of Ultratech into Veeco is proceeding extremely well with many key milestones now behind us," says Peeler. "All duplicative public company expenses have been eliminated, our sales forces have been successfully merged and our field service organizations have been integrated. As a result, we are even stronger than before, with the right staff in each region, focused on driving improved results," he adds.

"Our manufacturing consolidation initiative in New Jersey is largely completed," notes chief financial officer Sam Maheshwari. "We are realizing close to \$4m in annualized synergies beginning towards the end of this quarter."

For fourth-quarter 2017, Veeco expects revenue to rise to \$135–155m. "We are seeing robust demand in China for our MOCVD systems," says Peeler. "We are also seeing increased competition [targeting mainstream LED lighting applications]... as AMEC begins to ship systems. As a result, we are seeing some pricing pressure which will impact our gross margins," he adds. Gross margin is forecasted to fall to 39–41%. Operating expenses are expected to be \$49–51m. Net income should be \$0–7m (\$0.00–0.16 per diluted share).

"Generally Q1 revenues are lower than Q4. However, due to strong backlog and deferred revenues at this time, we expect Q1 revenues to be higher than Q4," says Maheshwari. "Secondly, given the current competitive environment in MOCVD business, we may see gross margins temporarily in the 30–35% range as we move beyond this calendar year," he notes.

"We are continuing to win busi-

ness in China despite increased competition, and we feel confident in our ability to maintain our lead as we execute on our technology and product roadmap," says Peeler. "During the quarter, we formally released our new MOCVD system, the EPIK 868, which provides a lower-cost and higher-productivity solution [doubling the capacity of the existing EPIK 700 by doubling the number of reactor modules to four]," says Peeler. The new system is "designed to meet the needs of our customers in China, demonstrating our long-term commitment to this important region," he adds.

"Overall, we expect calendar 2018 to be a growth year in revenues for us, despite MOCVD-driven gross margin pressure," says Maheshwari. "We expect operating income as a percentage of sales to be better in 2018 than 2017, due to operating leverage, synergy execution, new product releases and completion of certain initiatives," he adds.

www.veeco.com

Veeco and ALLOS demonstrate 200mm GaN-on-Si wafers for blue/green micro-LED adoption

ALLOS' epi technology transferred onto Veeco Propel MOCVD

Veeco Instruments Inc of Plainview, NY, USA has completed a strategic initiative with technology engineering & IP licensing firm ALLOS Semiconductors GmbH of Dresden, Germany to demonstrate 200mm gallium nitride on silicon (GaN-on-Si) wafers for blue/green micro-LED production. Veeco teamed up to transfer ALLOS' proprietary epitaxy technology onto its Propel single-wafer metal-organic chemical vapor deposition (MOCVD) system to enable micro-LED production on existing silicon production lines.

"With the Propel reactor, we have an MOCVD technology that is capable of high-yielding GaN epitaxy that meets all the requirements for processing micro-LED devices in 200mm silicon production lines," comments ALLOS' CEO

Burkhard Slischka. "Within one month we established our technology on Propel and have achieved crack-free, meltback-free wafers with less than 30µm bow, high crystal quality, superior thickness uniformity and wavelength uniformity of less than 1nm," he adds. "Together with Veeco, ALLOS is looking forward to making this technology more widely available to the micro-LED ecosystem."

Micro-LED display technology consists of <30µm x30µm red, green, blue (RGB) inorganic LEDs that are transferred to the display backplane to form sub-pixels. Direct emission from these high-efficiency LEDs offers lower power consumption compared with organic light-emitting diode (OLED) and liquid crystal displays (LCDs) while providing superior

brightness and contrast for mobile displays, TV and wearables, it is claimed. The manufacturing of micro-LEDs requires high-quality, uniform epitaxial wafers to meet the display yield and cost targets.

"In contrast to competing MOCVD platforms, Propel offers leading-edge uniformity and simultaneously achieves excellent film quality as a result of the wide process window afforded by Veeco's TurboDisc technology," claims Peo Hansson Ph.D., senior VP & general manager of Veeco MOCVD operations. "Combining Veeco's leading MOCVD expertise with ALLOS' GaN-on-silicon epiwafer technology enables our customers to develop micro-LEDs cost effectively for new applications in new markets."

www.allos-semiconductors.com
www.veeco.com

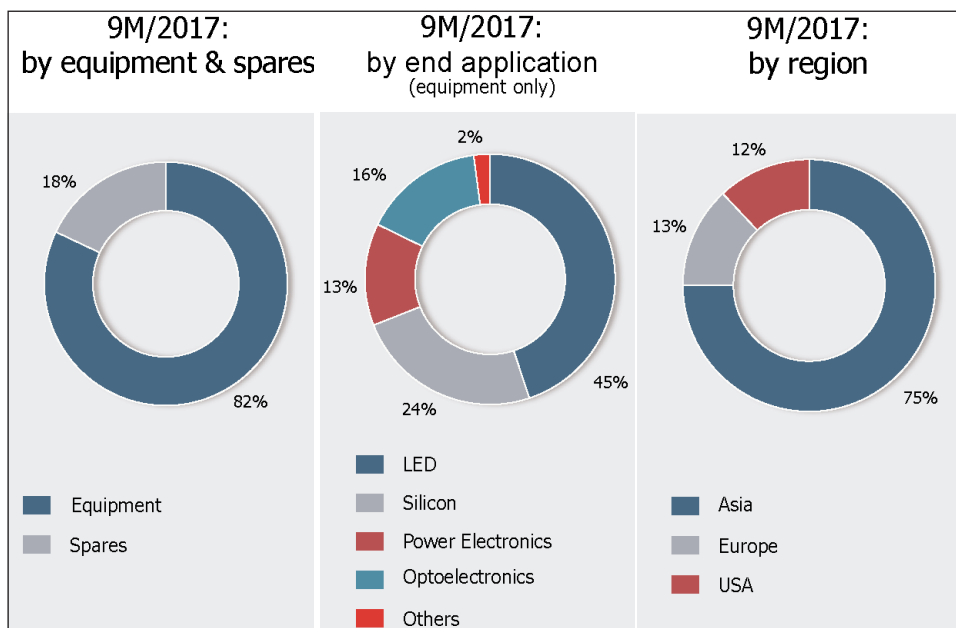
Aixtron enters net profit in Q3, aided by increased MOCVD demand for laser applications

Full-year order guidance raised again; on target for EBIT break-even

For third-quarter 2017, deposition equipment maker Aixtron SE of Herzogenrath, near Aachen, Germany has reported revenue of €62.2m, up 2.6% on €60.6m last quarter and 22% on €51m a year ago. However, this includes non-recurring positive effects of €4.6m from shipments made in prior years (but where payment had been regarded as unlikely), so adjusted revenue is €57.6m, down 5% on last quarter.

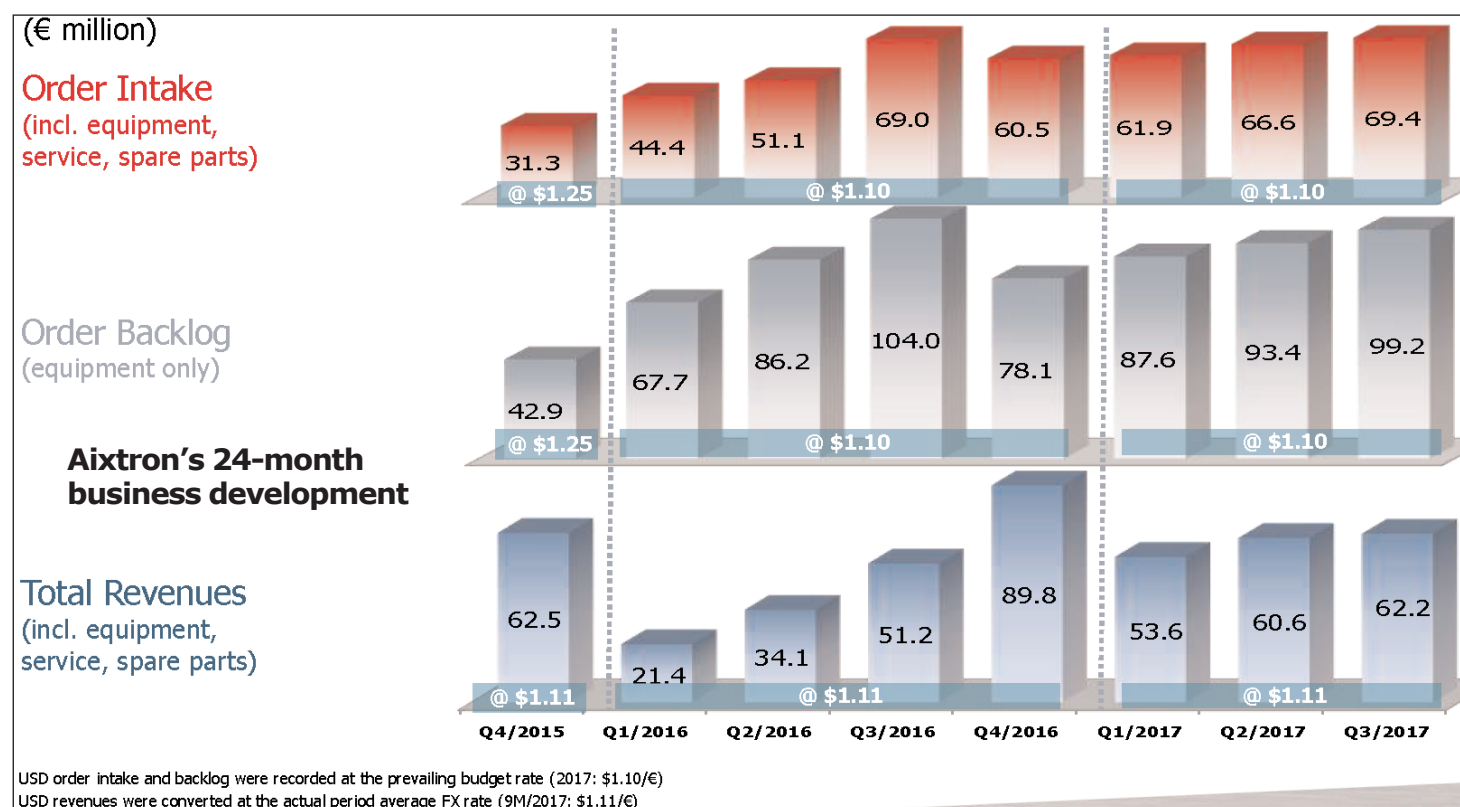
Adjusted to exclude the €4.6m of non-recurring items, gross margin improved to 35% from 26% last quarter — despite an unfavorable \$/€ exchange rate — due to better product mix and the absence of the low-margin sales that affected the first half of the year.

After excluding spending on ongoing restructuring activities (mainly related to the sale of Aixtron's ALD/CVD memory product line), adjusted operating expenses have been cut from €19.6m last quarter to €18.7m.



On an adjusted basis, compared with last quarter, there have been improvements both in the operating result (earnings before interest and taxes, EBIT) from -€3.6m to +€1.4m and in the net result from -€3.7m (-€0.03 per share) to +€1.1m (+€0.01 per share).

Due mainly to entering profit plus advance payments received from customers (which have grown to €42m), operating cash flow has risen from €8.7m to €13.2m. So, despite capital expenditure (CapEx) rising from €1.7m to €5m, free cash flow has hence still also risen,



from €7m to €8.2m. Reflecting the operational performance in combination with reduced and more efficient use of working capital, cash and cash equivalents therefore rose to €203.9m at the end of September, up from €197.1m at the end of June and €160.1m a year previously.

Driven by the continued strong demand seen in recent quarters for metal-organic chemical vapor deposition (MOCVD) systems for the production of vertical-cavity surface-emitting lasers (VCSELs) and other laser applications, ROY (red-orange-yellow) and specialty LEDs as well as power electronics, order intake rose by 4.2% from €66.6m last quarter to €69.4m. However, this includes a non-recurring positive effect of €4.9m from shipments made in prior years (but where payment had been regarded as unlikely), so adjusted order intake was €64.6m (down 3%). Nevertheless, at the end of September equipment order backlog was €99.2m, up 6% on €93.4m at the end of June.

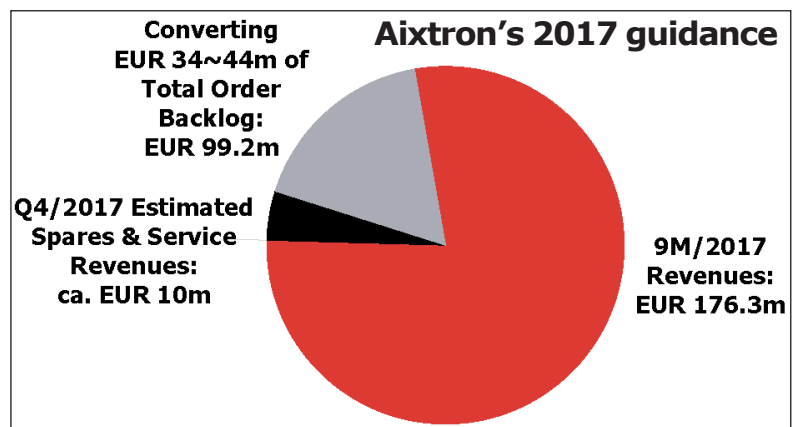
"Thanks to our broad product portfolio and the increased demand for MOCVD equipment for laser applications [including a significant order received in September from IQE], we are pleased about the order development," says president Dr Bernd Schulte. Given the increased demand across most of its markets, full-year 2017 Aixtron has therefore — for the second time this year — increased its guidance for orders, from €210–230m to €240–250m (at the prevailing budget rate of US\$/€1.10). It has also refined its revenue guidance, from €210–230m to €220–230m (consisting of the

Q1–Q3 revenue of €176.3m, supplemented by Q4 seeing €34–44m of the €99.2m order backlog converted into revenue, plus a forecasted €10m

of spares & service revenue in Q4). This guidance hence requires Q4/2017 revenue of just €44–54m.

This is even after excluding orders and revenue from the atomic layer deposition/chemical vapor deposition (ALD/CVD) memory product line (which is based at its US subsidiary Aixtron Inc in Sunnyvale, CA, USA) from the expected date of completion (by the end of 2017) of its sale to Eugene Technology Inc (a US subsidiary of South Korea-based Eugene Technology Co Ltd). The deal received approval from the Committee of Foreign Investment in the United States (CFIUS) on 23 October. As a result, Aixtron now expects to generate positive free cash flow and to achieve EBIT break-even for full-year 2017.

"Going forward, the major short-term growth driver will be around our MOCVD technology across specialty LEDs and laser applications," says Schulte. "In the mid-term, the emergence of wide-bandgap semiconductor power electronics applications represents a growing opportunity," he adds. "We are well on track to improve our margins and to optimize OpEx and align them



with the revenues we generate."

"We are very confident in our strategy in focusing on our core technologies and we believe that we are well positioned to take advantage of the opportunities we are seeing in front of us in compound semiconductors, carbon nanomaterials and OLEDs [organic light-emitting diodes]," concludes Schulte.

In order to return to profitability in 2018, Aixtron continues to execute restructuring measures as well as to seek the establishment of partnerships for its OLED business. The subsidiary APEVA SE for OLED deposition technology officially began operation on 1 October. Aixtron is continuing discussions with potential industry and financing partners in Asia to form a joint venture with APEVA. "Our OLED business is approaching major milestones in terms of customer qualification," notes president Dr Felix Grawert (who joined Aixtron's executive board in August). "Our Gen2 Pilot manufacturing tool is in final assembly and will be ready for testing by the customer this year," he adds.

www.aixtron.com

Aixtron completes sale of ALD/CVD memory product line to Eugene

Aixtron SE has completed the sale of its atomic layer deposition (ALD) and chemical vapor deposition (CVD) memory product line — which is based in San Jose, CA, as part of its US subsidiary Aixtron Inc — to Eugene Technology Inc, a US subsidiary of South Korea-based Eugene Technology Co Ltd (which

makes single-wafer ALD, CVD and plasma deposition and surface treatment systems).

The sale was announced in late May but received approval from the Committee on Foreign Investment in the United States (CFIUS) only in late October, after a determination that there were no unresolved

US national security concerns.

Aixtron will receive about \$60m for the assets being transferred and \$11m for open supplier orders for which it retains the liability to pay.

Aixtron Inc of Santa Clara, CA, USA will continue to provide sales and support for its continuing businesses.

www.eugenetech.co.kr

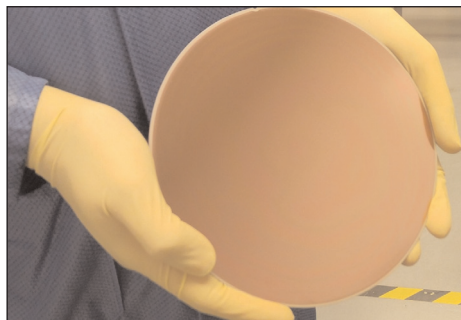
Kyma demos 200mm GaN HVPE on QROMIS' MOCVD GaN-on-QST wafers

GaN-on-QST template process transferred to new K200 HVPE tool

Kyma Technologies Inc of Raleigh, NC, USA — which provides wide-bandgap semiconductor crystalline materials, crystal growth equipment and GaN-based photoconductive semiconductor switch (PCSS) devices — has used its new K200 hydride vapor phase epitaxy (HVPE) growth tool to produce high-quality 200mm-diameter HVPE GaN-on-QST (QROMIS Substrate Technology) templates.

This follows Kyma's demonstration in 2016 of 150mm-diameter GaN-on-QST templates in partnership with QROMIS Inc of Santa Clara, CA, USA (formerly Quora Technology Inc, spun off from Micron Technology in March 2015) and Kyma's commissioning of its K200 HVPE growth tool in June 2017.

The demonstrated 200mm-diameter HVPE GaN-on-QST template consists of 10 μ m of HVPE gallium nitride (GaN) grown on a 5 μ m metal-organic chemical vapor deposition (MOCVD) GaN-on-QST wafer provided by QROMIS. X-ray diffraction (XRD) rocking curve linewidths for the templates fall in the range 250–330arc-sec for the symmetric {002} and asymmetric {102} XRD peaks, respectively, which is consistent with high structural quality. Low wafer bow (~50 μ m) and smooth surface



A 200mm-diameter HVPE GaN-on-QST template.

morphology suggest that these materials should support high-performance device manufacturing.

Kyma says that its newly constructed K200 HVPE tool represents a first for the industry and was designed to enable uniform and rapid growth of high-quality GaN on a number of different substrates.

"We have successfully transferred the process for making high-quality GaN to our K200 HVPE tool," notes president & CEO Keith Evans.

"We are currently engaging with customers interested in large-diameter GaN-on-QST templates."

Kyma and Qromis are partnered for this work under a Kyma-led US Department of Energy Phase IIB Small Business Innovation Research (SBIR) award (no. DE-SC0009653).

Fabless firm QROMIS recently began manufacturing 200mm QST

substrates and GaN-on-QST wafers using its foundry partner Vanguard International Semiconductor (VIS), which is planning to offer GaN power device manufacturing services on 8"-diameter QST platform in 2018.

"QROMIS' CMOS-fab-friendly 200mm-diameter QST substrates and GaN-on-QST wafers represent a disruptive technology, enabling GaN epitaxy from a few microns to hundreds of microns for GaN power applications from 100V to 1500V-or-beyond GaN power devices, in lateral, quasi-vertical or vertical forms, on the same 8" or 12" production platform at silicon power device cost," says QROMIS co-founder & CEO Cem Basceri.

"Kyma's K200 HVPE technology represents an important value-add to QST-based GaN power device manufacturing by enabling the low-cost deposition of a thicker and lower-defect-density GaN surface than is practically achievable using MOCVD growth alone."

Kyma is also teamed with a semiconductor equipment OEM to manufacture K200 HVPE tools for customers who prefer to bring Kyma's HVPE GaN growth process in-house.

www.qromis.com
www.kymatech.com

Niacet begins supplying high-purity anhydrous hydrogen chloride

After producing and supplying technical-grade AHCL (anhydrous hydrogen chloride) since 2013, Niacet Corp of Niagara Falls, NY, USA (a member of the American Chemistry Council with ISO 9001 and GMA Safe certifications that produces organic salts for the food, pharmaceutical, electronics and

technical industries) has entered the high-purity AHCL business serving the pharmaceutical and semiconductor industries. The high-purity ULSI product (with minimum purity of up to 99.999%+) will be available from its new manufacturing unit in Niagara Falls.

To complement this investment,

Niacet purchased the anhydrous hydrogen chloride packaging and distribution business of Alexander Chemicals. Niacet is now offering a full range of packaging options, from cylinders to tube trailers, for the technical, pharmaceutical and semiconductor industries.

www.niacet.com

Oxford Instruments announces winner of 2017 Sir Martin Wood Prize for Japan

The UK's Oxford Instruments plc has announced associate professor Michihisa Yamamoto of the University of Tokyo's Quantum-Phase Electronic Center (QPEC) and of the Center of Emergent Matters at Japan's Institute of Physical and Chemical Research (RIKEN) as winner of the 2017 Sir Martin Wood Prize.

Yamamoto was awarded the prize for his work on the 'Control and detection of quantum phase in semiconductor nanostructures'. This involved detecting and controlling quantum interference effects of travelling electron waves in nanostructures, opening a path to 'Quantum Electron Wave Technology'.

Yamamoto was awarded with the medal, certificate and a cash prize of ¥500,000 at the British Embassy in Tokyo by British ambassador Paul Madden on 10 November and gave a lecture on his work at the 2017 Millennium Science Forum



Dr Michihisa Yamamoto with Paul Madden, British ambassador to Japan.

organised by Oxford Instruments and chaired by professor Maki Kawai, director general of the Institute for Molecular Science. Guest speakers at the event were professor Eleanor Campbell from Edinburgh and Griff Jones, head of Science, Innovation and Global Challenges at the British Embassy.

The Millennium Science Forum was established in 1998 to promote sci-

entific exchange between Britain and Japan and award the Sir Martin Wood Prize to a young researcher from a Japanese university or research institute, who has performed outstanding research in the area of condensed matter science. The prize is named after Sir Martin Wood, founder & honorary president of Oxford Instruments plc.

The selection committee consists of eight senior professors from Japanese universities and is chaired by professor Hidetoshi Fukuyama of Tokyo University of Science.

The winner of the Sir Martin Wood Prize receives ¥500,000 in cash and the opportunity to give a series of lectures in UK and EU Universities, including Oxford University.

www.oxford-instruments.com

www.qpec.t.u-tokyo.ac.jp/yamamoto/english

www.cems.riken.jp/en/laboratory/qedru

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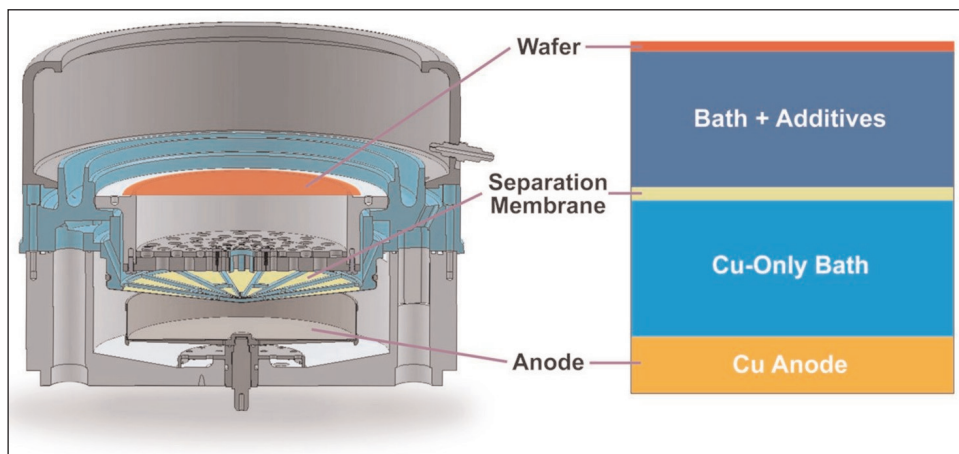
	Qty	ID	Diam	Type
MANIUM	1	1394	25.4mm	P
LA GLASS	22	2483	25.4mm	Undoped
PHENE	500	444	50.8mm	P
INGAAS EPI ON INP	267	446	50.8mm	N
ITO GLASS				
LINBO3				
NITRIDE ON SILICON				
SAPPHIRE				
SILICON				

ClassOne slashes via liner plating costs

ClassOne Technology of Kalispell, MT, USA (which manufactures Solstice electroplating systems for $\leq 200\text{mm}$ wafers), has unveiled a new plating technique that is said to provide significant cost reductions for compound semiconductor manufacturers who use gold plated vias.

"We have compound semiconductor customers that use gold for via liners who are switching to copper to save money," says president Kevin Witt. "When they implement the copper plating on our Solstice ECD system with the ClassOne CopperMax chamber, dramatic cost reductions are obtained — on the order of 70% lower metallization cost compared with their previous approach," he reckons.

The new savings result not just from replacing the bulk of the gold with copper but also from the additional copper-plating economies made possible by the unique CopperMax chamber design, says Witt. Consumables have been the largest single cost factor in copper plating, he adds, because the process required large volumes of expensive organic additives over the lifetime of the bath. Now, by employing a cation-exchange



CopperMax copper plating chamber for ClassOne Technology's Solstice electroplating system.

membrane to separate anolyte from catholyte, the CopperMax chamber effectively isolates additives from the anode, drastically reducing additive depletion and hence usage. Also, since the CopperMax bath remains clean much longer, bath life is extended by 15–20x, it is reckoned, resulting in increased uptime and throughput.

CopperMax also reduces copper anode expenses. Instead of solid machined copper material, the new chamber can use less expensive bulk anode pellets, cutting anode costs by over 50%. Plus, since the pellets provide much greater

surface area, the maximum plating rates can be increased.

In addition to the process improvements, the net result is a significant reduction in cost per wafer: compared with previous copper processes, the CopperMax chamber reduces additive consumption by over 95%, resulting in an overall cost-of-ownership reduction of almost 50%, it is estimated. Also, for users who switch from gold to copper via liners and do the plating on a Solstice system with CopperMax, the costs are cut by about 70%.

www.classone.com/products

CRAIC adds deep UV laser sources to 20/30 PV UV–visible–NIR microspectrophotometers

CRAIC Technologies Inc of San Dimas, CA, USA has introduced ultraviolet laser sources for use with its 20/30 PV microspectrophotometer. The major application will be to serve as an excitation source for fluorescence and photoluminescence (PL) microspectroscopy. Both methods require intense light sources and, by exciting in the ultraviolet, more materials can be caused to emit photons via a luminescent process.

"The addition of ultraviolet lasers as light sources expands the capabilities of CRAIC Technologies

microspectrophotometers," says president Dr Paul Martin. "Previously, we had offered only visible and NIR range lasers as light sources. Now, however, we can include UV lasers in the lineup. This means we now have the ability to excite microscopic sample areas in the ultraviolet, visible and near-infrared (UV-vis-NIR) region and measure the photoluminescence spectrum," he adds. "In response to customer requests, our fine team of engineers have dramatically expanded the capabilities of the 20/30 PV in terms of both fluor-

escence and photoluminescence microspectroscopy."

The UV lasers can be used either as powerful light sources for fluorescence microspectroscopy or can be incorporated in the new Photoluminescence package. The UV laser output is focused onto a microscopic sample area and the light that is emitted from that area is collected and measured by the 20/30 PV microspectrophotometer. The fluorescence or photoluminescence spectra are then analyzed.

www.microspectra.com/products/2030-microspectrophotometer



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Nanometrics' board names Pierre-Yves Lesaicherre as president & CEO

Nanometrics Inc of Milpitas, CA, USA (a supplier of process control metrology and inspection systems) says that Dr Pierre-Yves Lesaicherre is joining the firm as its president & CEO, and has also been elected to the board of directors (both effective on 27 November).

"His leadership experience in the semiconductor industry extends over 20 years, and his wealth of technological expertise in the semiconductor capital equipment industry surpasses well over 30 years," comments chairman Bruce C. Rhine. "Pierre-Yves has demonstrated operational excellence, technology leadership, and strategic vision, most recently as CEO of Lumileds, a \$2bn-revenue company," he adds. "Pierre-Yves' experience managing billion-dollar growth businesses makes him exceptionally well suited to lead the company through our next phase of growth."

Lesaiherre was most recently CEO of Lumileds — a provider of LED solutions for the automotive, mobile, television, Internet of Things (IoT) and illumination markets — from 2012 until 2017, during which time LED revenue nearly doubled despite the challenging competitive environment, and the firm grew to \$2bn in revenues, with over 9000 staff.



New CEO Pierre-Yves Lesaicherre.

Prior to Lumileds, Lesaicherre was senior VP & general manager at NXP Semiconductors from 2006 until 2011, where he managed three semiconductor product lines totaling over \$700m in sales. From 1998 until 2006, Lesaicherre served in various technical, product and business line management positions at Philips Semiconductors, following five years at NEC Semiconductor in DRAM process development.

Lesaiherre holds an MBA from INSEAD, and holds both a PhD and MS in Materials Science from the National Polytechnic Institute of Grenoble, France.

"Nanometrics has a reputation for technology and market leadership, along with an incredible culture

that focuses on customer results while also enjoying a positive team atmosphere," comments Lesaicherre. "The combination of great technologies and products, a solid track record of profitable revenue growth and industry out-performance, and a group of very talented employees in a dynamic company culture, present an exciting CEO opportunity," he adds.

"His impressive track record as the CEO of a large company focused on profitable growth in a highly competitive environment, combined with his deep technical background in semiconductor manufacturing and solid business operations experience, are a great match to the challenges of continued growth and shareholder value creation at Nanometrics," comments current CEO Dr Timothy Stultz.

"We appreciate and thank Tim for his leadership over the last 10 years as CEO," says Rhine. "Tim has done an exceptional job of growing Nanometrics, creating shareholder value and positioning the company as a leader in the industry," he adds. "Tim has agreed to continue to serve on the board of directors and work closely with Pierre-Yves to ensure a smooth and effective CEO transition."

www.nanometrics.com

Nanometrics announces \$50m share repurchase program

Nanometrics Inc of Milpitas, CA, USA (a supplier of process control metrology and inspection systems) says that its board of directors has authorized the repurchase of up to \$50m of the company's common stock.

"Nanometrics' management team and board of directors firmly believe in our long-term growth prospects. We are also committed to efficient capital allocation, as demonstrated today with this sig-

nificant stock repurchase authorization," says chairman of the board Bruce C. Rhine. "We intend to utilize our healthy balance sheet and the ability to generate free cash flow, given our outlook for revenue growth, to repurchase up to \$50m of the company's common stock," he adds. "We believe the company has the financial position to invest for future growth, as well as fund this stock repurchase program, which we

believe will create further value for our stockholders."

This \$50m program is effective immediately. Share repurchases under this program may be made through open market and privately negotiated transactions, at times and in such amounts as management deems appropriate.

As of 30 September, Nanometrics had \$140m in cash and cash equivalents and about 25.6 million shares outstanding.

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BluGlass presents latest RPCVD data at wide-bandgap workshop; files new patent application

BluGlass Ltd of Silverwater, Australia presented its latest remote-plasma chemical vapor deposition (RPCVD) technical data at the Workshop on Ultra-Precision Processing for Wide Band-Gap Semiconductors (WUPP-2017) in Monterey, CA, USA (6–7 November).

BluGlass is commercializing its proprietary low-temperature remote-plasma chemical vapor deposition (RPCVD) process for manufacturing indium gallium nitride (InGaN)-based LEDs, power electronics and solar cells, offering advantages including higher performance and lower cost, it is claimed.

Chief operations & technology officer Dr Ian Mann presented a talk 'RPCVD of III Nitrides: Growth and Applications', where he introduced new performance data on RPCVD p-GaN for green LEDs and power electronics applications and also discussed preliminary RPCVD InGaN results for red-green-blue (RGB) LEDs and solar applications.

"Our latest results and technical progress have stemmed from the hard work of the BluGlass technical team and the recently upgraded BLG-300," says Mann. "We will continue to further develop and market RPCVD in these key areas to attract new customers and strategic part-

ners whilst deepening our existing industry collaborations," he adds.

Also, BluGlass has filed a new provisional patent application and will continue to strategically file patent applications as key advances are demonstrated.

"Following recent advancements of the RPCVD technology and our new patent application filings, BluGlass is now in a position to actively build and enhance our industry presence and present the competitive RPCVD capabilities as we continue to advance our commercialization and marketing plans," says managing director Giles Bourne.

www.bluglass.com.au

SMI recruits scientists to expand MOCVD, ALD & HVPE product development

Structured Materials Industries Inc (SMI) of Piscataway, NJ, USA — which provides chemical vapor deposition (CVD) systems, components, materials, and process development services — has recruited two scientists to its R&D team. Dr Serdal Okur and Dr Arul C. Arjunan will work to develop advanced semiconductor materials and associated equipment by implementing technologies in metal-organic chemical vapor deposition (MOCVD), atomic layer deposition (ALD), hydride vapor phase epitaxy (HVPE) and related technologies.

"The addition of Dr Okur and Dr Arjunan comes at an important time for our R&D team as we look to pioneer new technology and products into the marketplace," says president Dr Gary S. Tompa. "These two individuals come from extraordinary backgrounds that, when combined, should make a synergistic impact on the organization."

Okur has a PhD in electrical and computer engineering from Virginia Commonwealth University with a background in physics and material



Dr Serdal Okur and Dr Arul C. Arjunan.

science. Prior to working for SMI, he was a postdoctoral fellow at Center for High Technology Materials, University of New Mexico, where he investigated novel light-emitting devices, such as LEDs and vertical-cavity lasers, and optical processes in these types of devices. He has expertise in compound, nitride and oxide semiconductor materials and devices, as well as in nanowire growth and processing. His recent work includes gallium oxide-based electronic and optoelectronic devices, supported by NASA and the US Department of Energy. He is author/co-author of 46 scientific articles.

Arjunan has a PhD in physics from Anna University in Chennai, India. He brings over 16 years of industrial and academic experience in areas

involving crystal growth (thin and thick film), instrumentation, and processing related to wide-bandgap materials (silicon carbide, III-nitrides, diamond, oxide and organic molecular materials) as well as narrow-bandgap materials (SiGeSn).

Arjunan has served as a principal investigator of many projects related to wide-bandgap semiconductor material processing for electronics and nuclear physics, with total funding worth over \$6.5m. Before SMI, he spent 11 years at semiconductor firm Sinmat Inc, where he most recently oversaw technology developments and marketing responsibilities related to wide-bandgap materials, serving as director of technology & marketing. Arjunan's career began as a post-doctoral scientist at the University of South Carolina and University of Florida, specializing in silicon carbide, III-N material growth, wafering and polishing. He has 46 publications in journals, 10 patent applications, an R&D 100 Award (2008), and has presented in over 60 conferences.

www.smicvd.com

CVD supplies Naval Research Laboratory with deposition equipment for 2D transition-metal dichalcogenides

CVD Equipment Corp of Central Islip, NY, USA (a designer and maker of chemical vapor deposition, gas control and other equipment for developing and manufacturing materials and coatings) has supplied 2D semiconductor deposition equipment to the US Naval Research Laboratory (NRL).

Earlier this year, CVD was awarded a contract to supply NRL with deposition equipment to further its research in novel 2D transition-metal dichalcogenide (TMD) materials. The equipment was received at the customer's facility in October.

Two-dimensional TMD semiconductors, including molybdenum disulfide (MoS_2), tungsten diselenide (WSe_2) and more exotic

materials such as bismuth telluride (Bi_2Te_3), are the subject of vigorous R&D. CVD says that its equipment provides the ability to produce atomically thin 2D films of optoelectronic semi-conductor materials with diverse physical properties that are not achievable in bulk semiconductors. Applications include flexible electronic and optoelectronic devices, biosensors, battery technology, valleytronics, and spintronics.

"The capabilities of CVD Equipment Corporation allowed us to specify exactly what we needed for our deposition equipment to develop new and innovative processes to optimize the synthesis and properties of this emerging class of atomically thin materials,"

comments Dr Berend Jonker, senior scientist at NRL's Materials Science & Technology Division.

CVD Equipment has shipped multiple systems for the synthesis of 2D TMDs this year, with more 2D TMD deposition systems in backlog and due to ship in 2018. The firm says that it works closely with customers in the design phase to ensure adherence to specifications and requirements of end users. Its vertically integrated engineering and manufacturing capabilities enable application-specific equipment that can be configured to suit distinct research and production needs.

www.firstnano.com/applications/transition-metal-dichalcogenides-tmds
www.cvdequipment.com

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Samsung introduces D-series Special Color chip-on-board LED packages for color-sensitive commercial lighting

South Korea's Samsung Electronics Co Ltd has launched the 'D-series Special Color' family of chip-on-board (CoB) LED lighting packages, which are engineered to bring out the most desirable color tones of objects whose viewing is particularly color-sensitive, making them optimal for many commercial lighting applications.

Through spectrum engineering, color spectra within the D-series have been tuned to deliver high color vividness, without the use of ultraviolet (UV) lighting chips. The packages deliver a TM-30 gamut index (Rg) of over 110, ensuring lighting with outstanding color and whiteness, says the firm. Currently, to provide almost as vivid color, many LED lamps instead use near-UV chips, which can damage the human eye and clothing after repeated exposure. Near-UV rays can display vivid colors, but only when the whites in the object being illuminated contain fluorescent



brightening agents. An alternative is to use expensive ceramic discharge metal-halide (CDM) lamps that do not last as long.

As color has a significant influence on consumer purchase decisions, the new D-series now offers lighting options for three of the most important segments of commercial goods: fashion (stylish clothing), meat and vegetables. The LED packages for each segment have been designed with the most effective combination of phosphors to

illuminate what is being sold in the most appealing way, claims the firm. To determine the most attractive color rendering and saturation levels based on subjective perceptions, Samsung ran extensive preference tests among many demographic groups worldwide.

"Our new D-series Special Color brings much greater value to the commercial lighting industry, reaching far beyond the ordinary image-rendering benefits of LEDs," says Jacob Tarn, executive VP of the LED Business Team at Samsung.

The D-series Special Color has been in mass production since late October. Packages generate 13–33W to create what is said to be the best combination of LEDs and phosphors for each commercial segment. Further, they come in the same shapes and sizes as the standard Samsung D-series to simplify retrofitting of existing luminaires.

www.samsung.com

Seoul Semiconductor first to receive low-risk eye-safety certification for natural-light LEDs

Seoul Semiconductor says that SunLike (which is claimed to emit light that comes closest to sunlight) has received an RG-1 Eye Safety certification based on the safety of its light source, and has been recognized for the highest level of safety among 25W COB-type LEDs.

Eye Safety certification is a rating based on safety from analyzing the LED wavelengths. In Europe, certification is essential, and the light source must rate higher than the RG-3 level otherwise eye-sight may be impaired if stared at directly, in which case the finished product must carry a warning label.

SunLike received the RG-1 grade in Eye Safety certification for its natural-light LED, which applies TRI-R technology from Toshiba Materials Co Ltd of Yokohama city,

Japan. The RG-1 grade is granted to a safe light source for which there is no biological risk, even if our entire lives were spend exposed to the light source. In particular, achievement of the RG-1 grade for the first time for a 25W single light source widely used for commercial and residential lighting is significant, says Seoul Semiconductor, as a natural light source with the highest level of safety has been commercialized.

Interest in the impact of light on health has increased since the award of the Nobel Prize in Physiology or Medicine to professor Jeffrey C. Hall of Maine University, professor Michel Rosbash of Brandeis University and professor Michael Young of Rockefeller University of USA, acknowledging the causal

relationship between biorhythms and human health. So, the SunLike natural-light LED is in the spotlight as a next-generation light source, Seoul Semiconductor reckons.

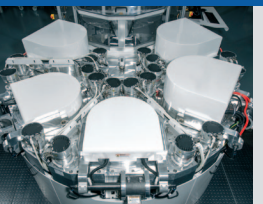
In addition, SunLike is not prone to the blurring problem that occur in most other artificial light sources. As a result, the unique color of an object appears at its best and the three-dimensional appearance of the object remains intact. SunLike is hence expected to be widely applied not only in places requiring a healthy lighting environment (such as home, offices, schools, medical institutions etc) but also in commercial facilities, museums, clothes stores, distribution stores etc, which must reproduce the natural color and texture of an object.

www.SeoulSemicon.com

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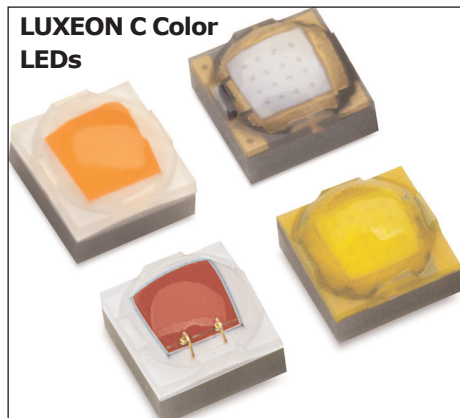
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Lumileds boosts output of color LED portfolio

Lumileds of San Jose, CA, USA says that it has considerably improved the flux across its color LED family. Performance improvements to the flagship LUXEON C Color Line include 20% higher lumen output in its LUXEON C Green and Cyan compared with the previous generation. The LUXEON C Red-Orange features a 12% flux increase and the LUXEON C Red an 8% flux increase.

"As the demands on our customer's fixtures become more challenging, we need to ensure our Color portfolio enables them to meet these demands," says Jennifer Holland, product line director of the LUXEON C Color Line. "This increase in flux across several key colors will give our customers a sig-



nificant boost in performance in existing designs as well as allow them to start from a higher level of performance in new designs."

Specifically engineered for color mixing through its standard focal length, the LUXEON C Color Line is suited to use in architectural, stage

lighting, emergency vehicle lighting, and color tunable lamps and fixtures. All LUXEON C Color Line LEDs are hot tested at 85°C to ensure performance at application conditions. Its thermal resistance (claimed to be the lowest in the industry, at 2.8°C/W) also helps to reduce heat-sink cost — or allows LEDs to be driven harder for higher output than is achieved with competing LEDs, it is claimed.

Extending these performance upgrades to other lines within the LUXEON Color LED family, Lumileds is also announcing 20% flux improvements for the Green and Cyan colors in the LUXEON Z Color Line and the LUXEON Rebel Color Line.

www.lumileds.com/products/color-leds

New office & innovation center opened in Shanghai Automotive, Specialty and Illumination business units to collaborate with lighting developers

LED maker Lumileds of San Jose, CA, USA has held an event to celebrate officially opening the doors of its new office and innovation center in Shanghai. The firm says that it is making a key investment in pursuing further growth in one of the biggest global markets in automotive, illumination and mobile applications.

The new office brings together Lumileds' three business units — Automotive, Specialty and Illumination — in one building for continued collaboration, since companies developing lighting applications require a partner that can collaborate with them to extend the boundaries of lighting, says Lumileds.

"Establishing a strong base in China demonstrates our commitment to the market," says CEO Mark Adams. "Lumileds wants to continue to make positive contributions to the region, and this new facility is testament to that goal."



The main entrance of Lumileds' new office in Shanghai, China (Building 1-A, No.19 & 20, Lane 299, Wenshui Road, JingAn District).

The grand opening was attended by Lumileds' senior leaders, as well as local Chinese dignitaries, including Zhou Haiying (deputy head of Jin An District) and Zhou Qun (chairman of

Shanghai Shibe High-Tech Co Ltd). Following the opening ceremony, Lumileds gave guests a tour of the new office and innovation center.

www.lumileds.com



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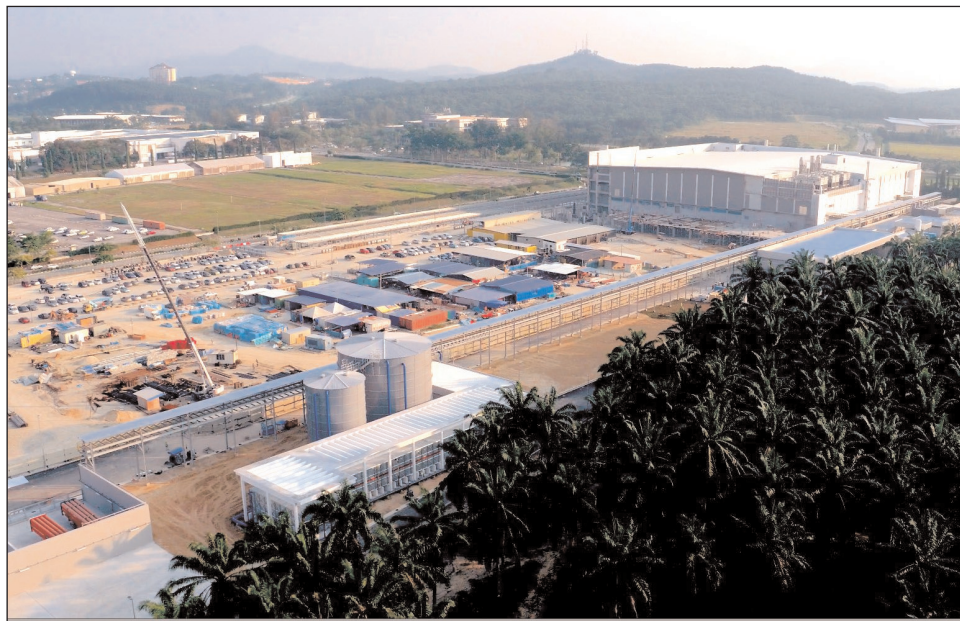
Osram's new LED chip plant in Malaysia enters operation €370m first stage to be followed by two additional expansions

Lighting company Osram GmbH of Munich, Germany says that its new LED chip factory in Kulim, Malaysia has begun operation on time (within the targeted end-2017), just 2 years after the announcement (in November 2015, as part of its 'Diamond' innovation and growth initiative) and 18 months after groundbreaking. "We are both on schedule and within budget," noted Osram Licht AG's CEO Olaf Berlien at the opening ceremony in Kulim.

"Given our enormous recent growth rates of 19% in the LED business, we are pleased to have the new production capacities," he adds. "Our investment in Kulim also attests to the technology shift and our transition to becoming a high-tech corporation: at the beginning of this decade, conventional lighting still accounted for 80% of Osram's business. Today, two-thirds of our sales are based on optical semiconductors."

The new factory is modular and hence expandable. A total of €370m has been invested in the first stage of completion. Osram can expand the factory in two additional stages, entailing total investment of up to €1bn, including expansion of LED assembly capacities in Osram's global factory alliance.

"With one week's production we could completely retrofit the street lighting of the metropolises New York, Rio, Hong Kong and Berlin with LEDs. To upgrade the entire street lighting worldwide, Kulim would have to produce LEDs five and a half years long exclusively for this purpose," says Aldo Kamper, CEO of the Osram Opto Semiconductors business unit in Regensburg, Germany. "Energy savings of up to 80%, compared to conventional street lights, can be achieved with LED lighting. In addition, LED has better light color stability and can be more quickly dimmed and adjusted, so that empty streets or



Osram's new LED chip factory in Kulim.

sidewalks do not always have to be illuminated with full brightness," he adds.

The Kulim plant will initially produce blue LED chips (which, via a phosphor-based converter layer, can generate white light) for general lighting purposes, such as public street lighting, but also for façade lighting, private and commercial interior and exterior lighting, or for billboards — as well as for special applications such as horticulture lights. The global LED market for general lighting is estimated to be €6bn in 2018, roughly 6% of which is for street lighting. An average growth rate in the market of 7% per annum is foreseen through 2020. The overall market for optoelectronic components — including general lighting — will be €17.5bn in 2018.

In the medium term, the plan is to also produce LED chips for premium applications, such as automotive lighting and video projection. Due to the new plant being a green-field development, no compromises had to be made in its design, in addition to featuring the latest technology. Compared with 4-inch wafer technology, the 6-inch production systems produce 125%

more LED chips per wafer in a single cycle.

Osram is currently investing worldwide in the expansion of the existing six sites in its LED production network. It is therefore also expanding its plant in Regensburg, which currently has about 2500 staff but will hire up to 1000 extra staff. Premium LED chips and laser diodes (used, for example, in high-quality car headlights) will be made there as well as infrared diodes for sensors (for applications including facial recognition in mobile phones, or in cars for intelligent assistance systems such as proximity control).

Osram will also be expanding its site in Schwabmünchen, Germany. In the future, it will manufacture LED primary materials in clean-rooms there. In addition, Osram has another plant for LED primary products in the US city of Exeter. In Wuxi, China, Osram is expanding its capacity for assembling LED chips into complete LEDs (with a housing and partly with primary optics). LED chips are also manufactured and assembled in Osram's plant in Penang, Malaysia (just 30km away from Kulim).

www.osram.com/cb/about-osram/kulim-factory

Osram and Continental planning JV for intelligent lighting solutions in the automotive sector

Osram Continental to combine expertise of Osram and Continental in solid-state lighting and light control

Lighting firm Osram GmbH and automotive technology firm Continental AG in Germany are to establish a Munich-registered 50:50 joint venture Osram Continental GmbH combining lighting technology with electronics and software to develop, manufacture and market intelligent lighting solutions for the automotive industry.

The aim is to generate annual sales in the mid-triple-digit-million-euro range with a workforce of around 1500 and 17 locations worldwide. Dirk Linzmeier (CEO) from Osram and Harald Renner (CFO) from Continental have been named as designated managing directors. The JV is scheduled to start in 2018, subject to final agreement on the binding contracts and anti-trust approvals.

Osram will transfer its automotive solid-state lighting (SSL) module business over to the JV. Continental will be incorporating its light control business from its Body & Security business unit. This will lead Osram Continental to combine semiconductor-based lighting modules, advanced electronics, optics and software expertise with access to sensor technology and innovative light sources. Osram Continental will therefore be able to offer a broad range of end-to-end, innovative lighting solutions, designed especially for headlight and tail-light applications. The intention is to work together to design coordinated and innovative products and solutions, and bring them to market more quickly. The JV will operate on the market as a standalone company.

"The joint venture is a sign that Osram is focusing its efforts consistently on digitalization," says Osram Licht AG chief technology officer Stefan Kampmann. "Continental's expertise in software and electron-



Hans-Joachim Schwabe, CEO of Osram's Specialty Lighting business unit (left,) and Andreas Wolf, head of Continental's Body and Security business unit (right).

ics is the perfect complement to our technology leadership in automotive lighting. It will create a forward-looking company for digital automotive lighting," he adds.

"The pace of innovation in the automotive industry lighting segment is rapid, and software is strengthening this dynamic," says Continental executive board member Helmut Matschi. "While conventional lighting expertise remains important to our customers, the addition of electronics to enable new light functions is taking on increased significance. The joint venture will systematically combine these two areas and raise them to a new level."

The automotive industry lighting market is in the grip of technological change, says Osram. Similar to the situation with general lighting, the market is moving toward semiconductor-based lighting solutions. Due to increasingly intelligent light functions in vehicles as well as new light-based design and application options, semiconductor-based technology, software and electronics are gaining progressively in importance, the firm adds. Each year, growth in the market for

semiconductor-based front lighting solutions is in the double-digit range. Market studies indicate that by as early as 2025 more than half of new cars worldwide could be fitted with semiconductor-based lighting solutions.

"Intelligent lighting solutions allow vehicle manufacturers a greater degree of flexibility when it comes to design, and help them to optimize development costs," says Andreas Wolf, head of Continental's Body & Security business unit. "The global presence of the Osram Continental joint venture is allowing us to cooperate closely with our customers in order to develop solutions exactly tailored to their needs... We have two technology companies combining their complementary expertise in the context of a joint venture to offer customers a unique range of solutions," he adds.

"Digitalization is bringing about new potential applications in automotive lighting and hence tremendous opportunities... Thanks to our combined offering of lighting and electronics solutions, we will be able to offer automotive sector customers cutting-edge products from a single source," says Hans-Joachim Schwabe, CEO of Osram's Specialty Lighting business unit.

"We will be in an even better position to drive forward innovations by working closely with the automotive industry to integrate lighting, sensor technology and electronics seamlessly in a single application," he adds. "This will allow us to drive forward new intelligent light functions, such as the combination of lighting and sensor technology in a module or light-based communication between the driver, other road users and the vehicle surroundings."

www.osram.com

www.continental-corporation.com

Nakamura receives Mountbatten Medal at IET's 2017 Achievement Awards for pioneering the development of blue LEDs and lasers

On 15 November, the Institution of Engineering and Technology (IET) — one of the world's largest engineering institutions (with over 168,000 members in 150 countries) — named the winners of its 2017 Achievement Awards, including the Mountbatten Medal for Nobel Prize winner professor Shuji Nakamura for his pioneering work to develop blue LEDs and lasers.

The IET Achievement Awards recognise individuals worldwide who have made exceptional contributions to the advancement of engineering, technology and science in any sector, through research and development in their respective technical field or through their leadership of an enterprise.

Nakamura used novel indium gallium nitride (InGaN) growth processes to enable the commercialization of blue LEDs as high-efficiency, low-power light sources, to which he holds the patent. He was also the first to demonstrate group III-nitride based high-brightness blue/green LEDs and violet laser diodes. His LED inventions have been used for multiple applications, including TV and mobile phone screens, due to their lower energy consumption, and enabled the development of the Blu-ray DVD.



"Professor Nakamura's inventions have resulted in highly successful commercial LEDs that not only save considerable energy consumption, but have revolutionized new technology such as the Blu-ray disk," commented IET president Nick Winser.

"Since the invention of the blue LED in 1993, many researchers joined the field and created many applications for solid-state lighting such as mobile phone screens, LED TV, and large displays," said Nakamura. "But the application with the greatest impact to the world's energy consumption is that of general illumination, recognizing that one quarter of all the world's electricity is used for lighting," he adds. "LED light bulbs are more than ten

times efficient than incandescent bulb, and they last for 50 years. At their current adoption rates, by 2020 LEDs can reduce the world's need for electricity by the equivalent of nearly 60 nuclear power plants. I hope that the invention of blue LED could contribute to overcome the global warming issues."

The Mountbatten Medal was established by the National Electronics Council in 1992 and named after its first chairman, The Earl Mountbatten of Burma, who was president of the Institution of Electronic and Radio Engineers (IERE) in 1947–48 and 1961–62, which merged with the Institution of Electrical Engineers (now the IET) in 1998. He was also an Honorary Fellow.

The Achievement Awards are part of the IET's Achievement Awards and Scholarships program, which this year provided over £1m in awards, prizes and scholarships to celebrate excellence and research in the sector and encourage the next generation of engineers and technicians. All IET awards seek to inspire and reward engineering excellence, including apprentices at the start of their careers, through to reputable, established professional engineers and technicians.

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ProPhotonix to distribute Integrated Optics laser modules

ProPhotonix Ltd of Salem, NH, USA, a designer and maker of LED illumination systems and laser diode modules for OEMs and medical equipment companies (as well as a distributor of laser diodes for Ushio, Osram, QSI, Panasonic and Sony) has announced a new partnership to distribute the laser module range of Integrated Optics UAB of Vilnius, Lithuania (an ISO9001:2015-certified manufacturer of compact laser sources for spectroscopy and LiDAR applications).

As a provider of laser technologies to OEMs worldwide, ProPhotonix offers a range to suit specific application needs. Integrated Optics' Matchbox and ARA laser series will complement its existing laser range, providing additional configurable laser module platforms for a broad range of applications and opening up new markets for ProPhotonix. Customized solutions are also available for more specific applications.

The MatchBox Series encompasses continuous-wave lasers, four-wavelength diode combiners and Q-Switch nanosecond lasers. Offering simplicity of integration and ease of use, the compact series provides power, consistency and high performance in one of the smallest packages in the world, it is claimed. With over 150 off-the-shelf product configurations, the laser module platform serves applications including microscopy, spectroscopy (fluorescence spectroscopy, laser-induced breakdown spectroscopy (LIBS) and Raman spectroscopy), medical diagnostics, flow cytometry, LiDAR, metrology, holography, and UV curing.

The ARA series of high-power wavelength combiners offers an original design incorporating four Matchbox lasers of differing wavelengths in a single unit. The series is suited to microscopy and spectroscopy.

"There are clear synergies between our companies' approach to the laser module market," believes Integrated Optics' CEO Evaldas Pabreza. "ProPhotonix' global sales team allows for Integrated Optics

products to be offered to a much wider customer base," he adds.

"Like ProPhotonix, Integrated Optics offers configurable platforms as well as custom solutions to suit specific application needs," says Jeremy Lane, managing director of ProPhotonix Ltd UK. "As a result of this agreement, ProPhotonix

extends the range of products it offers to OEMs," he adds. "Several existing customers have already expressed an interest in solutions combining the technologies of our two companies, including a recent MatchBox qualification and order in the amount of \$185,000."

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Princeton Lightwave acquired by Argo AI

LiDAR sensors to extend range and resolution for self-driving vehicles in urban environments

Self-driving technology developer Argo AI LLC of Pittsburgh, PA, USA (a subsidiary of Ford Motor Company) has acquired Princeton Lightwave Inc (PLI) of Cranbury, NJ, USA, which makes lasers and indium gallium arsenide (InGaAs)-based near-infrared/shortwave-infrared (SWIR) single-photon detectors including LiDAR (light detection and ranging) sensors.

LiDAR sensors are crucial to creating a three-dimensional view of the world that helps autonomous vehicles find where they are on the road and detect other vehicles, pedestrians and cyclists, says Argo AI's CEO Bryan Salesky in a blog posting.

The technology that underpins Princeton Lightwave's LiDAR sensors — which already serve the commercial mapping and defense industries — can help Argo to extend the range and resolution

needed to achieve self-driving capability in challenging urban environments, reckons Salesky. Princeton Lightwave's technology also complements and expands the capability of LiDAR sensors already available to the automotive industry, he adds.

With the addition of Princeton Lightwave, Argo reckons that it is positioned to innovate in both sensor hardware and the interface between sensor and software, enabling it to achieve performance improvements that would not otherwise be possible. Princeton Lightwave's technology can help Argo to unlock new capabilities that will aid its virtual driver system in handling object detection in challenging scenarios, such as poor weather conditions, and safely operating at high speeds in dynamic environments, believes Salesky.

Salesky says that Argo is exploring

how to increase the range, resolution and field of view of LiDAR, while also looking to lower costs and manufacture these sensors at scale, and that it needs to continue making improvements through dedicated R&D aligned with its overall hardware and software strategy.

Argo's expanded team remains focused on accelerating the development of a virtual driver system that's mandated for SAE levels 4 and 5 autonomous driving — meaning that there's no driver behind the wheel. By collaborating with its in-house hardware and software developers, as well as its supply base, the firm aims to create LiDAR sensors that not only meet the demanding performance required for high-volume production but also are affordable.

www.princetonlightwave.com

www.argo.ai

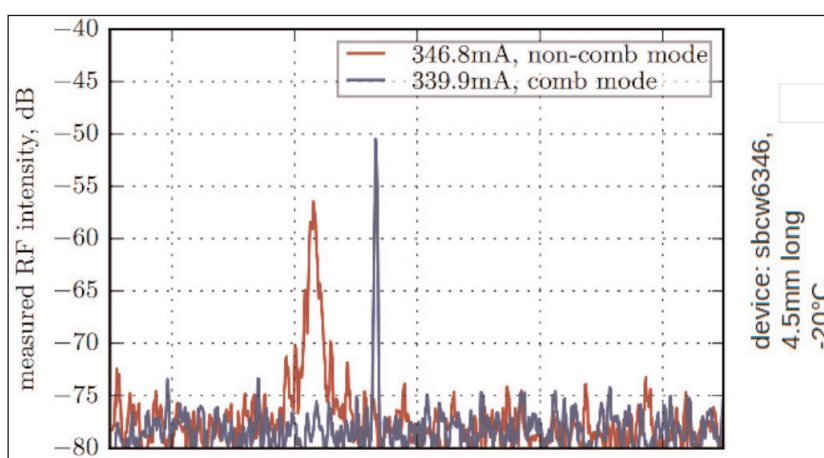
www.corporate.ford.com

Alpes Lasers launches frequency comb quantum cascade lasers

Alpes Lasers SA of St-Blaise, Switzerland — an engineering company pioneering advanced light sources, especially quantum cascade lasers (QCLs) — has introduced frequency comb quantum cascade lasers.

A frequency comb is a laser source whose spectrum consists of a series of discrete, equally spaced frequency lines. Originally developed at optical wavelengths (for which John L. Hall and Theodor W. Hänsch shared the 2005 Nobel Prize in Physics), frequency combs can be used for fast, high-sensitivity and high-resolution spectroscopy.

With up to 200mW of power spread over more than 100 comb teeth, Alpes Lasers' frequency comb quantum cascade lasers



Zürich, the firm's frequency comb quantum cascade laser is claimed to be the first commercially

cover the important mid-infrared 'fingerprint' region that is useful for identifying a wide range of complex molecules such as organic molecules, pollutants and/or explosives.

In development since 2012 in the Quantum Optoelectronics Group of professor Jérôme Faist at ETH

available laser of its type. Faist is "especially happy to see the quantum cascade laser comb come out from academia and become a commercial product, and in doing so help the development of broadband mid-IR spectroscopy".

www.alpeLasers.ch

Sofradir signs distributor ATD Electronique to extend European customer base for InGaAs-based SWIR detectors

Sofradir of Palaiseau near Paris, France — a subsidiary of Safran and Thales that makes infrared (IR) detectors for aerospace, defense and commercial markets — has entered into a distribution partnership with ATD Electronique of Chatou, Paris, France (a distributor of electronic components and CMOS image sensors) to extend its European customer base for short-wave infrared (SWIR) detectors based on indium gallium arsenide (InGaAs) technology.

European customers using Sofradir's InGaAs image detectors will now have the option to receive design support and supply-chain management services from ATD Electronique.

Sofradir says that its high-speed,

low-noise InGaAs SWIR detectors are suited to industrial applications (such as machine vision) where superior techniques are required to support increased production needs and faster inspection speeds. Other typical applications include semiconductor inspection, sorting of agricultural products, chemical purity analysis, and recycling and hot process monitoring for the glass or metal industries. This list is rapidly growing as industrial manufacturers increasingly solve challenges by using SWIR to go beyond the limits of conventional visible light cameras, says the firm.

Sofradir is partnering with ATD Electronique in offering customers "a new fully comprehensive technical and logistical support package

to integrate InGaAs detectors," says Frederic Aubrun, Sofradir's VP of sales. "The capacity of our products to meet increasing needs for wider scopes of vision, combined with ATD's know-how and experience in working with key manufacturers across Europe, constitute a high-added-value resource," he reckons.

Sofradir produces about 8000 IR detectors annually, with unit numbers steadily rising. Its InGaAs SWIR products are used in various industrial and surveillance sectors. ATD will help Sofradir to address market requirements for quick turnaround technical support, end-to-end imaging system expertise, and shorter procurement cycles.

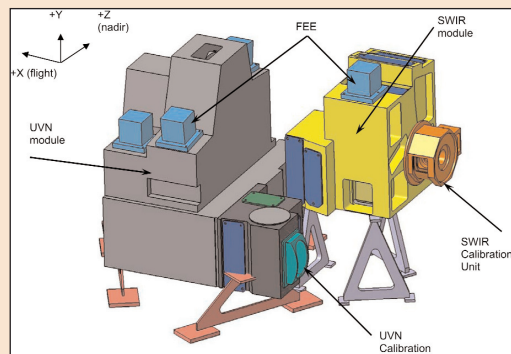
www.sofradir.com

Sofradir's Tropomi detector lifts off on Sentinel-5P satellite

Sofradir of Palaiseau near Paris, France — a subsidiary of Safran and Thales that makes infrared (IR) detectors for aerospace, defense and commercial markets — says that its detector Tropomi was among the instruments launched on 13 October on the Sentinel 5-Precursor satellite from the Plesetsk cosmodrome in Russia. The mission of Sentinel-5P (one of the fleet of satellites within Europe's Copernicus program) is to monitor Earth's atmosphere.

Sofradir's Tropomi detector is installed in the spectrometer of the same name; a monitoring instrument carried onboard the satellite, whose role is to map many trace gases such as nitrogen dioxide, ozone, formaldehyde, sulphur dioxide, methane, carbon monoxide and aerosols (elements affecting the quality of the air we breathe).

"Air pollution is a global challenge," says Sofradir's space activities manager Philippe Chorier. "So we are pleased to contribute to Sentinel 5-P's role in assuring the



continuity between Sciamachy, the imaging spectrometer on the Envisat satellite, and the future Sentinel 5 satellite, of which SWIR detectors for the high-resolution spectrometer UVNS are also in development at Sofradir."

According to the European Space Agency (ESA), once operational, Tropomi will map the global atmosphere daily with a resolution as high as 7km x 3.5km. Air pollution over cities can be detected at this resolution.

Sofradir's involvement in the Sentinel 5-P mission began in 2011 with the manufacturing of 1000x256 short-wave infrared

(SWIR) arrays (Saturn detectors) based on passive cooling and an optimized thermal interface in order to extend the operational lifetime of the detector. Flight models were delivered in 2012, performing in the range 140–150K with a capacity to collect data in the 2305–2385nm spectral band. This new large-format SWIR

detector in space comes after numerous other detectors called Neptune that Sofradir has previously supplied for launch and deployment in space (the Neptune detector is considered the 'little brother' of the Saturn detector, as the latter is twice the size). The Tropomi detector, which will be the first Saturn-based detector deployed in space, brings to 36 the number of Sofradir IR detectors that have been launched. Numerous other Saturn detectors are planned for launch in the near future through several other space missions, including HYSUI and PRISMA.

www.sofradir.com

CST receives £131,600 funding to develop wafer-based MWIR imagers with Glasgow and Gas Sensing Solutions Monolithic InSb PD/GaAs MESFET MWIR imager technology to be transferred into compact, commercially viable 4" wafer format

III-V optoelectronic foundry Compound Semiconductor Technologies Global Ltd (CST Global) of Hamilton International Technology Park, Blantyre, near Glasgow, Scotland, UK (a subsidiary of Sweden's Sivers IMA Holdings AB) is to lead the 'active-matrix, single-photon technologies on GaAs' project, in collaboration with the University of Glasgow and Gas Sensing Solutions. The project will develop light-weight, monolithic mid-wave infrared (MWIR) imagers, capable of detecting a single photon of IR light. This is primarily used to image gasses and diagnose their composition. Potential uses of the technology are widespread, once commercially viable, says CST.

"Current, commercially available MWIR imaging systems require expensive cryogenic cooling to operate," notes project lead Dr Laura Meriggi, device development engineer at CST Global. "They are bulky, use high-cost materials and are difficult to produce. However, if produced in a lower-cost format, they have the potential to be used to improve human health and



Project lead Dr Laura Meriggi, device development engineer.

Glasgow, with commercial partners QuantIC and Gas Sensing Solutions, has previously developed IndiPix, an MWIR imager that integrates InSb PDs with GaAs MESFETs

The Micro-System Technology (MST) group at the University of Glasgow, with commercial partners QuantIC and Gas Sensing Solutions (GSS),

safety in a wide range of markets, such as biomedical imaging and environmental monitoring," she adds.

"Potential applications range from military, home safety and the oil & gas industries, through to the monitoring of urban air quality and pollution."

has previously developed IndiPix, an MWIR imager that integrates indium antimonide (InSb) photo-diodes (PDs) with gallium arsenide (GaAs) metal-semiconductor field-effect transistors (MESFETs) to individually address each pixel. IndiPix was able to detect and image carbon dioxide concentration. It also operates at room temperature and eliminates the need for flip-chip bonding (the costly and low-yield manufacturing process that was previously used).

"The MWIR imaging project at CST Global will transfer the current monolithic MWIR imager technology into a compact, commercially viable 4" wafer format," says Meriggi.

"This will make it a highly cost-effective way of imaging trace gases."

The MWIR imaging project is government-funded through Innovate UK and the Engineering and Physical Sciences Research Council (EPSRC). CST Global is the project leader and will receive £131,600 contribution over 18 months from October 2017, with a total project fund value of £320,271.

www.CSTGlobal.uk

CST Global appoints ISO 9001:2015 quality & supply chain manager

CST Global has appointed Craig Robertson as quality and supply chain manager, reporting to the senior management team and responsible for on-going support and development of the ISO 9001:2015 Quality Management System (QMS). The scope of QMS applies to all 3" and 4" wafer fabrication and test processes, and is a pre-requisite of supplying customers operating in the data-center, cloud and telecoms markets.

"ISO 9001:2015 impacts the entire company, with all staff taking responsibility for their part in the process," notes Gary Palmer,



Craig Robertson.

VP operations. "Craig is to develop our existing business systems and processes through continuous improvement. This will extend to our key subcontractors, where Craig will introduce the management, production and test processes necessary for improved communication and control," he adds. "We operate in a complex and competitive market with an integrated supply chain, so Craig

also takes responsibility for business risk management."

Robertson's previous roles include project quality manager, supply chain & quality manager and operations manager in blue-chip, manufacturing companies in the UK, as both an employee and consultant. He also has experience of WEEE, CE, RoHS, and IPC compliance, as well as statutory, client, internal and industry requirements.

Robertson holds an Industrial Engineering with Manufacturing Systems degree, an MSc in IT Systems and an MBA from Strathclyde Graduate Business School.

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POET's Q3 revenue rebounds to \$715,420

DenseLight photonic sensors driving sales, as DFB, APD and NLW lasers begin sampling; ROSA on track for mid-2018 launch

For third-quarter 2017, POET Technologies Inc of Toronto, Canada and San Jose, CA, USA — a designer and manufacturer of optoelectronic devices, including light sources, passive waveguides and photonic integrated circuits (PIC) for the datacom and telecom markets — has reported revenue of US\$715,420, down on US\$861,545 a year ago but rebounding from US\$648,382 last quarter, primarily reflecting sales of photonic sensors made by Singapore-based subsidiary DenseLight Semiconductor Pte Ltd (acquired in May 2016) for test & measurement applications.

Gross margin was 51%, down on 63% a year ago but up from 50.5% last quarter. Net loss has risen from US\$2.8m (\$0.01 per share) both a year ago and last quarter to US\$3.6m (\$0.01 per share). However, this included non-cash, stock-based compensation of US\$1,088,170 and depreciation & amortization of US\$559,334, up respectively from US\$159,783 and US\$558,919 last quarter and US\$1,019,970 and US\$550,420 a year ago. During the quarter, cash and short-term investments fell from US\$9.8m to US\$7.5m.

"Our results in the third quarter continue to reflect our commitment to invest a majority of the company's engineering and production resources in new product development during 2017," says CEO Dr Suresh Venkatesan. Since May, POET has been granted six patents and submitted two new applications, bringing the total granted to 57 and the number of pending patent applications to eight.

During the quarter, POET launched new products from DenseLight, including distributed feedback (DFB) lasers for the 100G datacom market, avalanche photodiodes (APDs) for the 10G telecom markets, and a new family of narrow-linewidth (NLW) lasers for the distributed acoustic sensing (DAS) market.

"As planned and stated last quarter, we are currently sampling our DFB lasers, APD devices and NLW lasers with customers in China and Europe," says Venkatesan. "There is solid demand for these DFB lasers in both the silicon photonics and test & measurement markets as well as for our newly introduced NLW light modules for distributed acoustic sensing applications in the oil & gas and rail industries. Addi-

tional design, testing and qualification cycles are required prior to generating revenue, and we expect these products to augment our traditional sensing revenue in 2018. There has been an industry slowdown in the 10G GPON telecom market, so we are evaluating alternative sales channels for the APDs," he adds.

"We are making good progress and remain on track for a mid-2018 launch of our ROSA [receive optical sub-assembly] optical engine, which utilizes our dielectric photonics platform," Venkatesan continues. The integrated twin-waveguide 25G PIN detector under development has recently tested at bandwidths that exceed the requirements for 25Gbps channel rates. Combining four PINs into a single device (QuadPIN) will allow the optical engine to receive at a minimum speed of 100Gbps. Combining a quad-channel PIN detector and a quad-channel de-mux will form a critical piece of the ROSA. "Additional engineering, optimization and product qualification are required to complete the development of the ROSA optical engine," concludes Venkatesan.

www.poet-technologies.com

CST Global appoints China field application manager to support OEM, distribution and manufacturing sales

III-V optoelectronic foundry Compound Semiconductor Technologies Global Ltd (CST Global) of Hamilton International Technology Park, Blantyre, near Glasgow, Scotland, UK (a subsidiary of Sweden's Sivers IMA Holdings AB) has appointed Sam Zhang as field application manager for China, working closely with China country manager Alex Wen to provide technical support for the rapidly growing OEM, distribution and contract manufacturing sales channels.

"Sam has extensive pre- and post-sales technical support experience in the photonics industry," comments VP sales & marketing Euan Livingston. "He is a well known and respected engineer and manager, with over 15 years optoelectronics experience, including extensive knowledge of our customer's qualification testing and R&D system demands. He has held engineering, field application engineering and management roles at major international companies,

including CyOptics Inc (now part of Avago), Adva Optical Networking and Huawei Technologies," he adds. "His appointment is essential to our rapid growth in China, where we continue to see record sales of lasers into PON and GPON markets and a huge growth in demand for silicon photonic devices."

Zhang graduated from Xi'an Jiaotong University Material Physics department and has a Masters in Optical Communication and Optics.

www.CSTGlobal.uk

Lumentum returns to sequential quarterly revenue growth

Ramp up of VCSELs for 3D sensing outweighs China telecom & datacom inventory corrections

For fiscal first-quarter 2018 (to end-September 2017), optical and photonic optical component and subsystem maker Lumentum Holdings Inc of Milpitas, CA, USA has reported revenue of \$243.2m, down 5.8% on \$258.1m a year ago due to softer telecom demand but up 9.2% on \$222.7m last quarter. The return to strong sequential revenue growth is driven by 3D sensing business ramping up, counteracting the headwinds in the telecom and datacom markets.

Optical Communications revenue was \$207.9m (85.5% of total revenue), down 4.8% on \$218.3m a year ago but up 11.3% on \$186.8m last quarter.

Of this, Telecom revenue fell 33% year-on-year and 8% sequentially to \$110.4m. Datacom revenue was \$45.2m, up 2% on a year ago but down by 10% (\$5m) sequentially due to weaker-than-expected demand on 100G products. In contrast, Industrial & Consumer revenue was \$52.3m, up 217% sequentially and over 500% on a year ago, due primarily to the 3D sensing ramp for consumer mobile applications (contributing about \$40m).

Commercial Laser revenue was \$35.3m (14.5% of total revenue), down 1.7% on \$35.9m last quarter and 11.3% on \$39.8m a year ago, with an increase in kilowatt fiber lasers being offset by declines in other lasers. "We made progress on the production of our new Gen 3 kilowatt fiber laser [launched a few months ago] and grew fiber-laser revenue by 19% sequentially to \$12.9m," notes chief financial officer Aaron Tachibana. During the quarter, fiber-laser production was constrained due to specific materials, so the firm was unable to satisfy customer demand.

"We rapidly ramped our 3D sensing

revenue, received significant new orders for these products and made excellent progress on next-generation design-ins at numerous customers with our VCSEL [vertical-cavity surface-emitting laser] and edge-emitting lasers," says president & CEO Alan Lowe. "We also received our first high-volume order for edge-emitting lasers from an Asian-based consumer electronics customer," he adds. "Since April of this year we have received more than \$300m of 3D sensing customer orders, which we began to ship in earnest over the past few months."

"Other notable milestones include achieving production readiness on our 100G transceivers in our new Thailand factory and surpassing 20,000 units of Twin TrueFlex ROADMs [reconfigurable optical add-drop multiplexers] shipped since their introduction. These types of ROADMs are central to next-generation network architectures, and the level of shipments shows our continued leadership in this area [with capacity now exceeding \$60m revenue per quarter]," continues Lowe.

On a non-GAAP basis, gross margin is down from 34.2% a year ago but up from 32.9% last quarter to 34% due mainly to a favorable product mix.

In particular, Optical Communications gross margin was 34.7%, up from 31.1% last quarter, due partly

We rapidly ramped our 3D sensing revenue, received significant new orders for these products and made excellent progress on next-generation design-ins at numerous customers with our VCSEL and edge-emitting lasers

to the increase in volume for 3D sensing products (with Industrial & Consumer gross margin being above the corporate average). This is despite Commercial Lasers gross margin falling further, from 43.2% a year ago and 42.1% last quarter to 30%, due mainly to writing down excess and obsolete inventory of older-generation product.

Operating expenses were \$54.1m, up from \$52.8m last quarter but cut from 23.7% of revenue to 22.2% of revenue, and down from \$55.5m a year ago.

Although down on 12.7% a year ago, operating margin has risen from 9.2% last quarter to 11.8%, due mainly to improved operating leverage from the increase in volume.

Likewise, although down on \$30.7m (\$0.49 per diluted share), net income has risen from \$25m (\$0.39 per diluted share) last quarter to \$27.8m (\$0.43 per diluted share).

Capital equipment additions were about \$26m, including about \$15m in investments in both facility improvements and equipment to bring up the new manufacturing facility in Thailand.

During the quarter, cash and short-term investments have fallen from \$555.3m to \$532.5m.

"Like many in the telecom and datacom industries, we had headwinds in the first quarter," notes Lowe. "China has been reducing inventory levels for several quarters now. As inventories decline to targeted levels, demand should increase. We are seeing increased demand from our Chinese customers on certain product lines. These include ROADMs and CFP2 datacom transceivers. Demand for other product lines, notably coherent components remains muted. As anticipated, demand from North America telecom customers was down sequentially in the first

quarter as these customers also look to reduce inventory levels. In the second quarter however, we expect North American telecom demand to increase as inventory levels are worked down," he adds.

"We have made significant progress in rectifying previously highlighted challenges in the production of our Gen 3 fiber laser," says Lowe. "We expect our fiber-laser business to be on a growth trajectory over the coming quarters."

In the Commercial Lasers business, Lumentum recently secured some significant new orders, which has helped to drive the book-to-bill ratio to more than 1.5:1 for fiscal Q1/2018.

During fiscal Q1, 3D sensing revenue was limited by bottlenecks in equipment capacity, but these have since been resolved, says Lowe. The ramp up in 3D sensing business should accelerate significantly in fiscal Q2. "We shipped more 3D sensing revenue in October than we did during the entire first fiscal quarter. We expect monthly shipments to increase throughout the end of the calendar year due to strong demand for our products, says Lowe. "Yields to date have been consistent with our expectations."

For fiscal second-quarter 2018, due mainly to 3D sensing revenue increasing "materially" plus growth in both telecoms and commercial lasers (the latter rising about 20%), Lumentum hence expects revenue to leap by about 48% to \$345–375m.

Gross margin is expected to return to the range of low to mid-40. Operating margin should almost double to 21–23%. Diluted earnings per share could almost triple to \$1.05–1.25.

"Our new Thailand factory is now production ready for certain 100G datacom transceivers... Our own factory will help with our cost competitiveness, capacity and time to volume," says Lowe. "We will also be completing qualification of our short-reach 100G transceiver products in the second quarter, which will further expand our 100G datacom opportunity."

We shipped more 3D sensing revenue in October than we did during the entire first fiscal quarter. We expect monthly shipments to increase throughout the end of the calendar year

"Our 3D sensing revenue could remain at similar levels in our upcoming March quarter when compared to our second quarter, based on customer feedback and order rates," believes Lowe.

"Leaders in next-generation consumer electronics, virtual and augmented reality, as well as the automotive industry are looking to laser-based 3D sensing to enhance capabilities and enable new applications. Our investments in new products and technologies position us very well for all of these future trends," he says.

"We continue to make excellent progress with our ROADMs globally and we believe our new product pipeline will further our leadership position over time," continues Lowe. "In addition to capturing a large share of the initial network deployments this year in China, we are now sampling new advanced ROADMs specifically designed for China's next generation networks. We believe this positions us extremely well as the ROADM supplier of choice both in the near-term as well as for longer term in China. We expect China ROADM growth will be a meaningful growth driver for Lumentum in the coming years."

Lumentum appoints technology and product marketing executive Julie Johnson to board

Optical and photonic optical component and subsystem maker Lumentum Holdings Inc of Milpitas, CA, USA has appointed Julie Johnson as a director, expanding its board to seven members (six of whom are independent directors).

"Julie is an accomplished technology leader who brings global product management experience to the board," comments chairman Marty Kaplan. "Julie's appointment significantly strengthens and adds diversity to the board," he adds.

"Julie has managed large consumer electronics product divisions and will be an invaluable resource for me, the board, and my executive management team

as we expand our presence in consumer electronics," believes president & CEO Alan Lowe.

"Lumentum has the right management team, financial resources, an excellent product portfolio and a commitment to continue to innovate to meet the evolving needs of its global customer base," comments Johnson.

With over 25 years of operations, product development, and technology experience, Johnson is currently the senior VP product management at VeriFone (a global provider of technology that enables electronic payment transactions). Prior to VeriFone, she was corporate VP product

management at Lenovo (a Chinese multi-national technology company selling personal computers, tablet computers, smartphones, etc). Before Lenovo, Johnson was corporate VP – product management at Google. Prior to Google, she was VP of product management at global telecoms firm Motorola.

Johnson received a Master of Business Administration degree as well as a Master degree in Materials Science and Engineering, both from Massachusetts Institute of Technology. She also has a Bachelor degree in Math and Physics from Albion College.

www.lumentum.com

NeoPhotonics' Q3 revenue growth in North America and China offset by declines elsewhere

China customer inventory nearing normality, plus 400G product launches, to drive return to revenue growth in 2018 and profitability by mid-year

For its third-quarter 2017, NeoPhotonics Corp of San Jose, CA, USA (a vertically integrated designer and manufacturer of hybrid photonic integrated opto-electronic modules and subsystems for high-speed communications networks) has reported revenue of \$71.1m, down 2.9% on \$73.2m last quarter and 31.2% on \$103.3m a year ago. However, the latter was before NeoPhotonics divested its Low-Speed Transceiver product line in January.

Sales of High Speed Products rose further, from 81% of total revenue last quarter to 84%.

Sales of Networking Products & Solutions comprised the other 16%.

Sequential growth of 14% in North America and 5% in China was offset by declines in other regions. Of total revenue, China rose from 53% last quarter to 57% and the Americas from 20% to 23%, while Europe, the Middle East & Africa (EMEA) fell from 24% to 18% and Japan from 3% to 2%.

There were three 10%-or-greater customers: US-based Ciena (the largest customer outside China) fell back to 14% of total revenue (after strong growth last quarter), China's FiberHome Technologies was at 11%, and China's Huawei Technologies and its affiliate HiSilicon Technologies collectively (consistently NeoPhotonics' largest customer) rebounded somewhat to 39%, with revenue growing by 2% to almost \$30m. The four largest customers after Huawei comprised 41% of revenue, compared with just 35% a year ago.

"We are focused on growth initiatives in telecom, data-center and cloud markets, as well as operational execution to lower our breakeven level as China continues with steady though muted demand

[with the lingering impact of excess customer inventory]," says chairman & CEO Tim Jenks. "We are seeing continued traffic growth in China and customer inventory levels returning to normal ranges, and we are seeing success in our 400G product introductions as well as continued growth in our laser products," he adds. Laser revenue is up 25% year-on-year to almost half of total revenue. "Despite a challenging market due to the China inventory overhang, our suite of laser solutions (including transport, inter-data-center and intra-data-center solutions) has grown steadily over the year," says Jenks. "Growth drivers in our markets include metro deployments across the globe, China high-speed build-outs in advance of 5G wireless, and data centers and Big Data applications that are embracing our higher-speed technologies and leverage NeoPhotonics' core strengths."

On a non-GAAP basis, gross margin has fallen further, from 27.6% a year ago and 23.9% last quarter to 18.6% (below the 24–27% guidance), driven by: about 4 percentage points of increased under-absorption charges as the firm reduced factory loadings in order to limit inventory; and about 3.5 percentage points of increase in period costs (primarily for inventory write-offs and a warranty charge). These were partially offset by 2 points of improvement in product margin.

Operating expense (OpEx) were \$24.7m (34.7% of revenue), slightly higher than \$24.2m (33.1% of revenue) last quarter, driven by an increase in R&D associated with new products.

Driven primarily by factory under-absorption, net loss has worsened from \$6.6m (\$0.15 per diluted share) last quarter to \$10.9m

(\$0.25 per diluted share, worse than the \$0.17–0.07 guidance), compared with net income of \$2.9m (\$0.06 per diluted share) a year ago.

Cash used in operations was \$25m (compared with cash generation of \$2m last quarter). Capital expenditure (CapEx) was \$7m (cut from \$17m last quarter). Free cash flow was hence –\$32m. During the quarter, cash and cash equivalents, short-term investments and restricted cash fell from \$79m to \$73.7m, while restricted cash fell from \$3.3m to \$2.9m.

NeoPhotonics also entered into a new five-year \$50m revolving credit facility with Wells Fargo Bank (effective 8 September). On closing, NeoPhotonics drew \$30m under the new facility to pay off its prior credit facility with Comerica Bank (under which it borrowed \$20m) as well as to add cash to the balance sheet for working capital needs and general purposes.

NeoPhotonics' existing CITIC Bank loan of \$17m in China is drawn through early January. It is in discussions about renewal of the larger underlying credit line.

In addition, NeoPhotonics has about \$20m of unused credit with Shanghai Pudong Bank that remains available until July 2019.

"We believe that we have sufficient liquidity to meet business needs for the next year. Additional risks can and will be mitigated with already identified actions," says chief financial officer Beth Eby.

"As a part of our continuing actions to improve profitability and cash flow, in the third quarter we implemented restructuring actions to focus on key growth opportunities and to lower our breakeven revenue," notes Eby. These included a reduction in force, real-estate consolidation, a write-down of inventory for

certain programs and a write-down of idle assets. "We have reduced risk to the balance sheet and lowered our operating expenses going forward," she adds. The actions will reduce quarterly operating expenses by about \$2m and manufacturing spending (or under-absorption) by about \$0.6m when fully realized at the start of fiscal year 2018. Implementation costs should be about \$5.8m (\$2.3m in real-estate consolidation and fixed asset-write off, \$2m in inventory write-downs related to end-of-life projects, and \$1.5m in severance costs). The firm incurred about \$5.1m of these costs in Q3, with the remainder to be incurred in Q4. "Our actions balance the need for a sustainable level of operating expenses with long-term growth goals," says Eby. "Once we complete amortization of under-absorption charges we will have lowered our breakeven revenue from approximately \$100m to the mid-eighties, and we are continuing with actions to further reduce that breakeven point," she adds. "There is more work to be done and in process to balance our infrastructure and operations against the joint goals of growth and profitability."

For fourth-quarter 2017, NeoPhotonics expects revenue of

\$69–74m, with gross margin rebounding to 20–23%. Operating expenses should be cut to \$23–24m, with loss per share reduced to \$0.23–0.13.

NeoPhotonics expects cash used in operations to be about –\$10m. CapEx should rise to about \$10m. "We anticipate partially financing these cash requirements [of \$20m] with our existing unused credit facilities," says Eby.

"Customers [in China] are suggesting that inventories are less than one quarter for most products at this point," says Jenks. "While it is our expectation that recent tender awards such as those by China Mobile and China Unicom should create a more normalized demand environment in 2018, our discussions with China carriers indicate that network traffic continues to grow at a robust pace, necessitating continued network capacity adds."

"In the short-term, while the overall activity levels of our China customers may over-

Recent tender awards such as those by China Mobile and China Unicom should create a more normalized demand environment in 2018

shadow metro growth and 400G wins, we believe that the mid- and long-term market drivers for our business are compelling, as China continues to build out national backbone, provincial and metro networks, and as they advance in data-center deployments and prepare for 5G wireless," says Jenks.

"We have initiated a series of actions to focus our strategic direction on high-speed components and coherent solutions, recognizing the explosion of optics in the cloud, together with transitioning our product development to focus on some newer markets and opportunities that include next-gen components for data-center interconnects, the expanding market in cloud and converged edge and the impact of disaggregation, especially in data center and cloud. At the same time, a very bright spot for us is the growth of our laser business," Jenks continues.

"With the continued traffic growth in China and now that customer inventory levels are approaching normal ranges, together with our success in 400G product introductions, we anticipate returning to top-line growth in 2018 and profitability by mid-year," concludes Jenks.

www.neophotonics.com

Applied Optoelectronics announces 100Gbps per lambda PAM4 directly modulated lasers

Applied Optoelectronics Inc (AOI) of Sugar Land, near Houston, TX, USA — a manufacturer of optical components, modules and equipment for fiber access networks in the Internet data-center, cable broadband, fiber-to-the-home (FTTH) and telecom markets — has developed uncooled 100Gbps per lambda PAM4 directly modulated lasers (DMLs) for 400Gbps optical transceivers.

Transceivers based on DMLs are preferred in data-center applications due to their low power consumption and low cost compared

with solutions based on silicon and other external modulators. The 1310nm 53Gbaud PAM4 100Gbps per wavelength lasers leverage AOI's mature high-volume 25Gbps DML product platform, which was further optimized to achieve a high laser bandwidth of nearly 30GHz. At 100Gbps, the new lasers exhibit PAM4 eyes with a transmitter dispersion eye closure quaternary (TDECQ) value of 2.5dB, along with other performance metrics that make them suitable for use in 400G DR4, 400G FR4 and 100G DR1 transceivers that meet the IEEE

802.3 Ethernet transceiver standards.

"100Gbps directly modulated lasers are the key to next-generation 400G products for data-center applications," says Dr Jun Zheng, vice president of R&D. "By building on our current PAM4 DML platform development, we are now able to achieve 100Gbps per lane," he adds. "We believe that this solution is the best technical approach to extend the cost leadership AOI has engineered at 40G and 100G to 400G and beyond."

www.ao-inc.com

Oclaro reports quarterly revenue up 4% sequentially and 15% year-on-year

CFP2-ACO and QSFP28 transceivers drive fourth consecutive quarter of 40% gross margin and 20% operating income

For fiscal first-quarter 2018 (to end-September 2017), Oclaro Inc of San Jose, CA, USA (which provides components, modules and subsystems for optical communications) has reported revenue of \$155.6m (split about 48%:52% between client-side/datacoms and line-side/telecoms). This is up 4% on \$149.4m last quarter and 15% on \$135.5m a year ago, fueled by the continued strength of the CFP2-ACO and QSFP28 transceiver product lines.

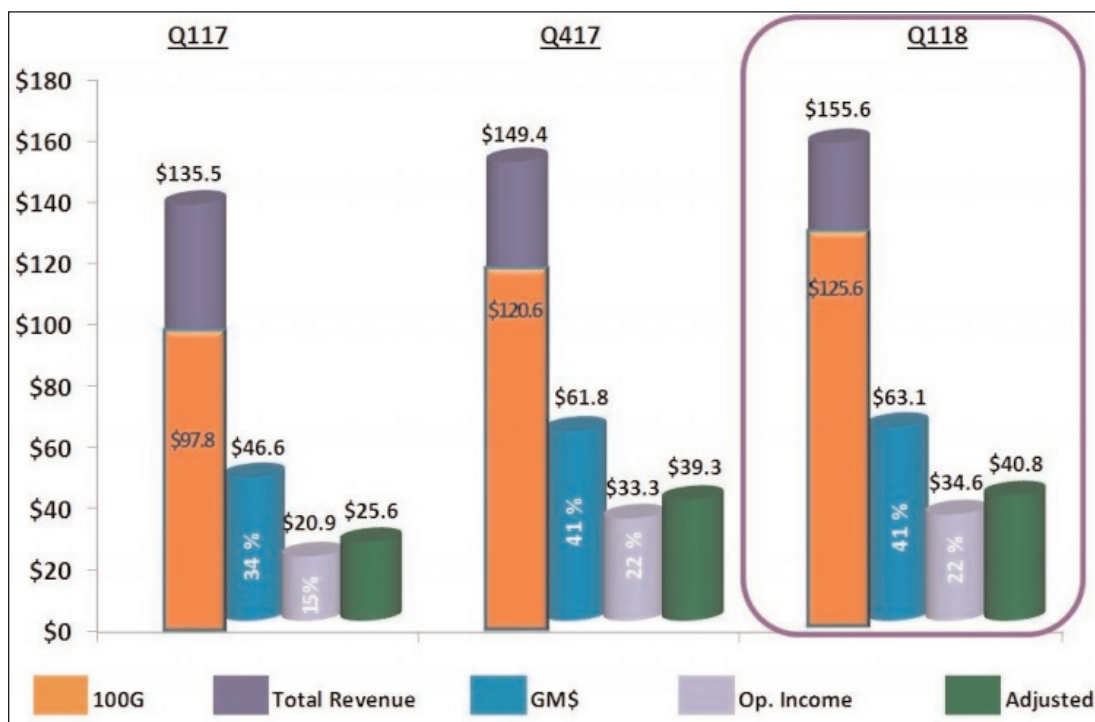
Sales from 100G-and-above products were \$125.6m (81% of total revenue), up 4% on \$120.6m last quarter and up 28% on \$97.8m (72% of total revenue) a year ago. Sales from 40G-and-below products were \$30m (19% of total revenue), down on \$37.7m (28% of total revenue) a year ago but up 4.2% on \$28.8m last quarter.

The growth came despite the headwinds facing the industry:

- China revenue fell for a third consecutive quarter, down 12% from last quarter, from 32% of total revenue to 27%, while the Americas rose from 39% to 47%, and Southeast Asia comprised 15% and Europe, the Middle East & Africa (EMEA) 11%.

- As expected, revenue for the 100G CFP family of client-side transceivers fell by more than 25% for the second consecutive quarter, down \$9m on last quarter to \$24m.

However, this decline was more than offset by growth in QSFP and ACO products. Excluding the CFPx family, 100G-and-above products grew by 16% on last quarter and by 89% on a year ago. So, despite the CFP decline, Datacom revenue



grew by 3% sequentially due to good execution by the firm's operations team on the ramp up of the QSFP28 family. Telecom revenue rose by 5%.

On a non-GAAP basis, gross margin was 40.6%, down slightly from 41.4% last quarter but up from 34.4% a year ago (and near the top of the expected 38–41% range), driven by growth in newer sub-100G products.

Operating expenses were \$28.5m (18% of sales, an improvement from 19% both last quarter and a year ago), despite R&D expenses growing from \$12.7m a year ago and \$15m last quarter to \$15.6m, while SG&A expenses were held roughly level at \$13–13.5m.

Operating income has risen further, from \$20.9m (15% of sales) a year ago and \$33.3m last quarter to \$34.6m (22% of sales), above the forecasted \$30–34m (20–21% of sales). Likewise, net income has risen further, from \$20m (\$0.14 per diluted share) a year ago and \$33.9m (\$0.20 per diluted share)

last quarter to \$34.5m (\$0.20 per diluted share).

Adjusted EBITDA has risen from \$25.6m a year ago and \$39.3m last quarter to \$40.8m. Hence, after subtracting capital expenditure (CapEx) of \$18m, overall cash, cash equivalents, restricted cash and short-term investments rose by \$22m, from \$257.5m to \$279.8m.

"Our near-term visibility includes continued softness in China, compounded by a recent slowdown in data-center sales," says CEO Greg Dougherty. "Our exposure on that data-center world — both through direct sales and indirectly through traditional network equipment manufacturers — has grown substantially," he adds. "We expect demand for QSFP28 LR4, which currently accounts for the majority of our QSFP sales, to be slower over the next few quarters as select data-center customers work off inventory. We are also seeing some customers adopting CWDM4 as an alternative approach to LR4. This development creates added

uncertainty and some downward pressures on revenues for Q2 and potentially Q3.

Therefore, for fiscal second-quarter 2018 (to end-December 2017), Oclaro expects revenue to fall to \$135–143m, due mostly to Datacoms, with revenue from China flat to slightly down. In particular, CFP should fall further, by about \$10m, from \$24m to \$14m (before falling by a further 30–40% in the March quarter, as China also begins to shift to QSFP platforms). 10G product revenue should continue to be relatively flat (and is projected to remain in the range of the high 20s to \$30m per quarter through fiscal 2018). Gross margin should fall to 36–39%.

“Despite our reduced outlook, we expect to remain solidly profitable

for the December quarter, which would serve as a further testament to our strong financial model,” says Dougherty.

Operating income is expected to fall back slightly, to \$19–23m (about 15% of sales, “better than pretty much anyone in this space,” says Dougherty). “We’re generating cash and performing better than I think anyone has ever performed in this space in terms

Growth will resume during H2/2018, driven by 100G-and-beyond coherent products, our QSP28, and our industrial-temperature-range 25G transceivers used in 5G

of operating income consistency,” Dougherty adds.

For fiscal full-year 2018, Oclaro is lowering its CapEx projection, from \$65–75m (similar to fiscal 2017) to \$55–65m, with an exit rate in June of about \$10m per quarter.

“Given our limited visibility, we’re not prepared to call bottom for revenue in China,” says Dougherty. “Revenue growth will resume during the second half of calendar 2018, driven by 100G-and-beyond coherent products, our QSP28, and our industrial-temperature-range 25G transceivers used in 5G applications,” he believes.

For calendar year 2018, Oclaro expects operating expenses to be \$30–32m per quarter.

www.oclaro.com

Finisar releases 100G SWDM4 QSFP28 transceiver to full production

Firm first to ship new MSA-compliant modules supporting legacy duplex multimode fiber infrastructure

Fiber-optic communications component and subsystem maker Finisar Corp of Sunnyvale, CA, USA says that it is now in full production of its 100G shortwave wavelength division multiplexing (SWDM) optical transceiver.

The pluggable QSFP28 transceiver is claimed to be the first mass-produced module capable of transmitting 100Gbps over a single pair of multi-mode fibers, enabling users to upgrade from existing 10Gbps to 100Gbps without altering the existing fiber infrastructure. The transceiver is also the first optical module on the market compliant with the 100G SWDM4 specification defined by the SWDM multi-source agreement (MSA).

Many data centers currently carry 10Gbps optical signals over duplex multi-mode fiber (MMF), where one fiber is used to transmit a signal and the other is used to receive a signal. When upgrading to 40G or 100G over MMF, data-center operators must quadruple the amount of fiber

deployed if they wish to use optical transceiver modules based on the IEEE 40GBASE-SR4 or 100GBASE-SR4 standards, both of which rely on four fiber pairs (i.e. 8 fibers). The transceiver, system and cabling suppliers that constitute the SWDM MSA have agreed on specifications that avoid the need for this additional fiber, and therefore allow data centers to further leverage their investment in their existing MMF plant.

Finisar says that it was the first optical transceiver vendor to complete reliability testing and release a 40Gbps SWDM4 module earlier this year, and is now also the first vendor to complete reliability testing and release a 100Gbps SWDM4 module. These modules comply with the 40G SWDM4 and 100G SWDM4 specifications of the SWDM MSA, respectively.

“The ability to leverage existing 10G fiber infrastructure not only saves our customers additional capital expenditure, but also

provides operational savings by eliminating the need for new fiber installation and associated facility upgrades,” comment James Wynia, director of network product management at Dell EMC.

“Finisar’s SWDM modules are the first of their kind to finish qualification and be released to mass production,” comments Dale Murray, principal analyst at LightCounting Market Research. “These duplex MMF modules provide systems vendors with a strong competitive advantage against other vendors who offer only parallel multi-mode optics at 40G and 100G to their data-center customers,” he adds.

In addition to the 40G SWDM4 and 100G SWDM4 modules currently in production, Finisar previously demonstrated an extended-reach 100G eSWDM4 module at the European Conference on Optical Communications in Gothenburg, Sweden (ECOC 2017) in September.

www.finisar.com

www.swdm.org/msa

Solliance raises efficiency records for roll-to-roll perovskite solar cells and modules

Cell efficiency boosted to 13.5%, from 12.6% in March

Solliance — a cross-border Dutch–Flemish–German thin-film photovoltaic (TFPV) solar energy R&D consortium in the ELAT (Eindhoven–Leuven–Aachen) region — has achieved record cell-level conversion efficiency of 13.5% and module-level aperture-area conversion efficiency of 12.2% for perovskite-based photovoltaics using industrially applicable, roll-to-roll (R2R) production processes.

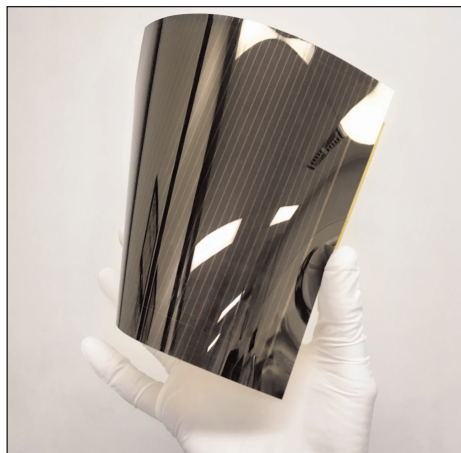
Following its previous cell record of 12.6% announced in March, Solliance reckons that the latest record is another step towards the rapid introduction of this new type of efficient solar cell technology.

Perovskites solar cells promise high efficiency from relatively simple production processes, bringing the potential for cheaper, greener energy. Moreover, they can be processed into thin, lightweight and potentially semi-transparent modules for integration into windows or curved construction elements.

Solliance and its partners aim to speed the market introduction of this technology by developing scalable industrial processes for fabricating large-area modules. The goal is to enable seamless integration in a broad variety of new energy-harvesting building blocks for infrastructure, building and vehicle construction and assembly.

In March, Solliance demonstrated R2R processes for both the electron transport and perovskite layers of the cells that make up the modules. Now, by further optimizing and re-validating these processes on its dual R2R coating line, Solliance has improved performance at both the cell and module levels.

After selecting two foil zones each about 10m long with visually good perovskite quality but with different R2R processing settings, 20 individual 0.1cm² solar cells were made in each zone. In one zone the maximum stabilized efficiency reached 13.5%



Solliance's large 160cm² module, which achieved aperture stabilized efficiency of 10.1%.

(measured under maximum power point tracking conditions over 5 minutes) and in the second zone a maximum of 12.5% was reached. The average stabilized cell efficiency in the best performing zone was about 1% higher than the previously reported run in March.

For each zone six 2cm x 2cm (4cm²) aperture modules, four 3.5cm x 3.5cm (10.5cm²) aperture modules and one 13cm x 12.3cm (160cm²) aperture module were produced by implementing a P1P2P3 laser scribe process, with 100% yield over all 22 fabricated modules. For the modules prepared from the best performing zone, the smaller modules of 4cm² showed a maximum aperture stabilized efficiency of 12.1%, with an average of 11.1% across the six modules. The larger modules of 10.5cm² achieved a maximum aperture stabilized efficiency of 12.2% with an average of 11.0% across the four modules. Last but not least, the large module of 160cm² (pictured) achieved an aperture stabilized efficiency of 10.1%.

All processing steps used low-cost materials and scalable processes at temperatures below 120°C, highlighting the potential for cost-effective, high-volume production of perovskite solar cells.

"These results show that the developed R2R process is very reproducible over different runs in time, which is very important for future reliable manufacturability," says Pim Groen, professor of SMART materials at the Technical University of Delft and program manager at Holst Centre/Solliance.

"The metals project at Solliance is hitting its targets," notes Richard Caldwell, managing director of Greatcell Solar (formerly Dyesol), which develops and commercializes perovskite solar cell (PSC) technology. "The successful translation of this PSC technology from the laboratory to the factory will open up massive commercial opportunities," he believes, highlighting the possibility to "solar-enable commercial and industrial roofing using low-cost R2R processes, thus opening up a whole new space to capture the Sun's energy."

After delivering incredible efficiencies in lab-scale photovoltaic cells, the challenge now is to scale up perovskite cells to larger modules with high efficiency and long lifetime at low cost. Solliance says that this demonstration of scalable roll-to-roll and sheet-to-sheet processes for the deposition of active layers and cell interconnections shows it is well placed to realize this upscaling. "We are confident of quickly boosting efficiencies above 15% for modules up to 30cm x 30cm," says Ronn Andriessen, program director at Solliance. "Our research shows that optimizing materials and processes is steadily improving the stability of perovskite devices under real-life operational conditions."

Solliance's research on the development and applications of perovskite-based PV modules is carried out in conjunction with industrial partners Greatcell Solar Limited, Solartek and Panasonic.

www.solliance.eu

Midsummer and Tarpon win MTI Technology award for flexible solar cells integrated into tarpaulins and canvases

Together with Midsummer AB of Järfälla, near Stockholm, Sweden — a provider of turnkey production lines for manufacturing flexible, lightweight copper indium gallium diselenide (CIGS) thin-film photovoltaic (PV) solar panels — Norwegian tent cloth company Tarpon Solar AS has developed flexible tarpaulins and canvases into which integrated solar cells have been laminated into the screen. The flexible fabrics enable industrial halls, temporary structures and tents, for example, to produce energy.

For this solution, Midsummer and Tarpon have now won the 1st place in the Technology and Innovation Competition MTI Technology award (a competition for new and established companies with a business concept in technology).

“Each cloth is made for the purpose



it will be used for, so the amount of fabric and type of fiber and layer vary,” says Tarpon’s technical manager Marius Borg-Heggedal. “The solar cells are integrated in the production itself and become part of the material.”

Tarpon develops canvases for large outdoor structures such as sun shading and stages. It has now designed a laminated fabric with stable, static structures that do not extend, and it realised that this

material has the properties needed to integrate with Midsummer’s thin-film solar cells.

“Being able to produce renewable energy in a canvas opens up so many different applications around the world,” says Midsummer’s project manager

Mattias Dahlberg.

Tarpon uses Midsummer’s thin-film solar cells as they are light enough, flexible and robust for the purpose. With the technology used, very light canvases can be produced. With integrated solar cells (producing about 120W/m²), the weight is almost the same as with conventional PVC material, and the canvas is also stronger and more durable, says Tarpon.

www.midsummer.se

Singulus supplying several TENUIS II CIGS solar module production systems to Chinese customer

Singulus Technologies AG of Kahl am Main, Germany (which makes production equipment for the optical disc and solar sectors) has signed a contract with the subsidiary of a major listed energy company and solar module manufacturer in China to supply several TENUIS II systems for wet-chemical coating processing in copper indium gallium diselenide (CIGS) solar module production. The firm has

already received the agreed payment on account. The contract volume is in the higher single-digit millions.

“Our company offers solutions for all important steps in the manufacture of CIGS solar modules,” notes CEO Dr Stefan Rinck.

Singulus reckons that its patented buffer layer coating technique is an efficient approach to the wet-chemical coating of CIGS thin-film solar modules. The second generation of

TENUIS production systems has a modular cluster design, which both significantly reduces the footprint and permits the simultaneous one-sided coating of two substrates. The new, unique concept for metering and temperature control brings a further reduction in processing time, yielding the advantage of a substantially higher throughput for the production system.

www.singulus.de

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Thin sacrificial layers of BN enable transfer of GaN gas sensors onto metallic foils and flexible polymers

Transfer technique could yield the production of low-cost wearable, mobile and disposable environmental sensors.

A team of researchers in France has developed a transfer technique based on thin sacrificial layers of boron nitride could allow high-performance gallium nitride (GaN) gas sensors to be grown on sapphire substrates and then transferred to metallic or flexible polymer support materials (Taha Ayari et al., *Scientific Reports* 7 (2017), article no. 15212). The technique could facilitate the production of low-cost wearable, mobile and disposable sensing devices for a wide range of environmental applications, it is reckoned.

Transferring the GaN sensors to metallic foils and flexible polymers doubles their sensitivity to nitrogen dioxide gas, and boosts response time by a factor of six. Sensors produced with the new process can detect ammonia at parts-per-billion levels and differentiate between nitrogen-containing gases. The simple production steps, based on metal-organic vapor phase epitaxy (MOVPE), could also lower the cost of producing the sensors and other optoelectronic devices.

"Mechanically, we just peel the devices off the substrate," says Abdallah Ougazzaden, director of Georgia Tech Lorraine in Metz, France and a professor in Georgia Institute of Technology's School of Electrical and Computer Engineering (ECE). "We can put the layer on another support that could be flexible, metallic or plastic. This technique really opens up a lot of opportunity for new functionality, new devices — and commercializing them."

The researchers begin the process by growing monolayers of boron nitride on 2-inch sapphire wafers using an MOVPE process at about 1300°C. The boron nitride surface coating is only a few nanometers thick, and produces crystalline structures that have strong planar surface connections, but weak vertical connections.

Aluminum gallium nitride (AlGaN/GaN) devices are then grown atop the monolayers at a temperature of about 1100°C, also using MOVPE. Because of the boron nitride crystalline properties, the devices are attached to the substrate only by weak Van der Waals forces, which can be overcome mechanically. The

devices can be transferred to other substrates without inducing cracks or other defects. The sapphire wafers can be reused for additional device growth.

"This approach for engineering GaN-based sensors is a key step in the pathway towards economically viable, flexible sensors with improved performances that could be integrated into wearable applications," the researchers say.

So far, they have transferred the sensors to copper foil, aluminum foil and polymeric materials. In operation, the devices can differentiate between nitrogen oxide, nitrogen dioxide, and ammonia. Because the devices are about 100µm by 100µm, sensors for multiple gases can be produced on a single integrated device.

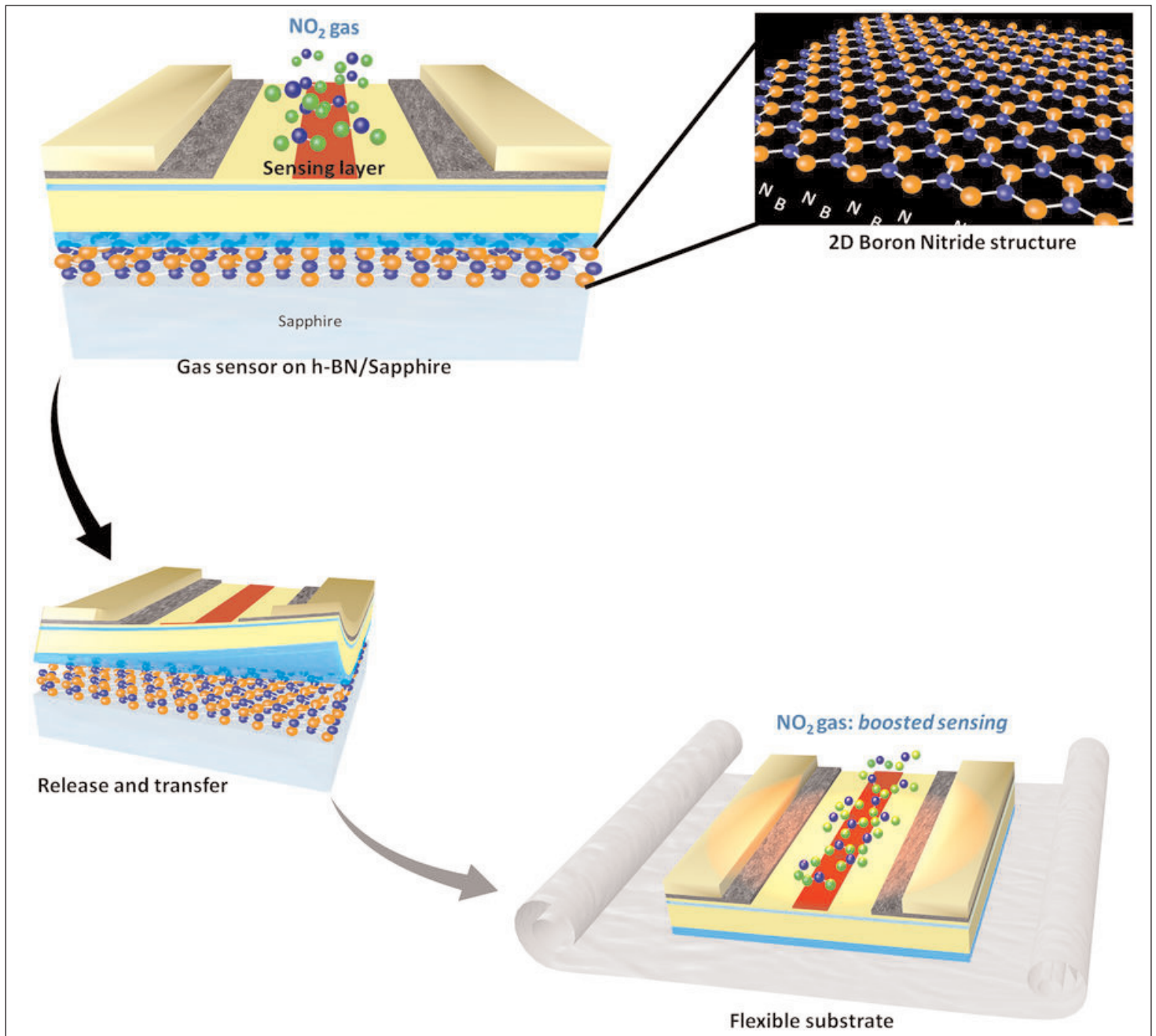
"Not only can we differentiate between these gases, but because the sensor is very small, we can detect them all at the same time with an array of sensors," says Ougazzaden, who expects that the devices could be modified to also detect ozone, carbon dioxide and other gases.

The GaN sensors could have a wide range of applications from industry to vehicle engines — and for wearable sensing devices. The devices are attractive because of their advantageous materials properties, which include high thermal and chemical stability.

"The devices are small and flexible, which will allow us to put them onto many different types of support," says Ougazzaden, who also directs the International Joint Research Lab at Georgia Tech CNRS.

To assess the effects of transferring the devices to a different substrate, the researchers measured device performance on the original sapphire wafer and compared that to performance on the new metallic and polymer substrates. They were surprised to see a doubling of the sensor sensitivity and a six-fold increase in response time, changes beyond what could be expected by a simple thermal change in the devices.

"Not only can we have flexibility in the substrate, but we can also improve the performance of the devices just by moving them to a different support with appro-



appropriate properties," he says. "Properties of the substrate alone makes the difference in the performance."

In future work, the researchers hope to boost the quality of the devices and demonstrate other sensing applications. "One of the challenges ahead is to improve the quality of the materials so we can extend this to other applications that are very sensitive to the substrates, such as high-performance electronics," says Ougazzaden.

The Georgia Tech researchers have previously used a similar technique to produce light-emitting diodes and ultraviolet detectors that were transferred to different substrates, and they believe the process could also be used to produce high-power electronics. For those applications, transferring the devices from sapphire to substrates with better thermal conductivity could provide a significant advantage in device operation.

Ougazzaden and his research team have been working

on boron-based semiconductors since 2005. Their work has attracted visits from several industrial companies interested in exploring the technology, he says.

In addition to Ougazzaden, the research team includes Georgia Tech Ph.D. students Taha Ayari, Matthew Jordan, Xin Li and Saiful Alam; Chris Bishop and Youssef ElGmili at Institut Lafayette; Suresh Sundaram at Georgia Tech Lorraine; Gilles Patriarche at the Centre de Nanosciences et de Nanotechnologies (C2N) at CNRS; Paul Voss, an associate professor in Georgia Tech's School of ECE; and Jean Paul Salvestrini, a professor at Georgia Tech Lorraine and adjunct professor in Georgia Tech's School of Electrical and Computer Engineering (ECE).

The research was supported by ANR (Agence Nationale de Recherche), the National Agency of Research in France, through the GANEX project. ■

www.nature.com/articles/s41598-017-15065-6

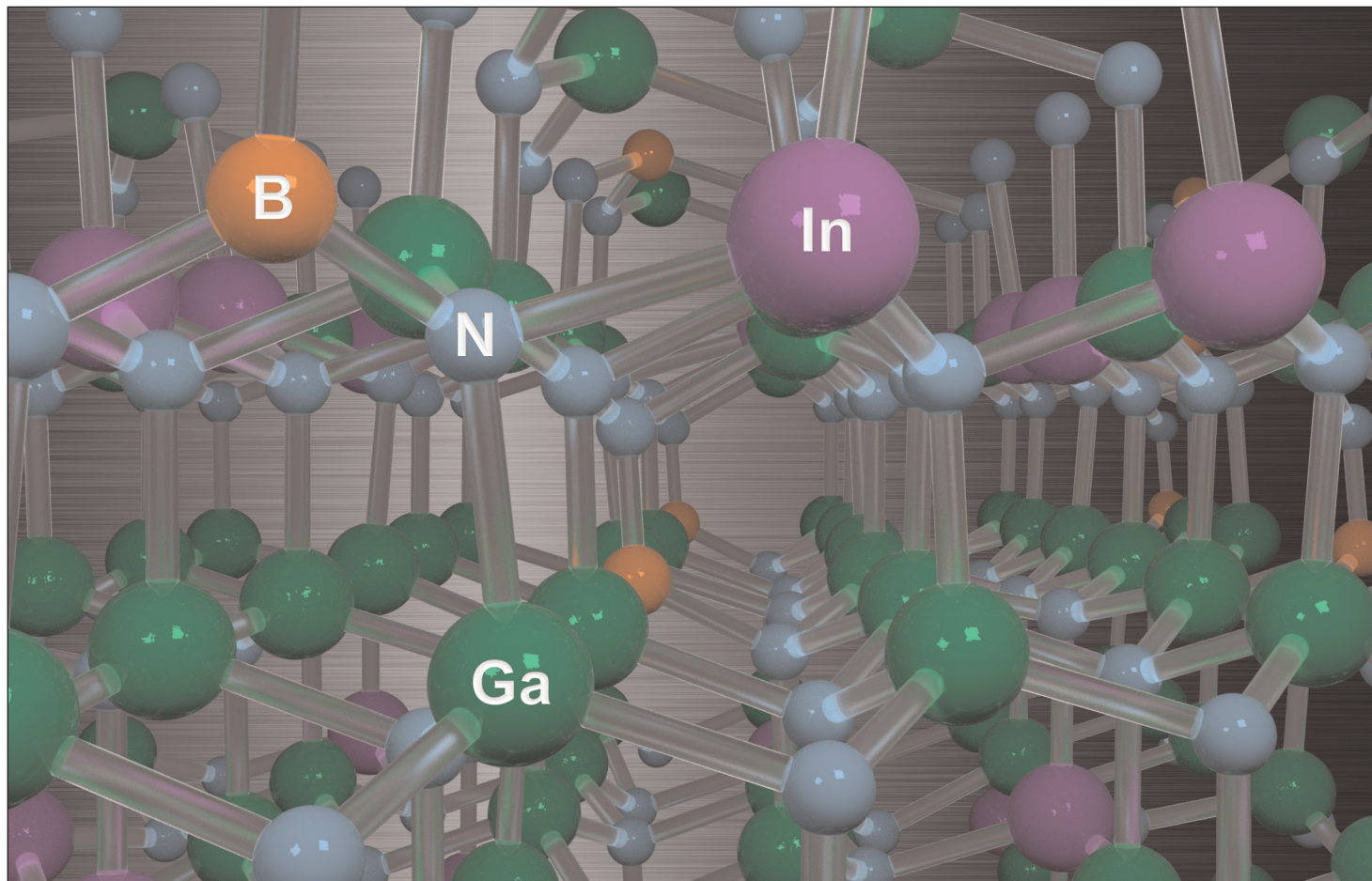
Michigan predicts incorporating boron in InGaN increases LED efficiency at high power

Incorporating boron and indium into gallium nitride in a 2:3 ratio yields BInGaN nearly lattice matched to GaN. Growth of boron concentrations up to 4.5% is predicted to allow thicker active regions, and hence higher efficiency.

Despite revolutionizing illumination, even top-of-the-line nitride LEDs are far from their maximum efficiency when operating at the high power needed for lighting applications. Logan Williams and Emmanouil Kioupakis at the University of Michigan have recently performed calculations that show that incorporating boron into the indium gallium nitride (InGaN) active region of nitride LEDs could be a step

towards realizing higher efficiency at high power ('BInGaN alloys nearly lattice-matched to GaN for high-power high-efficiency visible LEDs', Applied Physics Letters 111, 211107 (2017)).

Devices using InGaN/GaN face two major challenges to increasing efficiency. The first is efficiency droop, whereby LEDs are less efficient when operating at high power. The drop-off in efficiency is attributed primarily



Crystal structure of BInGaN alloy. Using atomistic calculations and high-performance supercomputers at the NERSC facility, Logan Williams and Emmanouil Kioupakis of the University of Michigan predicted that incorporating boron into the InGaN active region of nitride LEDs reduces or even eliminates the lattice mismatch with the underlying GaN layers while keeping the emission wavelength about the same. Lattice matching enables the growth of thicker active regions and increases the efficiency of LEDs at high power. (Image credit: Michael Waters and Logan Williams).

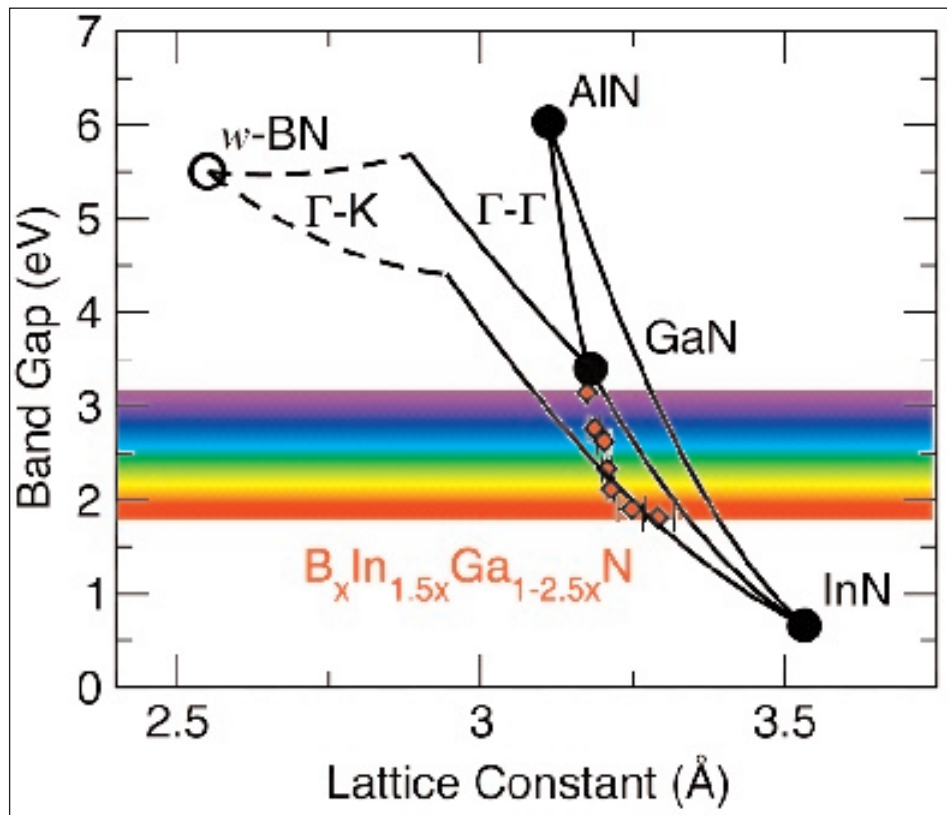
to the non-radiative Auger recombination mechanism, in which an electron and a hole recombine and excite a third carrier (either an electron or a hole) instead of emitting a photon. Auger is an implicit property of the material and cannot be directly eliminated, but a simple solution is to have a larger active region to spread carriers out over a greater volume. But this runs into the second problem — InGaN is not lattice-matched to GaN and growing thicker wells without forming defects is impossible.

Kioupakis and Williams reckon that they have found a way around both of these problems by studying the properties of co-alloying InGaN with boron. Using first-principles calculations and high-performance supercomputers at the National Energy Research Scientific Computing (NERSC) Center (a Department of Energy Office of Science User Facility, supported under contract no. DE-AC02-05CH11231), they found that incorporating B and In atoms into GaN in a 2:3 ratio yields BInGaN alloys that are nearly lattice matched to GaN. For small indium fractions, the mismatch was as low as $\pm 0.25\%$, allowing the possibility of growing thicker active regions that are more efficient at high power.

They also found that the electronic properties are conducive to creating LEDs in the desired visible wavelengths. Adding boron to InGaN does not significantly affect the character of the band edges, which remain primarily N and In states. This allows the energy bandgap of BInGaN to be tuned throughout the 3.39–1.75eV range, which includes the entire visible spectrum. This is in contrast to B GaN whose bandgap increases (away from the visible region) as a function of boron content and even becomes indirect for high boron concentrations.

The remaining question is: "Can the desired alloys be grown experimentally?" While the researchers do not have conclusive evidence, their calculations show that it is likely at least for BInGaN alloys with lower

The temperature required to incorporate boron into InGaN is 1.5x lower than the temperature necessary to incorporate boron into GaN. The researchers estimate that it will be possible to grow BInGaN with up to 4.5% boron concentrations using the techniques already in use



Bandgaps versus in-plane lattice constant for wurtzite nitride semiconductors. The BInGaN alloys predicted in this work are approximately lattice matched to GaN while their gaps span the entire visible range. Image from Applied Physics Letters 111, 211107 (2017).

amounts of boron. By studying the thermodynamic properties of both BInGaN and B GaN, they found that the temperature required to incorporate boron into InGaN is 1.5x lower than the temperature necessary to incorporate boron into GaN. Since B GaN alloys with boron concentrations of up to $\sim 3\%$ have already been grown experimentally, the researchers estimate that it will be possible to grow BInGaN with up to 4.5% boron concentrations using the techniques already in use. Nevertheless, experimental challenges remain regarding the growth temperature and the appearance of secondary phases that need to be further investigated.

Increasing the efficiency of LEDs could drastically reduce electricity usage for lighting, which currently comprises about 20% of the USA's total electricity usage. The researchers say that the BInGaN materials predicted in their study would allow for thicker active regions to be grown in common LED materials using techniques that are already widely used, taking a step in the right direction for overcoming the two major efficiency challenges currently faced by LEDs.

The work was supported by the Designing Materials to 282 Revolutionize and Engineer our Future (DMREF) Program under Award No. 1534221, funded by the US National Science Foundation (NSF). ■

<http://aip.scitation.org/doi/full/10.1063/1.4997601>
www.mse.engin.umich.edu

Hopes for mini-/micro-LED display market space invasion

Researchers and market analysts suggest that mass production could start in three to five years, or even sooner in niche applications, reports **Mike Cooke**.

The world is awash with liquid-crystal displays (LCDs) — from tiny indicator panels, through mobile phones, up to giant television screens. Most LCDs, particularly those with color capabilities, incorporate a backlight that now consists of light-emitting diodes (LEDs). In operation, the LCD part of the screen blocks or transmits light to give an image.

While LEDs have reduced power consumption compared with the previous system based on fluorescent technology, much of the light that is produced is wasted — a black screen consumes as much power as white. This is a problem both for the giant TVs and for mobile devices, where energy consumption reduces battery charge.

Developers of micro-LEDs plan to give every pixel an independent light-emitting source, cutting the backlight waste — the power consumption of future micro-LED displays is estimated at 10% that of LCDs. Already, this principle is used in large outdoor displays with arrays of regular-size LED devices, but close-range displays — TVs, smartphones, etc — need smaller LEDs.

Regular LEDs are of the order 0.5mm (500µm). Reducing the size to about a fifth gives 100µm mini-LEDs, which find application in ultra-fine pixel-pitch displays for control rooms and indoor advertising.

Micro-LED panels use arrays of individual red-green-blue (RGB) devices of less than 30µm, and even down to 2.5µm. Panels with micro-LEDs should be able to meet resolutions of 2000–6000 pixels-per-inch (ppi), much higher than the 400ppi used in retina LCD panels.

Apart from cutting the backlight waste, LED-based displays are competing with organic LEDs (OLEDs), which have been in development for a couple of decades.

The promise of inorganic LEDs is reduced power consumption along with higher brightness and contrast, even compared with OLEDs. Power consumption of

Table 1. LEDInside's view of advantages and disadvantages of different display technologies.

Display technology	LCD	OLED	Micro-LED
Mechanism	Backlight/LED	Self-emissive	Self-emissive
Contrast ratio	5000:1	∞	∞
Lifespan	Medium	Medium	Long
Response time	ms	µs	ns
Operating temperature	–40°C to 100°C	–30°C to 85°C	–100°C to 120°C
Power consumption	High	Medium	Low
View angle	Low	Medium	High
Pixel per inch	up to 800ppi	500ppi	>2000ppi
Cost	Low	Medium	High

micro-LED displays is expected to be 50% that of OLEDs. Micro-LED development is aimed at improving the quality and uniformity of epitaxial wafers needed for high yield and low cost.

Further hoped-for advantages include ultra-high resolution, high color saturation, quick response and long lifespan (Table 1).

The adoption of micro-LED technology depends on costs being closer to LCD panels than OLED panels — i.e. \$12–15 for a 5.8-inch LCD compared with \$65–70 for an active-matrix OLED display as used in the iPhone X. Production costs for micro-LED panels are projected to be reduced significantly by 2021. Meanwhile, Japan's Yano Research Institute expects the global micro-LED market to increase from \$7m this year to \$224m in 2020.

In addition to offering a performance target, OLEDs also stand as a warning to crystal-ball gazers. Many in the industry, including Samsung (2006), expected the technology to replace LCDs as the mainstream display technology. OLEDs were expected to deliver low power consumption, simple structure, wide color gamut, large viewing angles under sunlight, and quick response time, in a compact format.

OLED panels do consume less power, but they have also not realized early expectations in this regard, with savings falling below the original hopes by about 30%. Another problem is that manufacturing processes using organic materials have low yields for the highest performance, increasing costs.

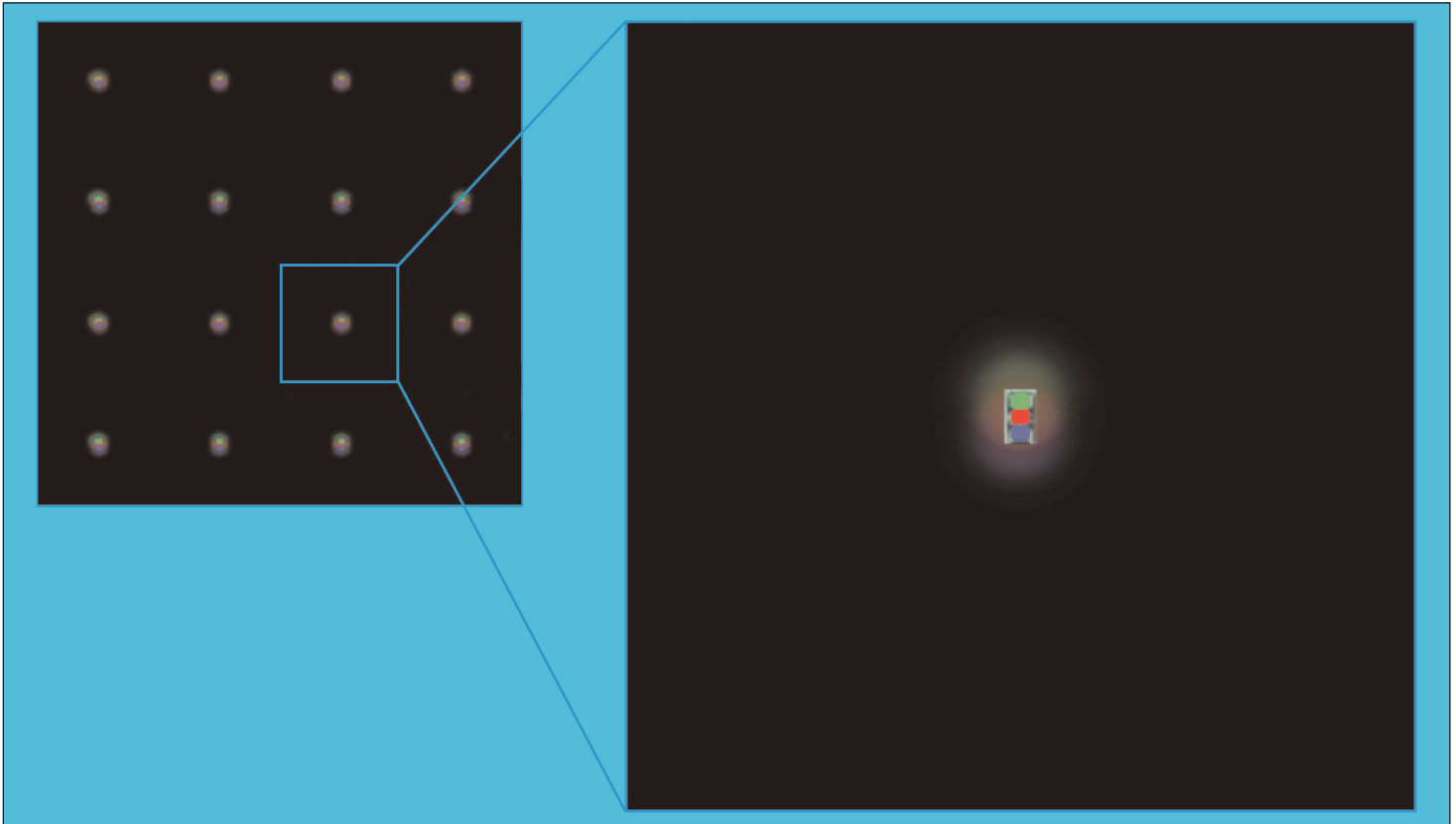


Figure 1. Sony's Crystal LED Integrated Structure giant display uses 0.003mm² pixel areas mounted on black display surface.

In many ways, it is not the LED technology that needs improvement — rather production costs and integration into the display production supply chain stand as the present challenges. The micro-LEDs must be accurately transferred and fixed en masse in a way that competes with LCD process speeds (with 10G panels produced in seconds).

Such manufacturing needs to separate epitaxial layers of micron-sized RGB LEDs from their substrates and transfer them onto a receiver substrate that could be glass or some flexible polymer. At the same time, the LEDs need to be connected with the control circuits on the receiver substrate.

Different companies see a variety of routes to mass micro-LED panel adoption, while costs are being reduced. Niche markets employing advanced capabilities could come first for micro-LED panels.

For example, LCDs and OLEDs both perform relatively poorly in competition with bright sunlight. Outdoor activity smart wearable devices could thus benefit from small but high-brightness screens.

Ditto automotive windshield displays, with 80% transparency for micro-LED panels, compared with 40% for OLEDs.

Small indoor screens for virtual/augmented reality (VR/AR) have 20% wider color gamut than OLEDs; and, at the other end, large-scale indoor displays, which could benefit from the variable shapes and areas of flexible panels, are also variously proposed.

Already, end-user companies such as Apple and Sony are developing micro-LED-based products. Sony's Crystal LED Integrated Structure (CLEDIS) giant displays uses 'ultrafine' RGB LED 0.003mm² pixel areas mounted on a black display surface (Figure 1).

At the other end of the supply chain, Epistar's president Jou Ming-jiunn commented in a June Digitimes report that US-based companies are inclined to apply micro-LED technology to wearables, VR and AR devices initially and then smartphones, while Asia-based firms, such as Samsung Electronics, are targeting large-size devices such as TVs. Epistar plans to produce 6-inch micro-LED epitaxial wafers, and possibly micro-LED chips, using existing equipment (which presently produces 4-inch LED epitaxial wafers) to meet these demands.

Market forces

Analysis firm Trendforce (through its LEDInside division) has been following micro- and mini-LED developments. LEDInside believes that replacing the entire LCD display chain could open up a market in the range \$30–40bn for micro-/mini-LED displays.

LEDInside estimates that manufacturing costs of micro-LED-based products are presently on average 3–4 times as much as products based on traditional display technologies. This analysis puts the possible replacement of LCD technology by micro-LED-based displays at least 3–5 years away. ▶

LEDinside research director Roger Chu believes that it is too early to determine the size of the micro-LED market because of differences among specification standards and manufacturing techniques. He adds: "New specification standards will raise the technology barrier for market entrants. The need for cross-industry collaboration will also prolong the R&D period for developers of micro-LED displays."

Chu also suggests that the developed mass transfer solutions may be used more widely to pick and place LEDs or other electronic components such as sensor chips.

While micro-LED displays are not on the immediate horizon, TrendForce/LEDinside does believe mini-LED-based backlight units will be rolled out in sample demonstrations next year as item 7 of its 'Top 10 Trends in Information and Communication Technology Sector for 2018' analysis. Devices on flexible substrate will allow curved displays. Mini-LED backlight units are also expected in smartphones, TVs, automotive displays and high-end gaming notebooks.

In its third-quarter 2017 results presentation, Epistar reported that it could be shipping products for mini-LED backlight units for large displays in first-half 2018. The company had been hoping for second-half 2017 production, but has had problem with yield rates and process stability.

Meanwhile, MarketsandMarkets Research Private Ltd claims that worldwide demand for micro-LED display and lighting panels could reach \$20bn by 2025, growing at a compound annual growth rate (CAGR) of 54.7% between 2019 and 2025. This market researcher suggests commercialization in smart-watches by 2019 and in smartphones and tablets by 2021. Associate director Sachin Garg comments: "Display applications will dominate and drive the growth of the market during the forecast period and are expected to account for more than 95% of the market by 2025."

Initial high-growth-rate applications are expected to be near-to-eye (NTE) devices, smartphones, tablets, laptops and heads-up displays (HUDs). Up to 2025, TV, PC monitor and digital signage applications have relatively low growth rate projections in the study. The researchers suggest that the growth will be mainly driven by consumer electronics.

Samsung Electronics has rolled out its 10.3mx5.4m 4K (4096x2160 pixels) Cinema Screen with brightness of 500nits (candela/cm²), first at Seoul's Lotte World Tower in July, and has signed up Major Cineplex Group (the largest cinema company in Thailand) to convert a 200-seat cinema at the Paragon Cineplex in Siam Paragon into its Cinema LED venue in October. Of course, at ~4pixels/cm (10ppi), these screens are not likely to be driven by mini-LEDs let alone micro-LEDs, unless they are pre-assembled in large numbers into separate pixels,

although there are stringent technical requirements in terms of color and dynamic range.

TV screens with 4K ultra-high-definition (UHD) specs consist of around 24million (3-colors x 4096 x 2160) separate LED devices which, even with so-called six-sigma production yield (99.99%), would consist of up to 2500 failed pixels. Inspection and repair will inevitably be needed before such products leave the factory.

PlayNitride

Taiwan's Digitimes has been following PlayNitride, which seems to be stepping up work in the area, particularly in the past few months. Epistar is a partial investor in PlayNitride.

Digitimes' "industry sources" say that Electronic and Optoelectronic System Research Laboratories (EOSRL) under the Industrial Technology Research Institute (ITRI) is cooperating with PlayNitride, LED driver IC design house Macroblock and PCB maker Unimicron Technology to develop ultra-fine pixel-pitch micro-LED panels.

Macroblock sources expect samples of large-sized indoor commercial display walls with ultra-fine pixel-pitch panels to be presented in first-half 2018, and trial production to begin in the second half. In this work, PlayNitride is responsible for developing micro-LED wafers without sapphire substrates, and EOSRL is developing related technology for mass transfer of

LEDinside research director Roger Chu believes that it is too early to determine the size of the micro-LED market because of differences among specification standards and manufacturing techniques. He adds: "New specification standards will raise the technology barrier for market entrants. The need for cross-industry collaboration will also prolong the R&D period for developers of micro-LED displays."

micro-LED chips onto printed circuit boards (PCBs) developed by Unimicron.

According to Digitimes, PlayNitride has finished one-color micro-LED wafers and expects to have two-color ones by the end of 2017. Macroblock's contribution is a micro-LED display driver IC MB15359 aimed at a fine pixel pitch of 0.9375mm. The MB15395 chip can detect misplaced micro-LEDs, facilitating early repair to improve the display quality and yields.

Meanwhile, PlayNitride chairman & CEO Charles Li spoke to Digitimes, saying that the company is starting trial production of micro-LED panels for niche markets. Li also reports that PlayNitride has hiked yield rates from

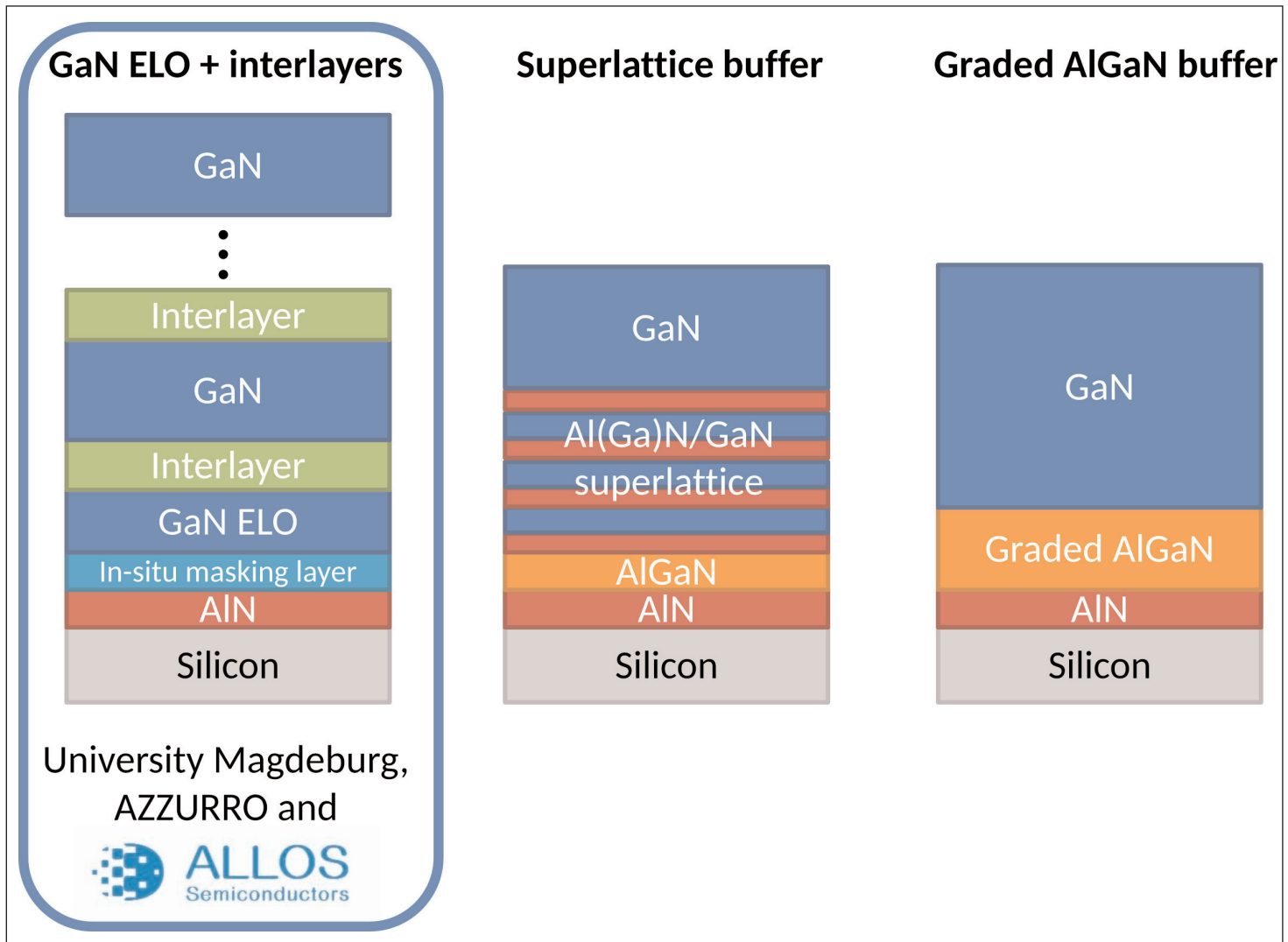


Figure 2. ALLOS approach compared with other often used technologies for GaN-on-Si.

30% initially to more than 99% — still short of the ideal level of 99.9999%. Despite its achievements, PlayNitride is finding it difficult to convince vendors to commit to micro-LED panels. Uniformity of LED epitaxial wafers and mass inspection of micro-LED chips (for which qualified machines are not yet available) are presently challenges, according to Li.

There are other small companies that have been working on micro-LED displays that have been reported over the years. However, the flow of news on their work seems to have been shut off a couple of years ago. For some, this indicates that their mission was accomplished by the sale of venture-capital-backed technology to large, established companies — e.g. Cork-based InfiniLED being taken over by Facebook's Oculus VR, or Luxvue going to Apple Inc. Others presumably have failed, while some have perhaps gone into 'stealth mode'.

GaN-on-silicon

Some parts of the supply chain are already being assembled. Veeco Instruments Inc with ALLOS Semiconductors AG have demonstrated 200mm GaN-on-Si wafers aimed at blue/green micro-LED production.

This involved ALLOS demonstrating proprietary epitaxy technology on Veeco's Propel single-wafer metal-organic chemical vapor deposition (MOCVD) system.

ALLOS' CEO Burkhard Slischka reports: "Within one month we established our technology on Propel and have achieved 200mm crack-free, meltback-free wafers with less than 30µm bow, high crystal quality, superior thickness uniformity and wavelength uniformity of less than 1nm."

ALLOS is a fabless intellectual property licensing and technology company, which is the successor of University of Magdeburg spin-off Azzurro Semiconductors AG. The company believes that only GaN-on-Si can deliver the super-uniform, CMOS-compatible large epiwafers needed for micro-LEDs. The ALLOS technique uses interlayers to manage the strain profile between the silicon and GaN lattice and thermal mismatch (Figure 2). ■

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III-nitride on silicon optoelectronics transfer to plastic and glass

An indium gallium nitride multiple quantum well diode has been operated in dual emitter/detector mode.

Nanjing University of Posts and Telecommunications and Zhengzhou University in China have used gallium nitride (GaN) on silicon technology to fabricate light-emitting and light-detecting diodes that can be transferred to metal, plastic and glass substrates [Zheng Shi et al, *Optical Materials*, vol72, p20, 2017].

The epitaxial structures were grown by metal-organic chemical vapor phase deposition (MOCVD) on (111) silicon. Step-graded aluminium gallium nitride (AlGaIn) was used as a buffer, bridging the thermal expansion and lattice mismatch between Si and GaN. Further layers consisted of a 3400nm n-GaN contact, nine 3nm InGaIn (indium gallium nitride) multiple quantum wells (MQWs)

separated by 10nm GaN barriers, and a 115nm p-GaN contact.

Circular 1.5mm-diameter diodes were fabricated with the nickel/gold p-electrode also serving as a reflector. The device was designed so that light entered or left through the back-side n-GaN. For transfer to foreign substrates, the back-side silicon, buffer and some of the n-GaN was etched with inductively coupled plasma, leaving the 2 μ m-thick diodes held in place with thin support beams (Figure 1). These struts were mechanically broken with probes for direct transfer to polyethylene terephthalate (PET) or glass substrates.

The flexibility of PET suggests the potential for

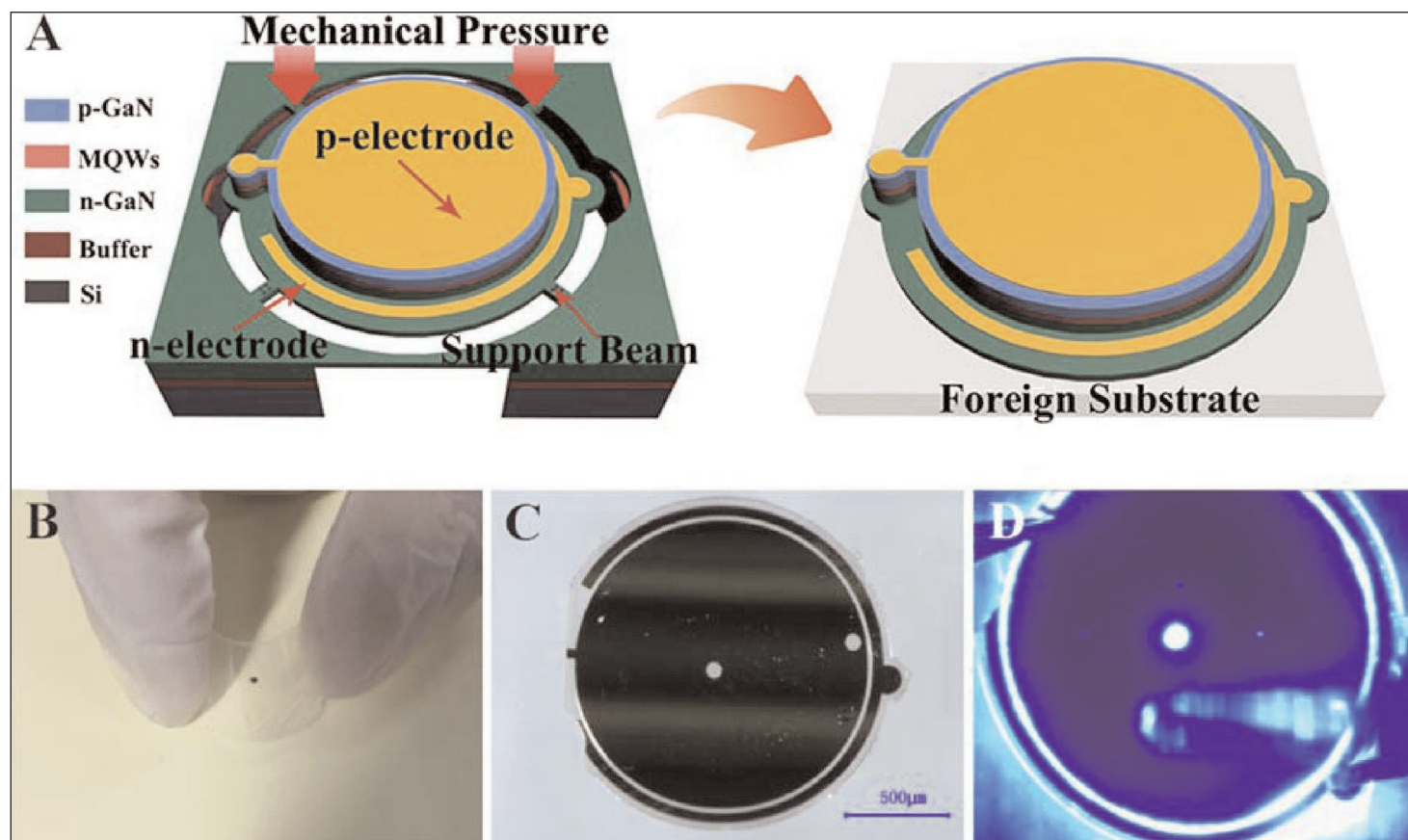


Figure 1. (A) Schematic fabrication and transfer procedures for MQW-diode-on-silicon. (B) Transferred MQW-diode on PET substrate. (C) Transferred MQW-diode on glass substrate. (D) Light emission image of MQW-diode-on-glass under current injection.

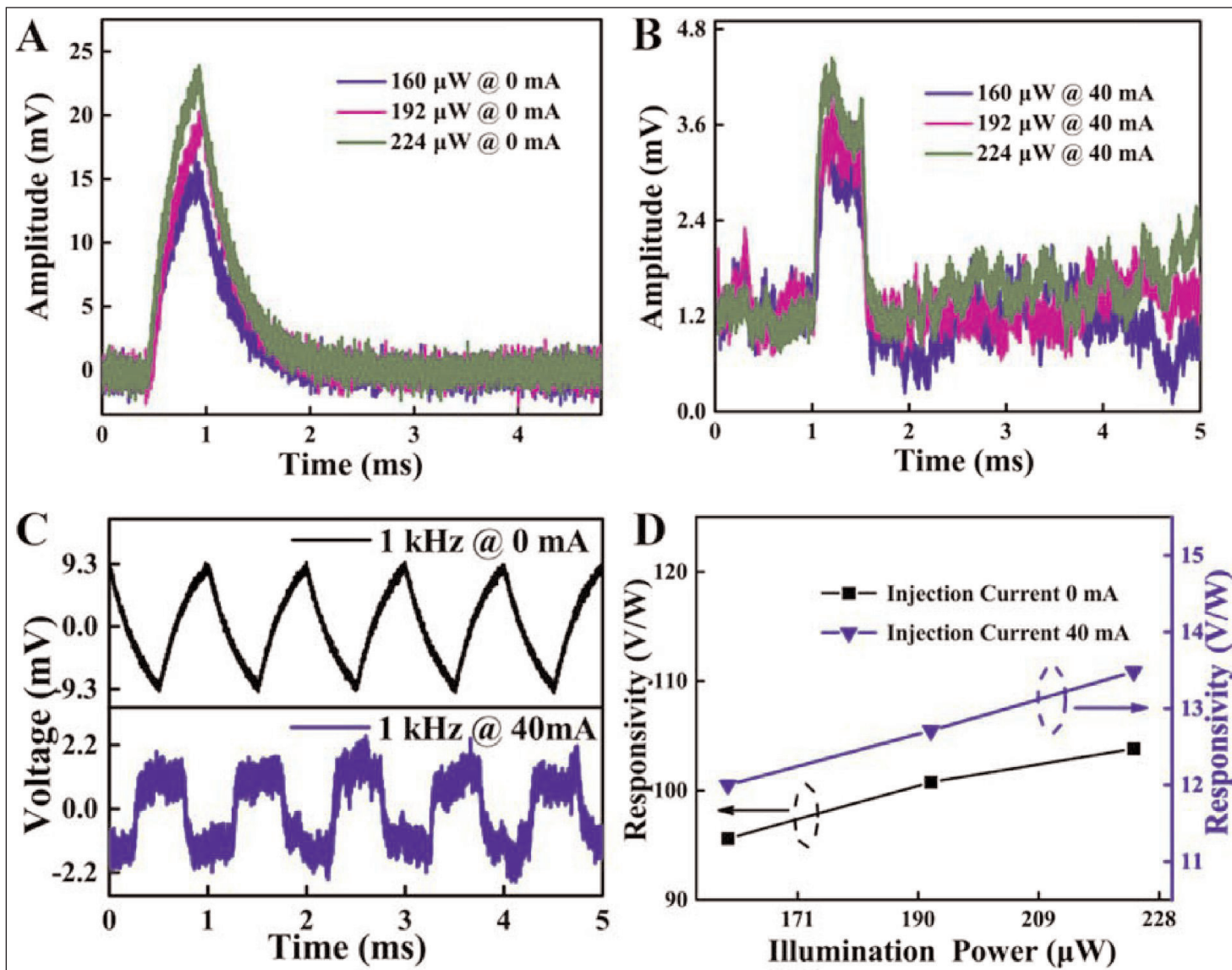


Figure 2. (A) Single light-detecting behavior of MQW-diode-on-glass. (B) Simultaneous light-detecting light-emitting behavior of MQW-diode-on-glass. (C) Continuously light-detecting response of MQW-diode-on-glass. (D) Induced voltage as a function of incident light power for MQW-diode-on-glass.

adjustable displays and wearable optical sensors. The researchers see the GaN-based diodes as offering improved efficiency, reliability and long-term stability, compared with organic light-emitting devices.

Before transfer, the etched diodes emitted wavelengths that red-shifted from 453.7nm to 454.9nm wavelength as the injection current increased from 5mA to 50mA. On glass, the corresponding wavelengths were 455.8nm to 461.9nm. The red-shift on transfer to glass is attributed to optically induced charge carriers giving rise to an internal electric field. A further effect is distortion from self-heating, which is constrained before transfer. The researchers suggest that transfer to metal could help reduce self-heating effects.

The devices were also tested under 3Mbits per second pseudo-random modulation, suggesting the potential for light communications.

At zero current injection, the diodes responded to illumination pulses, rising to a peak and decaying. The

researchers comment: "The 1.5mm-diameter MQW-diodes can be used as flexible solar cells to harvest energy from ambient light sources by integrating a capacitor circuit."

The diode responded with sharper decay, giving a more pulse-like voltage change, when operated in dual-mode with 40mA current injection. "The light-detecting plots exhibit the sharp decay processes because the photo-generated electron-hole pairs are quickly canceled by the injected electrons and holes," the team explains.

Dual-mode opens the possibility of full-duplex visible light communication. The device's millimeter-order size could allow the integration of transmitter, waveguide, modulator and receiver functionality on a single chip.

Under 410nm wavelength illumination, the response at zero injection was $\sim 100\text{V/W}$. Dual-mode response with 40mA injection was $\sim 10\text{V/W}$. ■

<http://dx.doi.org/10.1016/j.optmat.2017.05.039>

Author: Mike Cooke

AlN nanocolumns on gallium nitride templates

Selective-area growth achieves fill factor of more than 80%.

Researchers based in Spain, Germany and France have been studying nanocolumn (NC) selective-area growth (SAG) as a route to high-quality aluminium gallium nitride (AlGaN) materials with high aluminium content [A Bengoechea-Encabo et al, *Nanotechnology*, vol28, p365704, 2017]. In the reported work, the team from Universidad Politécnica de Madrid in Spain, Otto-von-Guericke University Magdeburg in Germany and CRHEA-CNRS in France grew AlN nanocolumns on GaN templates.

High-Al-content AlGaN is needed for deep ultraviolet (UV) optoelectronics due to the wider bandgaps up to 6.2eV for pure AlN, which corresponds to a wavelength of $\sim 200\text{nm}$. Presently, AlGaN LEDs emitting wavelengths shorter than 300nm have increasingly miserable efficiency due to high levels of threading dislocations ($>10^8/\text{cm}^2$) and low extraction efficiency of photons due to electromagnetic-wave polarization effects.

High-quality crystalline AlN is expensive and only available in small-area substrates. The researchers hope that nanocolumn growth on GaN-on-sapphire templates could become building blocks for individual nanodevices or the basis for quasi semi-polar or non-polar AlN pseudo-templates due to the high filling factors achieved. Lattice mismatches between high-Al-content AlGaN and the substrate are smaller on AlN, compared with GaN. Growing nanocolumns can reduce strain effects that generate defects. Also, the nanocolumn structuring could improve light extraction.

Other potential applications include micro/nano electro-mechanical systems using piezoelectric mechanical effects, high-mobility transistors with high breakdown voltage, field-emitters and single-photon emitters.

The AlN nanocolumns were grown by plasma-assisted molecular beam epitaxy (PAMBE) on GaN-on-sapphire templates. Masking for the nanocolumns was provided by a 7nm titanium nitride (TiN) film. The holes in the mask were placed in a triangular net patterned by colloidal lithography. The holes were 170nm diameter with 280nm pitch. The GaN/sapphire template was produced by metal-organic chemical vapor deposition (MOCVD), giving substrates with polar (0001) and semi-polar ($11\bar{2}2$) crystal orientations.

The first part of the PAMBE growth was of 860°C GaN nanocolumns to avoid parasitic AlN deposition and nucleation on the TiN mask (Figure 1). The nanocolumn growth

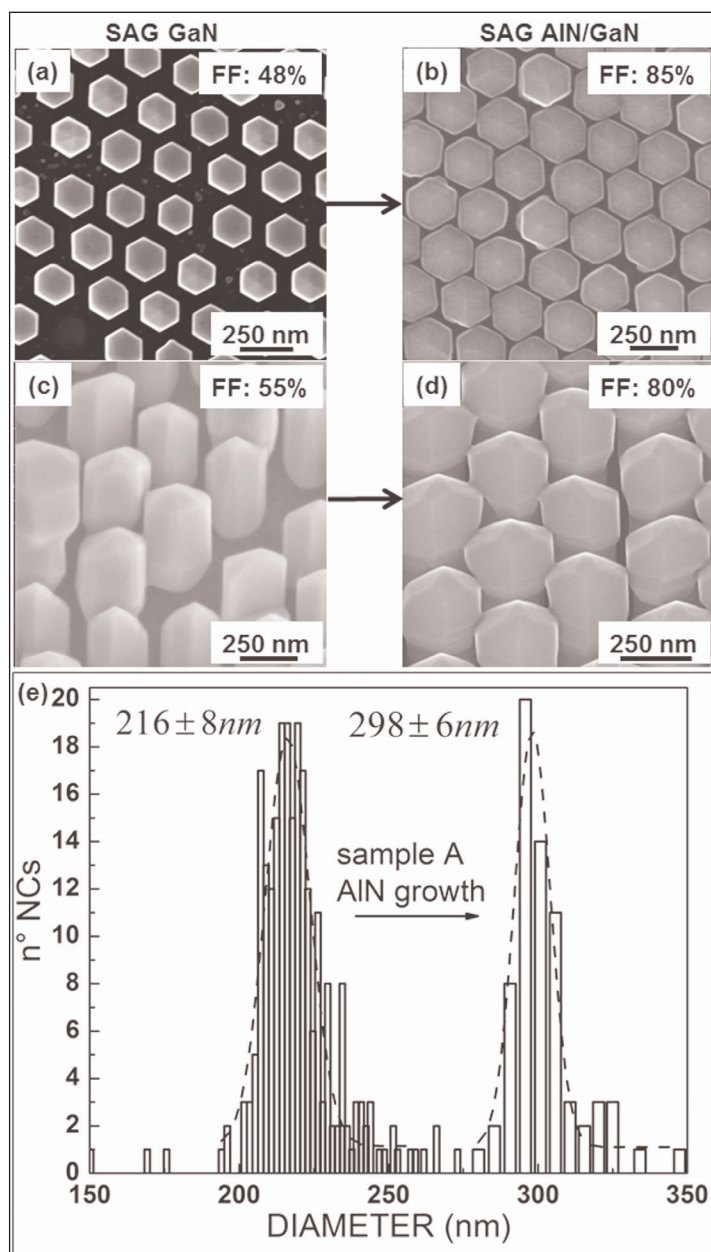


Figure 1. Top-view scanning electron microscope (SEM) pictures of: (a) SAG GaN nanocolumns (NCs) grown on (0001) GaN/sapphire template and (b) after AlN overgrowth (sample A); (c) SAG GaN NCs grown on ($11\bar{2}2$) GaN/sapphire template, and (d) after AlN overgrowth (sample B). (e) Diameter distribution before and after sample A's AlN growth.

was then continued with 860°C AlN deposition. Shadowing effects by the GaN part of the nanocolumn blocked parasitic deposition. The filling factors were higher than 80%.

The nanocolumns on (0001) templates were vertical, while those on ($11\bar{2}2$) GaN were inclined 58° from normal

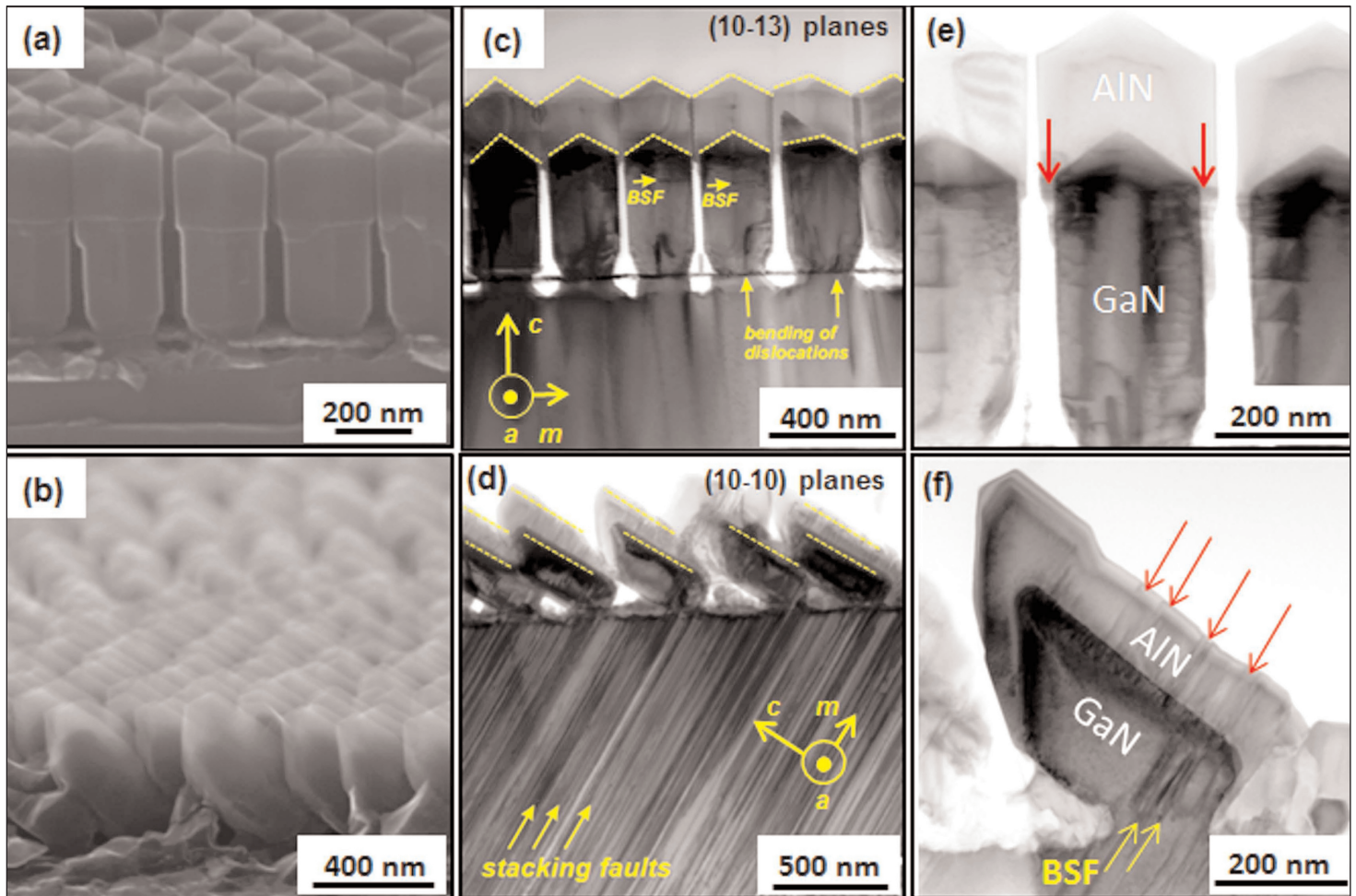


Figure 2. Bird's-eye view SEM pictures of (a) sample A and (b) sample B. (c) and (d), cross-sectional scanning transmission electron microscope (STEM) bright-field images taken on samples A and B, respectively. Dashed lines mark the main AlN/GaN interfaces and top surfaces. (e) and (f), Cross-sectional STEM bright-field images of individual NCs of samples A and B. Red arrows indicate location of extended defects, found in basal plane.

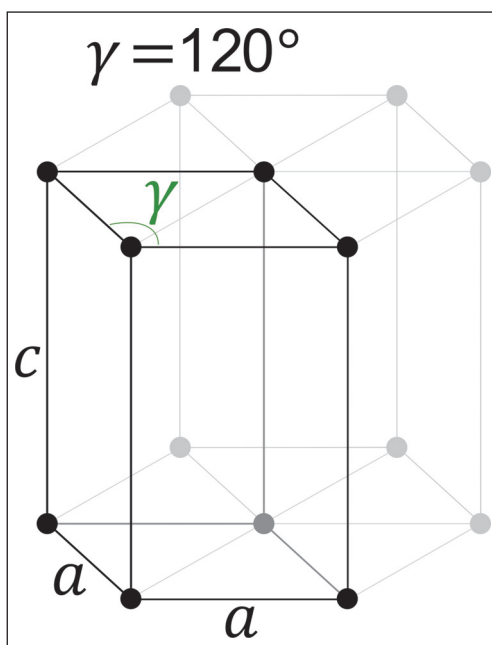


Figure 3. Hexagonal lattice. By Bor75 – Own work, CC BY-SA 3.0, <https://commons.wikimedia.org/w/index.php?curid=24101066>

with [0001] preferential growth direction. The lengths of the nanocolumns were 450nm in both cases. The diameters of the GaN (0001) and (11 $\bar{2}2$) structures were 216 and 221nm, respectively.

The diameter of the (0001) nanocolumns increased to 298nm after AlN growth with a core-shell structure at the interface region. At the same

time, the AlN growth in the radial direction seems to be limited so that nanocolumn coalescence does not occur. X-ray analysis resulted in estimates of the AlN 'c' and 'a' lattice parameters (Figure 3) of 4.982Å and 3.11Å, respectively. The team says that these values are close to being strain-free for AlN. The tops of the columns were pyramidal, consisting of semi-polar {1 $\bar{1}03$ } planes.

The inclination of the (11 $\bar{2}2$) nanocolumns makes the growth more difficult to describe with uneven exposure to the PAMBE growth (Figure 2). The dominant top surface was the non-polar (1 $\bar{1}00$) m-plane. The defect density in the non-polar plane was two orders of magnitude lower than in the semi-polar GaN template.

The researchers comment: "The high crystalline quality and the fact that the top facets would reduce or remove the polarization fields in both (Al,Ga)N/GaN and (In,Ga)N/GaN heterostructures make these kinds of nanostructures appealing building blocks, or pseudo-templates, for emitters and detectors working in the deep-UV and UV range whose efficiency nowadays is limited by the quality of the available material." ■

<https://doi.org/10.1088/1361-6528/aa78e6>

Author: Mike Cooke

Low-threshold indium arsenide quantum dot lasers on silicon

Researchers have claimed the lowest threshold for any kind of Fabry–Perot laser grown on silicon.

University of California Santa Barbara (UCSB) in the USA claims record low threshold currents for indium arsenide (InAs) quantum dot (QD) laser diodes (LDs) grown on silicon (Si) [Daehwan Jung et al, Appl. Phys. Lett., vol111, p122107, 2017]. The team says further that the 6.7mA threshold achieved is the lowest for any kind of Fabry–Perot laser grown on silicon. The use of QDs ameliorates problems arising from threading dislocations in lattice-mismatched crystal structures on silicon.

Combined with silicon photonics (waveguides, etc), the researchers see potential for a monolithically integrated, efficient light source to power high-performance, chip-scale optical interconnects to meet growing demand for data bandwidth.

The researchers used on-axis (001) gallium phosphide (GaP) on Si substrates, which are available commercially from NAsPIII/V GmbH in diameters up to 300mm. Although miscut off-axis silicon enables gallium arsenide (GaAs) to be grown directly without anti-phase domains, on-axis substrates are preferred for manufacturing in standard CMOS processing foundries. GaP has been found to terminate anti-phase domains within 40nm of the silicon interface.

Solid-source molecular beam epitaxy was used to create a 3 μ m GaAs buffer (Figure 1). The buffer growth included four cycles of thermal annealing between 320°C and 700°C under arsenic over-

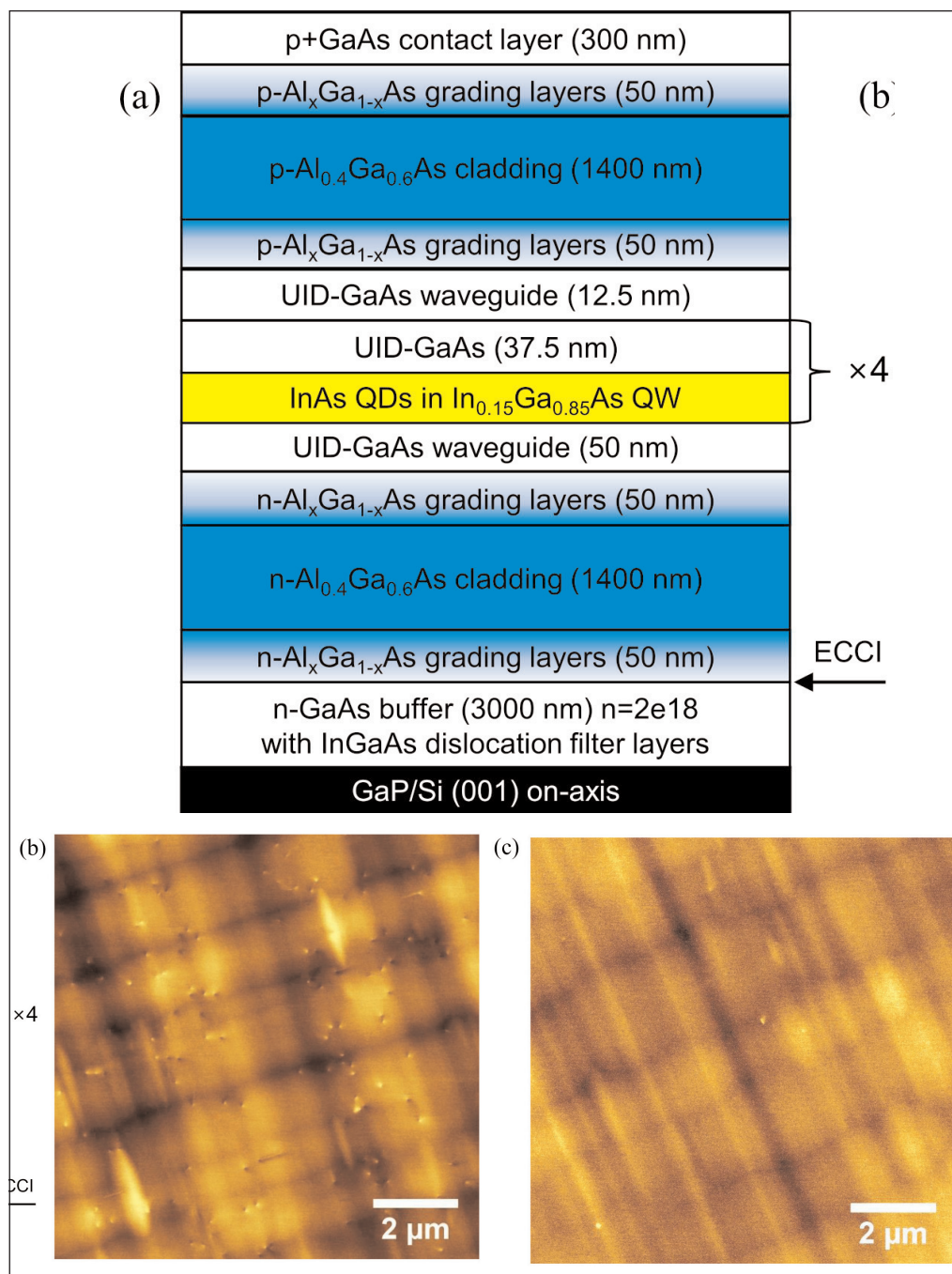


Figure 1. (a) Cross-sectional schematic of InAs QD laser structure grown on GaP/Si substrate. (b) Electron channeling contrast images showing threading dislocations before and (c) after optimization of GaAs/GaP/Si template.

pressure to annihilate dislocations. A 500°C super-lattice dislocation filter in the form of 10 layers of In_{0.1}Ga_{0.9}As was further inserted into the buffer layer. The filter reduced the surface roughness from 5.45nm root-mean-square to 2.48nm, according to atomic force microscopy (AFM).

Electron channeling contrast imaging (ECCI) measurements suggested that threading dislocation densities (TDDs) were reduced by a factor of 20 to $7.3 \times 10^6/\text{cm}^2$, compared with a non-optimized buffer.

The laser diode structure was completed with molecular beam epitaxy. The active QD region was grown at 495°C , producing 2.55 monolayer InAs dots in 7nm InGaAs wells. The bottom separate-confinement heterostructures were grown at 580°C , while the top half of the structure was grown at 560°C .

A separate single-layer InAs QD sample designed for photoluminescence analysis showed a peak at 1285nm. "The full-width at half-maximum is $\sim 28\text{meV}$, indicating an excellent QD size homogeneity," the researchers add. AFM analysis suggested a QD density of $\sim 5.2 \times 10^{10}/\text{cm}^2$, similar to what is seen in InAs QDs on pure GaAs substrate. The QDs were found to have an excited state 84meV above the ground state.

Ridge-waveguide laser diodes were fabricated with the cavity lengths defined by cleaving after wafer thinning to 150–200 μm thickness. A 1485 $\mu\text{m} \times 2.5\mu\text{m}$ device had a threshold current of 9.5mA in continuous-wave operation. The researchers say that this is significantly lower than for previous on-axis and miscut QD-based laser diodes on silicon. "We believe that the significant threshold reduction is attributed to the increased internal quantum efficiency in the devices grown on the low-TDD GaAs templates," they write.

The output power reached more than 71mW per facet for ground-state lasing. Excited-state lasing began at 400mA. The lasing wavelength was initially at 1270nm, with more Fabry–Perot longitudinal lasing modes kicking in as the current increased to 15mA.

A 2600 $\mu\text{m} \times 8\mu\text{m}$ laser diode reached an output power of 175mW with 27.5mA threshold ($132\text{A}/\text{cm}^2$). The wall-plug efficiency (WPE) was 29.5% at 175mA. Ground-state lasing continued up to 80°C with $\sim 7\text{mW}$ output.

The researchers comment: "This demonstrates that the QD lasers on GaP/Si can operate in a harsh environment such as those found in data-center and high-performance computing applications."

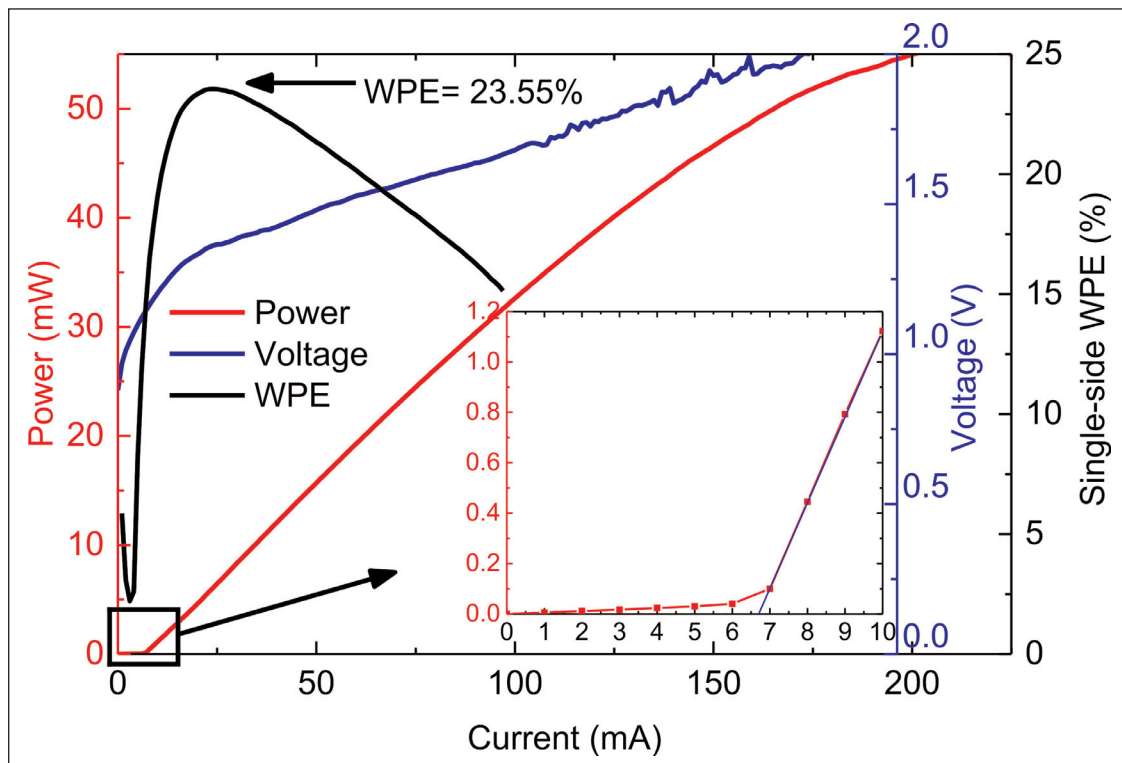


Figure 2. Single-side CW light output power-current-voltage LIV and wall-plug efficiency curves from a $1090\mu\text{m} \times 3\mu\text{m}$ laser with one 95% HR-coated facet. Inset: continuous-wave threshold current of 6.7mA at 20°C .

The device had a low characteristic temperature for the threshold of 32K, indicating rapid thermal fall-off of performance, but the researchers hope that p-modulation doping in the active region will improve temperature characteristics.

The as-cleaved devices had a minimum threshold current density of $147\text{A}/\text{cm}^2$ at 20°C , lower than the previously reported value of $\sim 425\text{A}/\text{cm}^2$ from high-reflectivity-coated QD lasers grown on on-axis (001) silicon substrates. The researchers attribute the low threshold to "the high-quality GaAs template with low TDD in addition to the low transparency current from using a reduced number of QD layers (four instead of five to seven) in the active region".

The highest WPE was 38.4% at 74mA from a $1366\mu\text{m} \times 4\mu\text{m}$ QD laser. The output power of the device was 18.6mW. There was a wide range of WPEs and output powers achieved due to fabrication non-uniformities and imperfect wafer cleaving.

Coating of one facet with 95% high-reflectivity (HR) structures consisting of layers of tantalum oxide and silicon dioxide was carried out on a $1090\mu\text{m} \times 3\mu\text{m}$ device. The threshold current was 6.7mA (Figure 2). The researchers comment: "We believe that this value is the lowest threshold current density to date for any kind of Fabry–Perot lasers on Si substrates. Its corresponding threshold current density is $205\text{A}/\text{cm}^2$, and the maximum single-side WPE is 23.55%." ■

<http://dx.doi.org/10.1063/1.4993226>

Author: Mike Cooke

Reverse-blocking GaN-on Si high-electron-mobility transistor

Researchers claim a record high reverse breakdown of 900V, enabled by an integrated tri-anode Schottky drain.

Ecole polytechnique fédérale de Lausanne (EPFL)

in Switzerland has claimed a record high reverse breakdown voltage (V_{RB}) of 900V for a reverse-blocking gallium nitride on silicon (GaN-on-Si) metal-oxide-semiconductor high-electron-mobility transistor (MOSHEMT) [Jun Ma et al, IEEE Electron Device Letters, 11 October 2017]. The reverse blocking was enabled by an integrated tri-anode Schottky drain structure with metal wrapped around etched nanowires.

The forward-bias breakdown (V_{FB}) was also high at 800V and 20nA/mm with grounded substrate. The team comments: "Both the high V_{FB} and V_{RB} were achieved in a single integrated device in this work, instead of using a discrete transistor in series with an SBD [Schottky barrier diode], which can greatly simplify the circuit design, reducing its size, resistance and parasitic components, and improve the efficiency of power converters."

In particular, reverse-blocking transistors are needed for cyclo-converter, matrix converter, current source and multi-level inverter circuit formats. Up to now, integrated reverse-blocking devices have tended to have low reverse breakdown (less than 685V) and/or

high reverse current leakage (more than 0.4 μ A/mm). By contrast, EPFL's single integrated device has performance comparable to circuits using state-of-the-art discrete devices.

The epitaxial structure (Figure 1) consisted of a 2nm GaN cap, 24nm aluminium gallium nitride ($Al_{0.25}Ga_{0.75}N$) barrier, 300nm GaN channel, and 5 μ m buffer. The two-

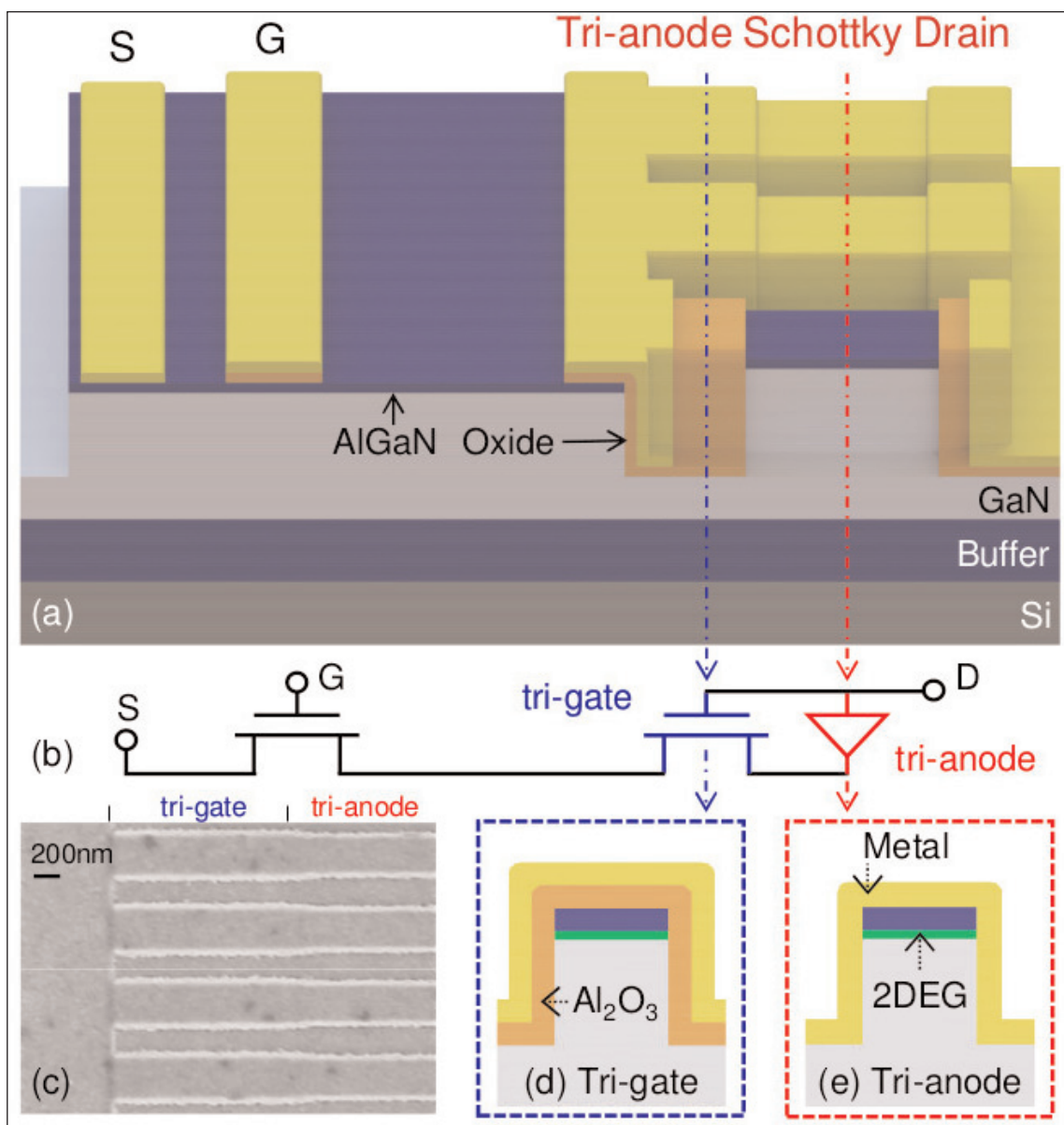


Figure 1. (a) Schematic and (b) equivalent circuit of reverse-blocking MOSHEMT. (c) Top-view scanning electron microscope image of hybrid tri-anode Schottky drain and schematic cross-sections of (d) tri-gate and (e) tri-anode regions.

dimensional electron gas near the barrier/channel interface had a measured carrier concentration of around $1 \times 10^{13}/\text{cm}^2$ with $2000 \text{cm}^2/\text{V}\cdot\text{s}$ mobility.

The nanowires for the drain region were etched to a depth of 180nm by inductively coupled plasma. The width and spacing of the wires were 300nm, giving a 50% fill factor. The devices were electrically isolated through mesa etching. The ohmic source contact consisted of titanium/aluminium/titanium/nickel/gold, annealed at 830°C in forming gas (hydrogen and nitrogen) for 30 seconds.

The oxide insulation layers — 10nm silicon dioxide and 10nm aluminium oxide — were applied by atomic layer deposition (ALD). Selective removal of the oxides was performed in the tri-anode region to give a Schottky contact. The gate and drain contacts were nickel/gold. Wet etching removed the oxide materials in the access and ohmic contact region. The lack of passivation from oxides in these regions did not affect leakage, according to the researchers.

The physical dimensions of the device were $1.5\mu\text{m}$ gate-source, $2.5\mu\text{m}$ gate length, $12.5\mu\text{m}$ gate-drain. The field plate (FP) was $1.3\mu\text{m}$; the tri-gate region $1.2\mu\text{m}$. The device width was $60\mu\text{m}$. The team comments: "The tri-gate region (Figure 1(d)) works as tri-gated FPs to shield the tri-anode region from high voltages, which along with the planar FP improves the V_{RB} ."

The RB-MOSHEMTs had a maximum drain current of $520 \text{mA}/\text{mm}$ and a differential on-resistance of $14\Omega\cdot\text{mm}$, normalized to the width of the device. A reference device with ohmic drain achieved a higher current ($550 \text{mA}/\text{mm}$) and lower resistance ($13\Omega\cdot\text{mm}$). The researchers suggest that the difference could be made up by increasing the fill factor of the tri-anode region. The turn-on voltage for the RB-MOSHEMT was 0.58V . The forward drain bias for $150 \text{mA}/\text{mm}$ current was 2.1V in the reference transistors and 2.9V for the RB-MOSHEMT.

The (non-blocking) reference had a $280 \text{mA}/\text{mm}$ current when the drain was reverse biased at -15V . At the same voltage, the RB-MOSHEMT had a leakage current $19 \text{nA}/\text{mm}$, a factor of 7 orders of magnitude

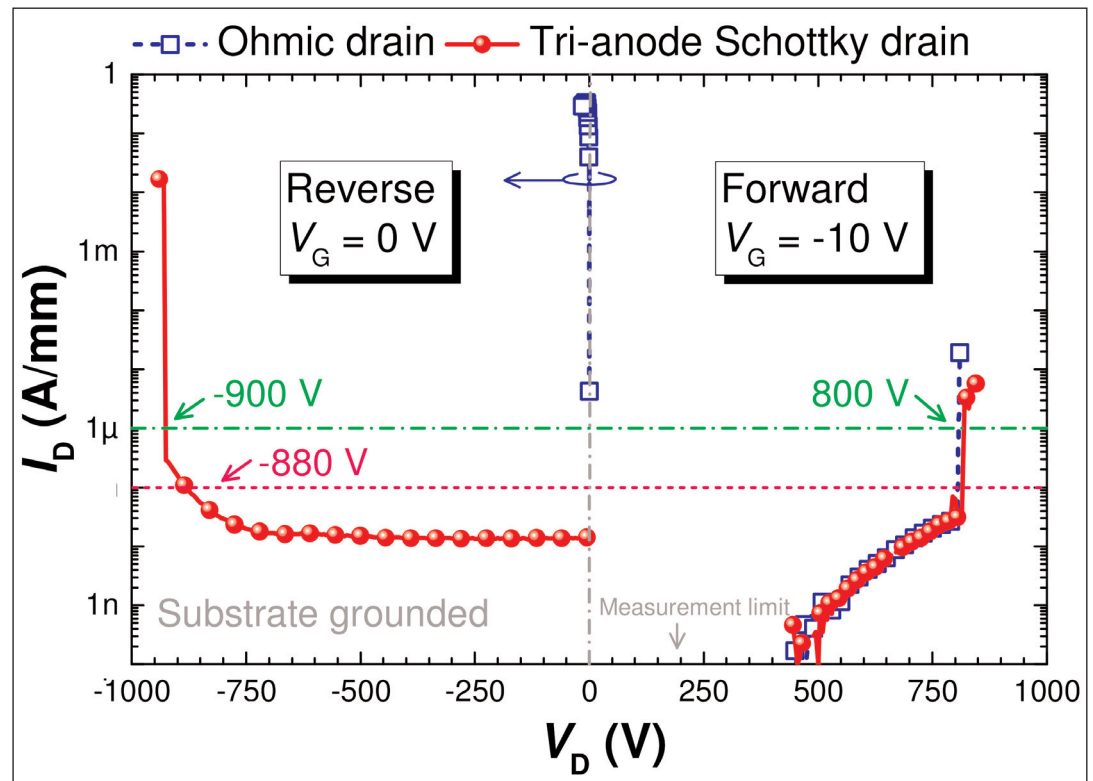


Figure 2. Breakdown characteristics of RB-MOSHEMTs and MOSHEMTs measured at room temperature with grounded substrate.

difference. The blocking was independent of the gate potential over the range from -10V to $+5 \text{V}$.

The gate threshold for $1\mu\text{A}/\text{mm}$ was -6.6V for both devices. The subthreshold swing and on/off current ratios were also similar, at $100 \text{mV}/\text{decade}$ and 10^{10} , respectively. The subthreshold swing suggests an oxide/semiconductor interface trap density of $1.24 \times 10^{12}/\text{cm}^2\cdot\text{eV}$,

At 150°C , the on-voltage decreased to 0.53V , while the on-resistance increased to $26\Omega\cdot\text{mm}$. The reverse blocking current also increased by an order of magnitude to $0.57\mu\text{A}/\text{mm}$ ($570 \text{nA}/\text{mm}$). This is still below $1\mu\text{A}/\text{mm}$, indicating "excellent potential of the RB-MOSHEMTs for high-temperature applications," the researchers say.

The forward breakdown of the devices occurred at 800V with the gate potential at -10V and $0.02\mu\text{A}/\text{mm}$ current. The off-current at 650V was $6 \text{nA}/\text{mm}$. The reverse blocking of RB-MOSHEMTs broke down at around -900V . The current at -750V was $0.02\mu\text{A}/\text{mm}$.

The team comments: "The high VRB obtained in this work is attributed to the better-distributed electric field under reverse biases. In the hybrid tri-anode drain, two field plates (e.g. the planar and the tri-gate regions) are integrated with the tri-anode, by simply engineering their pinch-off voltages with the tri-gate approach, which spread effectively the electric field and improved the V_{RB} ." ■

<https://doi.org/10.1109/LED.2017.2761911>

Author: Mike Cooke

Vertical gallium nitride p-n diode with 5.0kV breakdown

Researchers have used a guard-ring structure with a resistor to reduce electric field crowding at the edge of the device.

Hosei University and Sciocs Co Ltd in Japan have presented a vertical gallium nitride (GaN) p-n diode with a breakdown voltage (V_B) of 5.0kV [Hiroshi Ohta et al, International Conference on Solid State Devices and Materials, Sendai, Japan, 22 September 2017, session N-6-02]. The team comments: "This value is the highest among so-far reported V_B of the vertical structure GaN p-n diodes."

The device used a guard ring and resistor structure to reduce the potential at the edges of top contact where fields tend to crowd and become critical, causing breakdown.

The material for the structure was grown by metal-organic vapor phase epitaxy. The substrate was free-standing GaN created using void-assisted separation — the threading dislocation density was less than $3 \times 10^6/\text{cm}^2$. Thermal annealing at 850°C for 30 minutes activated the magnesium p-type doping by removing hydrogen.

The resistor between the guard ring and central portion of the p-contact consisted of 4 μm -wide Hitachi Chemical Co Ltd HD8820 photosensitive polyimide, patterned and then cured at 350°C for 30 minutes. The circular palladium ohmic electrode had a diameter of 60 μm .

The specific on-resistance of the device was 1.25m $\Omega\text{-cm}^2$ at 5V forward bias. This was close to the value for a circular p-n diode without guard-ring structure. Reverse bias with the guard-ring structure increased the breakdown to 5.0kV, about 200V greater than the 4.8kV value found for the diode without. Baliga's figure of merit with guard-ring

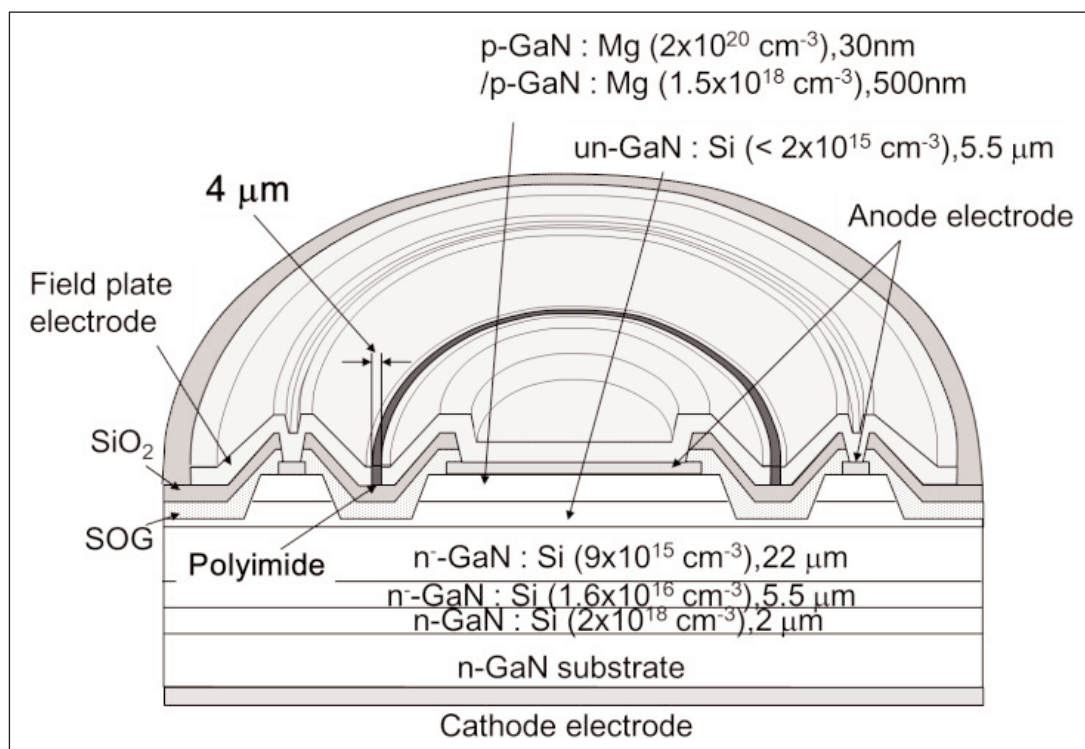


Figure 1. Schematic of GaN p-n diode with guard-ring structure.

structure (V_B^2/R_{on}) was 20GW/cm 2 .

The site of the breakdown (Figure 2) was found to be the edge of the main ohmic contact and not the guard ring, suggesting that the polyimide resistor had successfully kept the voltage of the guard-ring below its breakdown value, while not impacting the on-resistance. The researchers hope to increase the breakdown further by optimizing the resistor structure between the ohmic contact and guard ring. ■

www.ssdm.jp

Author: Mike Cooke

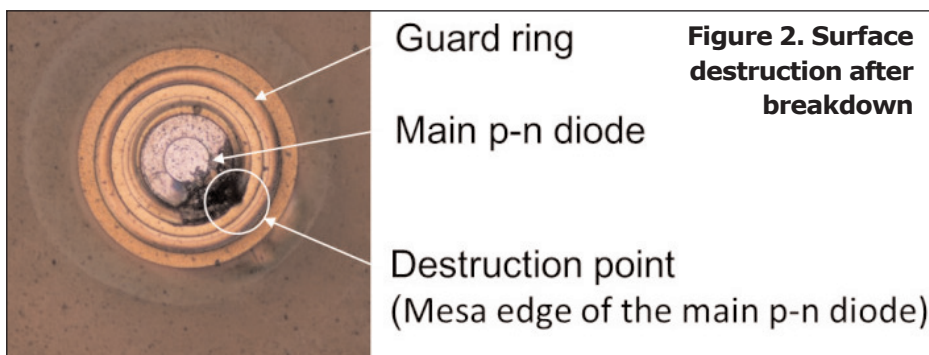


Figure 2. Surface destruction after breakdown



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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

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3081 Zanker Road,
San Jose, CA 95134, USA
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Fax: +1 408 428 9600
www.semi.org

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San Francisco, CA USA

E-mail: info@ieee-iedm.org

www.ieee-iedm.org

5–7 December 2017

9th PV Performance Modeling and Monitoring Collaborative Workshop 2017 (PVPWC-9)

Solar Research Institute of HIT, Weihai, China

E-mail: pvpwc@hitwh.edu.cn

http://pvpwc.hitwh.edu.cn

6–9 December 2017

48th IEEE Semiconductor Interface Specialists Conference (SISC 2017)

San Francisco, CA USA

E-mail: pmcintyre@ieeesisc.org

www.ieeesisc.org

13–15 December 2017

SEMICON Japan 2017

Tokyo Big Sight, Tokyo, Japan

E-mail: jcustomer@semi.org

www.semiconjapan.org

27 January – 1 February 2018

SPIE Photonics West 2018

Moscone Center San Francisco, CA, USA

E-mail: customerservice@spie.org

http://spie.org/SPIE-PHOTONICS-WEST-conference

4–8 February 2018

IEEE International Solid-State Circuits Conference (ISSCC 2018)

San Francisco, CA, USA

E-mail: Issccinfo@yesevents.com

www.isscc.org

13–15 February 2018

Strategies in Light/The LED Show 2018

Long Beach Convention Center, Long Beach, CA, USA

E-mail: registration@pennwell.com

www.strategiesinlight.com

4–8 March 2018

IEEE Applied Power Electronics Conference and Exposition (APEC 2018)

San Antonio, TX, USA

E-mail: apec@apec-conf.org

www.apec-conf.org

14–16 March 2018

SEMICON China 2018

Shanghai New International Expo Centre, China

E-mail: semichina@semi.org

www.semiconchina.org

14–16 March 2018

LASER World of PHOTONICS CHINA 2018

Shanghai New International Expo Centre, Shanghai, China

E-mail: info@world-of-photonics-china.com

www.world-of-photonics-china.com

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15–19 April 2018**SPIE Defense + Commercial Sensing**Gaylord Palms Resort & Convention Center,
Orlando, Florida, USA**E-mail:** customerservice@spie.org**http://spie.org/conferences-and-exhibitions/
defense--commercial-sensing**

22–25 April 2018**UV LED Technologies & Applications**

MELIÁ Hotel Berlin, Germany

E-mail: conference@advanced-uv.de**www.iuva.org/BerlinConference**

22–26 April 2018**SPIE Photonics Europe 2018**Strasbourg Convention & Exhibition Centre,
Strasbourg, France**E-mail:** info@spieeurope.org**http://spie.org/SPIE_Photonics_Europe_Conference**

13–17 May 2018**30th IEEE International Symposium on
Power Semiconductor Devices and ICs
(ISPSD 2018)**

Palmer House Hilton Hotel, Chicago, IL USA

E-mail: info@ispsd.org**www.ispsd2018.org**

5–7 June 2018**PCIM Europe (Power conversion and
Intelligent Motion) 2018**

Nuremberg Messe, Germany

E-mail: daniela.kaeser@mesago.com**www.mesago.de/en/PCIM/main.htm**

18–22 June 2018**2018 IEEE Symposium on VLSI Technology
and Circuits**

Hilton Hawaiian Village, Honolulu, HI, USA

E-mail: vlsi@vlsisymposium.org**www.vlsisymposium.org**

24–29 June 2018**IEEE 45th Photovoltaic Specialists
Conference (PVSC 2018)**

Washington, DC, USA

E-mail: info@ieee-pvsc.org**www.ieee-pvsc.org**

9–11 July 2018**IEEE Photonics Society's 2018 Summer
Topicals Meeting Series**

Waikoloa, Hawaii, USA

E-mail: i.donnelly@ieee.org**www.sum-ieee.org**

23–28 September 2018**13th European Microwave Integrated
Circuits Conference (EuMIC 2018), part of
21st European Microwave Week (EuMW 2018)**

IFEMA, Madrid, Spain

E-mail: eumwreg@itnint.com**www.eumweek.com/conferences/eumic.html**

3–5 December 2018**IEEE International Electron Devices Meeting
(IEDM 2018)**Hilton San Francisco and Towers,
San Francisco, CA, USA**E-mail:** iedm@his.com**www.ieee.org/conference/iedm**

5–8 December 2018**49th IEEE Semiconductor Interface
Specialists Conference (SISC 2018)**

San Diego, CA, USA

E-mail: meetings@ucsd.edu**www.ieeesisc.org**

2–6 February 2019**IEEE International Solid- State Circuits
Conference (ISSCC 2019)**

San Francisco, CA, USA

E-mail: Issccinfo@yesevents.com**www.isscc.org**

17–21 March 2019**IEEE Applied Power Electronics Conference
and Exposition (APEC 2019)**

Anaheim Convention Center, CA, USA

E-mail: apec@apec-conf.org**www.apec-conf.org**

7–9 May 2019**PCIM Europe (Power conversion and
Intelligent Motion) 2019**

Nuremberg Messe, Germany

E-mail: daniela.kaeser@mesago.com**www.mesago.de/en/PCIM/main.htm**

24–28 June 2019**IEEE 46th Photovoltaic Specialists
Conference (PVSC 2019)**

Chicago, IL, USA

E-mail: info@ieee-pvsc.org**www.ieee-pvsc.org**

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Fort Lauderdale, FL, USA

E-mail: i.donnelly@ieee.org**www.sum-ieee.org**



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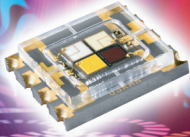


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