

semiconductor **TODAY**

COMPOUNDS & ADVANCED SILICON

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UV optoelectronics on silicon

LEDs for horticultural applications

II-VI acquiring Finisar • Mini-LED market adoption •
December-quarter guidance reduced in VCSEL supply chain



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Veeco's New TurboDisc EPIK700 GaN MOCVD System

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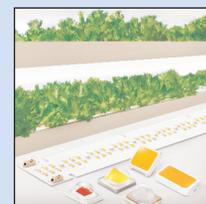
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p48 Cover: Samsung has launched new horticulture LED lineups, including full-spectrum packages and modules as well as color LEDs. Optimized for greenhouses and vertical farming, the LEDs provide a broader spectrum of light for healthier plant growth, enhanced farming environments and reduced system cost.

Opto consolidation dependent on US–China trade

On 9 November it was announced that Silicon Valley-based Finisar – one of the world's two biggest optical communications component makers (with annual revenue of about \$1.3bn) – is being acquired for \$3.2bn by Pennsylvania-based engineered materials and optoelectronic component maker II–VI Inc (which will hence more than double its annual revenue from \$1.2bn to \$2.5bn) – see page 60.

As well as making silicon carbide (SiC) substrates, II–VI has over the years made diverse III–Vs compound semiconductor-based acquisitions, including Anadigics of Warren, NJ, USA in 2016, bringing gallium arsenide (GaAs)- and gallium nitride (GaN)-based RF component manufacturing capabilities. Most recently this has allowed it to collaborate with Japan's Sumitomo Electric on 6"–wafer GaN-on-SiC high-electric-mobility transistor (HEMT) production (see page 21). The 6" GaAs wafer fabrication lines have enabled II–VI to make vertical-cavity surface-emitting lasers (VCSELs), which are facing mass adoption for 3D sensing in consumer electronics (e.g. facial recognition in Apple's iPhone X) and for light detection & ranging (LiDAR) in autonomous vehicles. However, II–VI is one of the smaller suppliers of VCSELs, whereas Finisar in December 2017 gained \$390m in funding commitments from Apple to supplement its existing 4" VCSEL fab in Allen, Texas with a new 6" fab in Sherman, Texas (currently ramping up for VCSEL production by end-2018).

This follows March's announcement of the acquisition of Oclaro for \$1.8bn by fellow Silicon Valley-based firm Lumentum (the former communications and optical products business of JDSU, which previously had acquired many smaller opto firms). Finisar's longer-than-expected VCSEL ramp-up benefitted rival Apple supplier Lumentum, helping it to overtake Finisar as the largest optical communications component maker. Collective Lumentum–Oclaro annual revenue is \$1.9bn.

On 6 December, the Lumentum/Oclaro merger received anti-trust clearance from the Chinese authorities (necessary due to China's two largest telecom equipment makers Huawei and ZTE being customers). This had been in doubt due to the US government's ban in May on exports of chips to ZTE (since rescinded in July, after payment of a fine) for breaking US sanctions on exports to Iran and North Korea. Hopes are therefore raised for Chinese approval of the II–VI/Finisar merger, especially after the 90-day moratorium between the USA and China on any further increases in trade tariffs (agreed on 1 December at the G20 meeting in Buenos Aires).

However, further doubts arose after the arrest the same day in Canada (at the request of US authorities) of Huawei's chief financial officer for allegedly breaking sanctions against Iran. This follows the exclusion of both Huawei and ZTE equipment from being used in 5G networks by the USA, Australia, New Zealand and Japan, citing national security concerns.

Earlier this year Huawei overtook Apple to become the second biggest smartphone supplier (after Samsung). Although Huawei is the biggest customer of many firms, the effect of Apple's disappointing iPhone sales growth is behind the reductions in December-quarter revenue guidance rippling through the supply chain, from device makers like Qorvo (page 9) and Lumentum (page 65) to epiwafer supplier IQE (page 32). The advent of 5G therefore raises the stakes for many in the ongoing trade/technology disputes between the USA and China.

Mark Telford, Editor



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Editor

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

Commercial Director/Assistant Editor

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

Advertisement Sales

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

Original design Paul Johnson
www.higgs-boson.com

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

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

Regular issues contain:

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

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SEMI issues the first power semiconductor and compound semiconductor fab outlook

Report covers 530 compound-related and 430 power-related facilities

Global industry association Semiconductor Equipment and Materials International (SEMI) has announced what it says is the industry's first data on worldwide fabrication plants for power and compound semiconductors, with the new report 'Power and Compound Fab Outlook' providing front-end semiconductor fab information (including over 890 listings spanning 530 compound-related and over 430 power-related facilities) and a forecast (quarter by quarter) to 2022 for global manufacturing capabilities (fab construction, capacity and equipment investments).

Power devices are becoming important as energy-efficiency standards tighten to meet growing demand for power-thrifty high-end consumer electronics, wireless communications, electric vehicles (EVs), green energy, data centers, and both industrial and consumer IoT (Internet of Things) applications. Semiconductor fabs around the

world have responded with improvements to power usage in every aspect of electronics including power harvesting, delivery, transformation, storage and consumption, says the report. Cost structure and performance are critical in power electronics, dictating the pace of

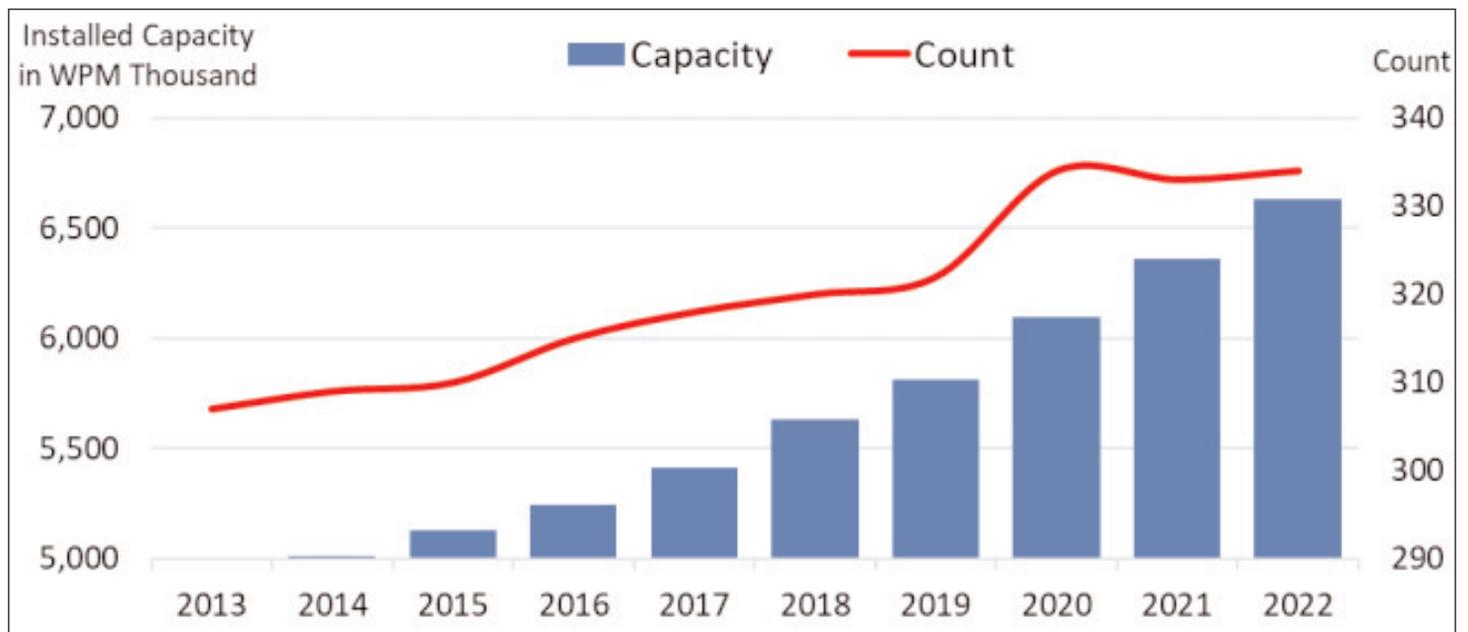
Power devices are becoming important as energy-efficiency standards tighten to meet growing demand for power-thrifty high-end consumer electronics, wireless communications, electric vehicles, green energy, data centers, and both industrial and consumer Internet of Things applications

market growth and technology adoption.

With compound materials driving significant gains in the energy efficiency of power devices, the 'Power and Compound Fab Outlook' report highlights particular compound materials that have been adopted in semiconductor fabs, providing information on related tool and material markets as well as power and compound materials capacity and investments in fabs by region, wafer size and product type.

Materials covered include silicon carbide (SiC), gallium nitride (GaN), gallium arsenide (GaAs), indium phosphide (InP) as well as other III-V and II-VI materials. Technology highlighted includes metal-organic chemical vapor deposition (MOCVD), LEDs, epitaxy, IGBTs, HEMTs, MOSFETs, BCDs and other devices.

www.semi.org/en/power-compound-fab-outlook



Power-related wafer capacity and facility count (excluding epi and LED). Source: Power & Compound Outlook, November 2018, SEMI.



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Qorvo's quarterly revenue rises 8% year-on-year to a record \$884m

Strength in infrastructure offsetting near-term weakness in Wi-Fi

For its fiscal second-quarter 2019 (ended 29 September 2018), revenue was a record \$884.4m (\$29m above the midpoint of guidance), up 28% on \$692.7m last quarter and 8% on \$820.6m a year ago, extending a strong start to fiscal 2019 after supporting a series of large product ramps and seeing robust design activity in both the Mobile Products (MP) and Infrastructure & Defense Products (IDP) groups.

Qorvo had two 10%-or-more customers, one of which was a large China-based OEM.

Revenue for Mobile Products was \$667m, up 5.9% on \$630m a year ago and up 37% on \$486m last quarter, reflecting strong seasonal ramps of flagship smartphone products (with about 30% of Mobile business going to China, not including Huawei). The firm increased its content on key customer programs, and helped to enable early 5G smartphone designs. During the quarter, Qorvo:

- was selected by Samsung to supply 3.5GHz 5G front-end modules (FEMs) for a series of a 5G mobile handset demonstrations across multiple base bands;
- sampled an industry-first dual-band 3.5GHz and 4.9GHz 5G FEM to a leading China-based smartphone maker; and
- began shipping RF Fusion Phase 6 for Vivo's newest flagship smartphone (the NEX). RF Fusion Phase 6 leverages Qorvo's premium bulk acoustic wave (BAW) and surface acoustic wave (SAW) filter technologies to deliver complete main path coverage in two placements: a low-band module and a mid/high-band module.

Revenue for Infrastructure & Defense Products was \$218m, up 5.3% on \$207m last quarter and another quarter of double-digit year-on-year growth (up 14.7% from \$218m).

Demand was particularly strong in Infrastructure, led by strength in base stations across all OEMs (driven by strength in both 4G and 5G deployments) as well as strong demand for small-cell and massive MIMO products. This includes 27% year-on-year growth in gallium nitride (GaN)-based revenue (driven by broad market demand, including 5G infrastructure for the MIMO deployments). During the quarter, IDP:

- began shipping a dual-band Wi-Fi iFEM powering Facebook's family of portal video communication devices (its recently launched digital video assistant);
- supplied a 5.9GHz FEM optimized for Qualcomm's 9150 cellular vehicle-to-everything (C-V2X) chipset, supporting multiple automotive OEMs in worldwide field trials;
- was selected by tier-one automotive supplier Continental to deliver multiple solutions enabling always-on automotive connectivity to cellular networks around the world;
- secured design wins from a leader in wearable and location technology to supply 2.4GHz FEMs for multiple consumer wearable devices; and
- was awarded a design win by CommScope to supply 28GHz high-power amplifiers for 32-element phased-array 5G deployments, targeting large venues with dense cellular traffic (such as concert halls, convention centers and sporting arenas).

"Defense is certainly still the strongest part of our GaN portfolio, but the base station is going to grow at a rapid pace and will outstrip the overall growth of GaN," reckons IDP president James Klein.

Qorvo saw strong demand for its solid-state GaN Spatium high-power products for electronic warfare (EW) and communications applications. However, Defense revenue is a little bit off of the record seen in the second half of last year. "Defense

and Wi-Fi have pulled back a bit, but in both the fundamentals are both very, very strong," notes Klein. "The technologies we have are matched very well with where we see both of those marketplaces going." In particular, the deployment of phased-array radars and higher frequencies of operation are increasing demand for RF solutions that leverage GaN, GaAs and other semiconductor processes.

"Our products and technologies make Qorvo uniquely positioned to partner with our customers to develop their most compelling products," says president & CEO Bob Bruggeworth.

"The September quarter was a record revenue and earnings quarter," notes chief financial officer Mark Murphy. "Our portfolio strategy and operational improvements are yielding stronger and more consistent results," he adds.

On a non-GAAP basis, gross margin was 47.7%, up from 44% last quarter and 47.4% a year ago (and exceeding the 47.5% guidance).

Operating expenses have grown further, from \$158.2m a year ago and \$160.5m last quarter to \$168.3m, related primarily to BAW and GaN capacity additions in the fabrication plant in Richardson, TX (although this was better than the expected \$170m).

Net income was a record \$224.9m (\$1.75 per diluted share, above the expected \$1.62), up from \$124m (\$0.96 per diluted share) last quarter and \$198.4m (\$1.52 per diluted share) a year ago.

Operating cash flow was \$214.5m (almost tripling from \$75.3m last quarter). Capital expenditure (CapEx) rose again, to \$70.1m (from \$43.6m). Free cash flow was hence \$144.4m (more than quadrupling from \$31.7m).

Qorvo repurchased \$87m of stock (its third-highest quarter of repur-

chases, outside the firm's accelerated share repurchase program, making about \$187m in the last six months — higher than the free cash flow generated over that period). Cash and cash equivalents rose from \$334m to \$558m. During the quarter, Qorvo redeemed its remaining 6.75% notes (due 2023), and repurchased \$436m of 7% notes (due 2025). The firm also issued \$630m of 5.5% notes, maturing in 2026. "With these actions, we've lowered our interest costs and extended our average debt maturity to 2026," says Murphy. "We are below our long-term leverage target and retain significant financial flexibility to grow the business and return capital to shareholders," he adds.

"Qorvo's record revenue and EPS in the September quarter reflect the progress we're making on shaping the portfolio and improving operationally," says Murphy. "Our outlook calls for a strong December quarter with higher volumes and ongoing cost control."

For fiscal third-quarter 2019 (to end-December 2018), Qorvo expects revenue of \$880–900m, with Mobile Products up slightly in support of seasonal phone ramps. "For China, we see a relatively healthy channel but, given the strength from China-based handset manufacturers year-to-date, we are taking a measured view on demand in the back half of the fiscal year," notes Murphy. IDP should post another solid quarter,

with strength in infrastructure offsetting near-term weakness in Wi-Fi.

Gross margin should rise to 50%. This is up 230 basis points from 47.7%, a little over half due to continued product and customer mix and the remainder due to net lower cost (i.e. factory productivity and lower inventory charges), partially offset by some price effects and SAW-related effects (the SAW underutilization is actually down on a percent basis, but not on an absolute dollar basis). "Margin outlook remains positive as we transition the mix of our product portfolio, improve factory utilization and drive productivity," says Murphy. "We expect gross margins in the back half of the fiscal year to average 50% or more."

OpEx is forecasted to fall slightly to \$165m in fiscal Q3. "We expect OpEx to trend down slightly through the back half of the year, with full-year OpEx ending at 20% of sales," he adds.

Diluted earnings per share is expected to rise to \$1.95 in fiscal Q3. "The earnings power of the business is increasing as we grow in the right areas and remain disciplined in capital and operating spend," says Murphy.

Based on higher revenue, stronger margins and lower working capital, operating cash flow is expected to strengthen in fiscal second-half 2019.

CapEx should peak for the fiscal year in Q3 with BAW and GaN capacity investments in Richardson

and the continued build-out of BAW capacity at the new fabrication plant in Farmers Branch, TX. Due principally to ongoing BAW and GaN capacity additions at the firm's Texas fabs, CapEx is projected to end the year a little over \$300m (just under 10% of sales, after falling sharply last year to 9%).

"We thought it would continue to go down, but we brought some of this spend for Farmers Branch in, so we're just a little bit higher than we expected," notes Murphy. "We expect CapEx as a percent of sales to resume a downward trend next year," he adds.

"About 70% of our capacity in BAW is on 6" and 30% is on 8", and we are undertaking — over the next year between wafer conversions and bringing Farmers Branch online — bringing on more 8". So, this time next year, we will have actually the reverse of what we have now, roughly 30% 6" and 70% 8"," says Murphy. "Based on our current plans — which also include not only that wafer conversion but also die shrink programs, yield improvements, cycle time etc — we believe we have the capacity to meet what we believe is our revenue outlook."

Qorvo's outlook remains essentially unchanged, with full-year revenue growth of about 10%, gross margin rising to 50% or more for the fiscal second half, and OpEx at about 20% of sales for the full fiscal year.

www.qorvo.com

Qorvo reduces December-quarter guidance

Apple supplier cites demand changes for flagship smartphones

Due to recent demand changes for flagship smartphones, for fiscal Q3/2019 (to end-December 2018) Qorvo has cut its guidance for revenue from \$880–900m (given on 31 October) to \$800–840m (below the prior year's \$844.8m), for non-GAAP gross margin from 50% to 49.5% (due primarily to lower factory utilization) and for diluted earnings per share from \$1.95 to \$1.70. Guidance for operating expenses has been cut by \$4m,

from \$165m to \$161m, due to expense control and lower incentive compensation.

Like Lumentum (which has also cut its December-quarter revenue, margin and earnings guidance in the last 24 hours), Qorvo is a supplier to iPhone maker Apple, which warned earlier in November that holiday sales would fall short of expectations, blaming weakness in emerging markets and foreign exchange costs.

Qorvo notes that its forecast of demand from China-based handset makers remains measured and largely unchanged. Also, its current forecast of demand across markets served by its Infrastructure and Defense Products (IDP) segment is tracking within the range of prior expectations.

For fiscal fourth-quarter 2019 (to end-March), Qorvo currently expects sequential revenue to fall by less than 10%.

Skyworks reports record quarterly revenue over \$1bn, and ninth consecutive record year

Earnings to dip slightly in December quarter after Avnera acquisition raises operating expenditure

For full-year fiscal 2018 (to 28 September), Skyworks Solutions Inc of Woburn, MA, USA (which manufactures analog and mixed-signal semiconductors) has reported a ninth consecutive year of record revenue, at \$3.868bn, up 6% on fiscal 2017's \$3.651bn.

For fiscal fourth-quarter 2018, revenue was a record \$1.008bn, up 13% on \$894.3m last quarter and 2.4% on \$984.6m a year ago (and exceeding the guidance of \$1bn), despite a "choppy end-market environment". However, this includes six weeks of revenue (about \$6m) from fabless semiconductor supplier Avnera Corp of Beaverton, OR, USA — a developer of analog system on chips (ASoCs) — acquired on 17 August.

By market sector, Mobile (Integrated Mobile Systems and Power Amplifiers) comprised 72% of revenue (up from 70% last quarter) and Broad Markets 28% (down from 30%, but still growing at a double-digit rate on both a year-on-year basis and a full-year basis, reaching an annualized run rate of \$1.1bn).

Strong design-win traction during the quarter across the mobile ecosystem and the Internet of Things (IoT) included the following:

- powering Samsung's Galaxy flagship smartphones;
- validating world-class performance of the Sky5 suite for 5G New Radio architectures;
- introducing 5G wideband, 16-state antenna aperture tuners;
- securing wireless networking sockets at Cisco for high-density enterprise applications.
- capturing LTE Cat M content within u-blox's machine-to-machine modules;
- deploying massive MIMO and small-cell solutions for global infrastructure;

- supporting DOCSIS 3.1 cable TV modems/gateways with 2.4GHz and 5GHz front-ends;

- leveraging smart audio solutions across Microsoft, Nintendo and Sony gaming consoles;

- ramping connectivity and telematics engines with BMW, Geely, Hyundai, Tesla and Toyota; and

- launching millimeter-wave RF technology at a major avionics supplier.

"We are capturing large-scale design wins across all key segments, spanning industrial, home automation, enterprise, automotive and defense as well as numerous flagship mobile platforms," says president & CEO Liam K. Griffin.

On a non-GAAP basis, gross margin was 51.2%, up from 50.9% last quarter and 51% a year ago. Full-year gross margin has risen from 50.8% for 2017 to 51.1% for 2018.

Despite rising further from \$123m a year ago and \$130m last quarter to \$136m, operating expenses (OpEx) as a proportion of revenue have been cut from 14.5% last quarter to 13.5%.

Operating income was \$379.6m (operating margin of 37.6% of revenue), up only slightly on \$379.2m a year ago but up from \$324.8m last quarter. Full-year operating income has risen from \$1379.1m for 2017 to \$1449.5m (37.5% operating margin) for 2018.

Net income was \$349.7m (\$1.94 per diluted share, exceeding the \$1.91 guidance), up from \$299.9m (\$1.64 per diluted share) last quarter and \$338.8m (\$1.82 per diluted share) a year ago. Full-year net income has risen from \$1.205bn (\$6.45 per diluted share) for 2017 to \$1323.4m (\$7.22 per diluted share) for 2018 (a ninth consecutive year of record EPS).

"Skyworks delivered a record fourth quarter and fiscal 2018,

marking our ninth consecutive year of revenue and non-GAAP earnings growth — demonstrably outperforming the broader semiconductor industry," says Griffin.

Cash flow from operations was \$209m (making \$1.3bn in full-year 2018). Capital expenditure (CapEx) was \$112m, taking full-year CapEx to slightly over \$400m (just over 10% of revenue). During the quarter, Skyworks paid \$68m in dividends and spent \$235m repurchasing stock (making \$1.003bn in cash returned to shareholders in full-year fiscal 2018 — \$243m of dividend payments and \$760m in share buybacks — representing 55% growth in cash returns compared with fiscal 2017, and comprising well over 100% of the free cash flow). During the quarter, cash and investments fell from \$1.649bn to \$1.050m. The firm has no debt.

Following the end of the quarter, Skyworks' board of directors has declared a cash dividend of \$0.38 per share, payable on 18 December, to stockholders of record on 27 November.

For fiscal first-quarter 2019 (to end-December 2018), Skyworks expects revenue of \$1–1.02bn (including \$15–16m from Avnera, so flattish quarter-to-quarter). This includes continued strength in broad markets (continuing to see strong double-digit year-on-year growth), coupled with the launch of a diverse set of new high-performance mobile solutions, offsetting unit declines in premium smartphones and overall China softness.

Skyworks therefore expects gross margin to also be flat, at 51.2% ("As we look into the back half of fiscal 2019, we will continue to make further improvements on gross margin toward our target of 53%," says the firm's senior VP & chief financial officer Kris Sennesael).

Operating expenses should rise to \$140m due to incurring the first full quarter of OpEx from acquisition Avnera. Diluted earnings per share should fall only slightly to \$1.91. Sennesael expects CapEx to remain at or about the same percentage of revenue as it was in fiscal 2018.

"Despite the near-term industry weakness, we have a clear path to deliver our tenth consecutive year of revenue and non-GAAP earnings growth in fiscal 2019," says Sennesael. "This outlook is driven by sustained double-digit growth across our broad markets business, a powerful and expanding design-win pipeline encompassing a wide range of customers and applications, world-class operational execution and scale, and finally our unwavering commitment to creating shareholder value," he adds.

"Our conviction is based on a number of strategic catalysts. First, we're seeing a significant uptick in demand for our base-station and small-cell massive MIMO solutions, as carriers around the world require LTE Advanced technologies to achieve multi-gigabit speeds, driving network efficiency, higher capacity and greater coverage. Skyworks' vast experience is at the forefront of these initial deployments, leveraging our complete portfolio, including amplifiers,

circulators and switches as well as system-level highly integrated engines. We are well-positioned to support the rapid deployments of the world's leading infrastructure OEMs," Griffin says.

"Second, on the other hand of the broadband connection, our smartphone opportunity is poised for a step up in architectural complexity, which in turn drives a dramatic increase in addressable content for us. This expansion is driven by entirely new bands, complementing existing systems, reformed frequencies and expanded use of multi-channel carrier aggregation."

"Skyworks already offers the industry's broadest portfolio for 4G LTE, proven and selected by the most discerning market-leading customers. We've demonstrated technology leadership across a vast set of critical product categories, as our market-tested solutions resolve increasingly complex architectures, preparing us for the performance gains demand in 5G," Griffin continues.

"As 5G rapidly approaches, we are pushing the performance envelope with our comprehensive Sky5 platform and positioning Skyworks to extend our reach across a wide array of high-growth applications. Skyworks is uniquely positioned to capitalize on the rapidly approaching 5G upgrade cycle and build upon

the strong foundation we've established over the past decade," he believes.

"Our solutions uniquely cover the spectrum from low-to-high and ultrahigh bands, leveraging SkyOne and DRx modules to optimize transmit and receive performance. Beyond cellular, we augment this portfolio with equally innovative WiFi, power management, precision GPS and tuning solutions."

"Further, we see compelling TAM [total addressable market] growth driven by new product functionality, including 4x4 MIMO, antenna multiplexing and new millimeter-wave technologies. At the same time, the broader IoT category continues to accelerate. With expanded 5G network capacity on the horizon, we expect 75 billion devices will be connected by 2025. That's three times today's installed base," Griffin notes.

"Leveraging our leadership across all major wireless standards, including 802.11ac and ax, LoRa, Bluetooth, ZigBee and Z-Wave as well as 4G LTE and 5G, we are well positioned to capture a disproportionate share of this growth, particularly with the advent of autonomous vehicles, virtual reality, industrial IoT and frictionless commerce," he believes.

www.skyworksin.com

Skyworks deploys 5G infrastructure solutions enabling high-capacity small-cell and massive MIMO platforms

Skyworks is ramping 5G small-cell and massive MIMO (multiple-input, multiple-output) solutions that significantly enhance network efficiency, delivering higher capacity with greater coverage.

As small cells are low-power, easy-to-implement radio access points that operate in both licensed and unlicensed spectrums with a typical range of 10m to several hundred meters, mobile operators are utilizing a scalable grid of small cells to facilitate powerful, high-speed connectivity in support of data intensive and quickly

emerging 5G applications. Skyworks says its portfolio creates viable new options for cellular and wireless providers to cost-effectively address mounting system requirements.

"Skyworks' leading small-cell architectures are enabling high-density platforms, creating faster, more robust communication and, in turn, expanding carrier capacity," states David Stasey, VP & general manager of diversified analog solutions. "We are bringing next-generation networks closer to subscribers while at the same time partnering with smartphone man-

ufacturers via our innovative Sky5 suite. Our comprehensive approach across both infrastructure and user equipment uniquely positions us to empower end-to-end 5G connectivity," he reckons.

Skyworks says its engines deliver the performance required for 5G, providing greater overall system efficiency and wide instantaneous bandwidth capability. The firm's complete 5G base-station portfolio encompasses small-cell amplifiers, circulators, high-performance low-noise amplifiers and high-isolation switches.

Anokiwave appoints senior VP of business development

Anokiwave Inc of San Diego, CA, USA — which provides highly integrated silicon core chips and III-V front-end integrated circuits for millimeter-wave (mmW) markets and active antenna-based solutions — has appointed Alastair Upton as senior VP of business development, based at the firm's office in Billerica, MA, and leading its strategic accounts, managing partnership programs, and providing telecoms expertise. Anokiwave says that the appointment comes at a strategic time with opportunities for continued growth in the rapidly developing mmW 5G, SATCOM and aerospace & defense (A&D) markets.

Upton has 38 years of experience in the semiconductor industry,

covering both defense electronics and high-volume commercial applications at companies such as GE Aerospace, Lockheed Martin, RF Micro Devices (now Qorvo), MACOM and IDT.

Prior to joining Anokiwave in June, Upton served in leadership roles including senior director of RF product marketing, VP of engineering, Carrier Networks business unit director, and general manager of the Digital Cellular product line. Anokiwave reckons that his global experience across several generations of technology and networks gives him a uniquely comprehensive perspective on the telecoms and other RF markets.

"Alastair is a seasoned executive

in the telecommunications industry and is already taking Anokiwave to higher levels of mmW market leadership by leading the O-RAN Alliance efforts and by providing new thought leadership in our 5G market strategy," says chief operating officer Carl Frank. "Alastair's leadership, along with his vast industry knowledge and depth of experience, is the perfect mix of expertise that will be beneficial to the continued growth and success of Anokiwave," he believes.

Upton has an MS Executive Engineering Degree from the University of Pennsylvania and a B.Sc. Electronic and Electrical Engineering from the University of Leeds, UK.

www.anokiwave.com

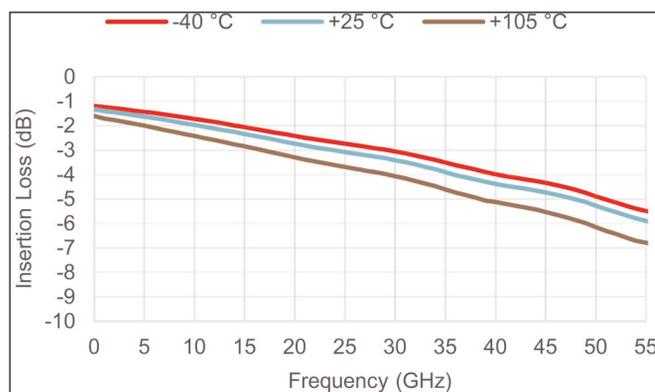
pSemi enters volume production of first 55GHz single-chip SOI digital step attenuator

Murata company pSemi Corp of San Diego, CA, USA (formerly Peregrine Semiconductor Corp) — a fabless provider of radio-frequency integrated circuits (RFICs) based on silicon-on-insulator (SOI) — has announced volume production of the PE43508 6-bit, 50Ω digital step attenuator (DSA).

Originally introduced at the IMS 2018 exhibition in June as a 50GHz product before the stated operating frequency range was extended, the millimeter-wave product is claimed to be the first single-chip silicon-on-insulator (SOI) DSA to support the entire 9kHz to 55GHz frequency range.

"After additional testing, we concluded the original 50GHz DSA name was selling this impressive product short," says CEO Jim Cable. "The PE43508 delivers exceptional performance beyond 50GHz, further supporting pSemi's claim that RF SOI can deliver a high-performing and reliable solution at high frequencies," he adds.

Suitable for 5G test & measurement applications, the PE43508



The PE43508 features low insertion loss across a wide frequency and temperature range.

maintains a monotonic response across the entire frequency range (0.5dB and 1dB monotonicity through 55GHz) and features low insertion loss (covering a 31.5dB attenuation range in 0.5dB and 1dB steps), low attenuation error and good return loss. It also delivers glitch-safe attenuation state transitions, meaning no increased power spike during a state transition.

The PE43508 has an extended temperature range from -40°C to +105°C, an HBM ESD rating of 1kV and an easy-to-use digital control

interface supporting both serial addressable and parallel programming. The DSA supports 1.8V control signals and has an optional VSS_EXT bypass mode.

Offered as a flip-chip die, volume-production parts, evaluation kits and samples are available now. For 1000-quantity orders, each PE43508 is \$50.

The 55GHz DSA joins pSemi's high-frequency portfolio, which includes a 40GHz switch (PE42524) and two 60GHz switches (PE42525 and PE426525) based on the same UltraCMOS technology platform. These monolithic ICs are suitable for applications such as test & measurement and 5G wireless infrastructure, and can be used in more traditional high-frequency applications such as very small-aperture satellite terminals.

www.psemi.com/products/digital-step-attenuators-dsa/pe43508

GlobalFoundries begins client prototyping of first 300mm SiGe foundry technology to meet growing data-center and high-speed wireless demands

Qualified process and design kits scheduled in second-quarter 2019

GlobalFoundries of Santa Clara, CA, USA (one of the world's largest semiconductor foundries, with operations in Singapore, Germany and the USA) says that its 9HP silicon germanium (SiGe) process is now available for prototyping on its 300mm wafer manufacturing platform.

The firm says the move signifies the strong growth in data-center and high-speed wired/wireless applications that can leverage the scale advantages of a 300mm manufacturing footprint. By tapping into GlobalFoundries' 300mm manufacturing expertise, clients can exploit increased production efficiency and reproducibility for high-speed applications such as optical networks, 5G millimeter-wave wireless communications and automotive radar.

GlobalFoundries manufactures SiGe solutions on its 200mm production

line in Burlington, Vermont. The migration of 9HP, a 90nm SiGe process, to 300mm wafers manufactured at the firm's Fab 10 facility in East Fishkill, NY, establishes a 300mm foothold for further roadmap development, ensuring continued technology performance enhancements and scaling, reckons the firm.

"The increasing complexity and performance demands of high-bandwidth communication systems have created the need for higher-performance silicon solutions," says Christine Dunbar, VP of the RF business unit. "9HP is specifically designed to provide outstanding performance, and in 300mm manufacturing will support our client's requirements for high-speed wired and wireless components that will shape future data communications."

The 9HP process extends a history of high-performance SiGe BiCMOS technologies designed to support

the massive growth in extremely high data rates at microwave and millimeter-wave frequencies for the next generation of wireless networks and communications infrastructure, such as terabit-level optical networks, 5G mmWave and satellite communications (SATCOM) and instrumentation and defense systems. The technology is said to offer superior low-current/high-frequency performance with improved heterojunction bipolar transistor (HBT) performance and up to a 35% increase in maximum oscillation frequency (F_{max}) to 370GHz compared with its predecessors, SiGe 8XP and 8HP.

Client prototyping of 9HP on 300mm at Fab 10 in East Fishkill, NY on multi-project wafers (MPWs) is underway now, with qualified process and design kits scheduled in second-quarter 2019.

www.globalfoundries.com/SiGe

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3–5 Power Electronics secures financing from Sturm Family Office to accelerate commercialization of GaAs-based power semiconductors

Funds to help prepare for product commercialization in second-half 2019 and forge partnerships to speed GaAs devices to market

3-5 Power Electronics GmbH (35PE) of Dresden, Germany — which specializes in developing and producing gallium arsenide (GaAs) power semiconductors — has secured new financing from the Sturm Family Office (SFO) of Bad-Mergentheim in Germany.

35PE has pioneered a first-of-a-kind process to deposit thick GaAs layers on top of GaAs substrates to produce high-voltage/high-current power semiconductors. The process aims to produce superior power devices at a lower manufacturing cost than devices fabricated from silicon or silicon carbide (SiC).

Near-term applications include industrial motor drives, uninterruptible power supplies (UPS) and renewable energy products, such as wireless chargers for solar and wind inverters. Future applications include electric vehicles (EVs), robotics and 5G technologies.

Founded in late 2015 to optimize GaAs technology to enable power devices, 35PE has raised €5.3m (\$6.10m) to date, including funds previously secured from Shanghai-based SINO Alliance Investment Ltd. The new funds will be used to prepare 35PE's operations for product commercialization which is planned for second-half 2019, and to forge partnerships with established leaders to help speed the firm's GaAs devices to market.

Samples of the GaAs diodes have been submitted for testing to power module makers in Europe and China. Applications include battery charging, welding and industrial heating.

GaAs technology has been used for decades to produce low-voltage/high-frequency devices, but now — because of its inherent advantages over silicon, silicon carbide (SiC),



gallium nitride (GaN), and other materials — it is being leveraged to build compact high-power semiconductor devices. Devices based on GaAs technology deliver higher energy savings, superior performance and greater reliability than those based on silicon, says the firm. For example, compared with a conventional SiC Schottky diode in a 3.3kW wireless charging system, a GaAs-based device was shown to consume nearly 20% less power. Also, GaAs-based power modules and systems can be as much as 50% smaller and lighter than the silicon alternative. In addition, compared with devices fabricated with wide-bandgap (WBG) SiC and GaN materials, GaAs-based devices are far less costly to manufacture, while demonstrating equal (and often better) performance advantages.

35PE says that its vision was to stretch the capabilities of GaAs technology and simultaneously improve the manufacturing economics. Thick GaAs layers are imperative for the production of high-power devices (>600–1700V and up to 100–150A). The firm claims to be first to pioneer deposition technologies to produce high-

power GaAs devices in high volume.

“While we’ve laid the foundation to deliver a unique enabling technology solution to the power electronics industry, the new funding will help us build a global business,” reckons CEO Dr

Gerhard Bolenz. “Most importantly, with growing customer interest in our technology, we can size our infrastructure for speedy response and service,” he adds.

“The technology is clever, differentiated and enabling, with real potential to transform the power electronics industry,” believes SFO. “With nearly 90 years of collective semiconductor experience, the 35PE team has achieved critical technology milestones by executing with focus and discipline, and using their resources wisely.”

At its headquarters in Dresden’s Silicon Saxony region, 35PE has established a lean model to develop, produce and distribute high-voltage GaAs wafers and related semiconductor devices for power electronics. Multiple patents have been filed worldwide and one has already been granted. In addition, the firm has established select distribution networks in Asia to create an efficient feedback loop between it and end-users. In parallel, it is pursuing partnerships with strategic investors and global manufacturers to execute more speedily on its technology roadmap and accelerate its market entry.

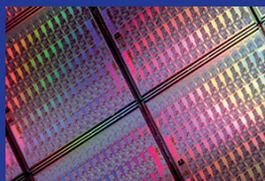
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Sanan IC achieves automotive quality management system certifications

Sanan Integrated Circuit Co Ltd (Sanan IC) of Xiamen City, Fujian province (China's first 6-inch pure-play compound semiconductor wafer foundry) has attained additional certifications for its manufacturing management systems. The firm recently earned IATF 16949:2016 Automotive Quality Management System (QMS) certification, and this June also completed ISO27001:2013 certification for Information Security Management standards compliance.

These are in addition to existing certifications that include ISO9001:2015 Quality Management and Assurance Systems, IECQ QC080000:2012 Hazardous Substance Process Management (HSPM), ISO140001:2015 Environmental Management Systems (EMS), and OHSAS 18001:2007 Occupational Health and Safety Management.

"Having these procedures and disciplines in place not only gives us a solid foundation to be a world-

class, large-scale wafer manufacturer, but it also shows our company's commitment to quality, security and safety, which our customers demand and which our employees expect," says CEO Raymond Cai. "These management systems definitely help us strive for constant improvements in efficiency, productivity, communications and environmental awareness."

Founded in 2014 as a subsidiary of Sanan Optoelectronics Co Ltd (China's largest LED epiwafer and chip maker, based on GaN and GaAs technologies), Sanan IC focuses on large-scale III-V semiconductor wafer foundry manufacturing, namely for gallium arsenide (GaAs) HBTs, pHEMTs, BiHEMTs, integrated passive devices (IPDs), filters, gallium nitride (GaN) power HEMTs, silicon carbide (SiC) and indium phosphide (InP) for RF, millimeter-wave, power electronics and optical communications markets.

Among the applications for these process technologies is automotive, such as for vehicle-to-everything (V2X) communications, collision-avoidance sensors, hybrid/electric vehicle (HEV/EV) charging and motor drives. With IATF 1694 compliance, Sanan IC's customers can meet the automotive industry's quality system requirements.

To mitigate information and intellectual property (IP) protection concerns, ISO27001 compliance facilitates best practice for an information security management system (ISMS). It sets guidelines for implementing and monitoring security measures as well as for risk management of both the company's and customers' proprietary information and IP. Sanan reckons that practicing and maintaining these security management procedures, combined with the other quality and environmental systems, leads to building and establishing customer confidence and trust.

www.sanan-ic.com

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HBTs pHEMTs BiFET/BiHEMTs

ROHM unveils 1700V SiC power module with high reliability in extreme environments

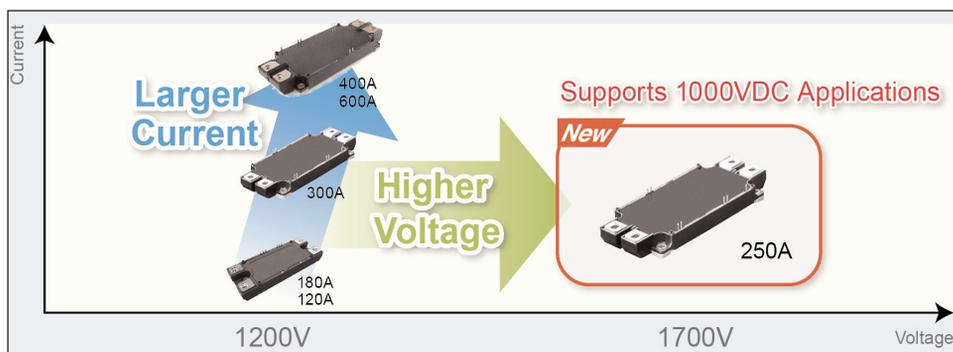
Power semiconductor maker ROHM of Kyoto, Japan has announced the development of a 1700V/250A-rated SiC power module that provides what is claimed to be the industry's highest level of reliability optimized for inverter and converter applications such as outdoor power generation systems and industrial high-power supplies.

In recent years, due to its energy-saving benefits, SiC has been seeing greater adoption in 1200V applications such as electric vehicles (EVs) and industrial equipment. The trend towards higher power density has resulted in higher system voltages, increasing the demand for 1700V products. However, it has been difficult to achieve the desired reliability, so silicon-based insulated-gate bipolar transistors (IGBTs) are typically preferred for 1700V applications.

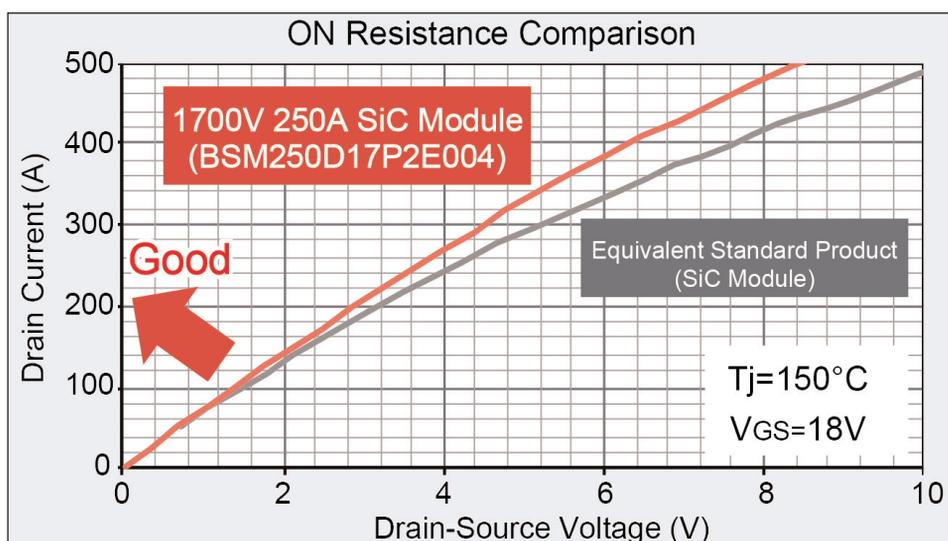
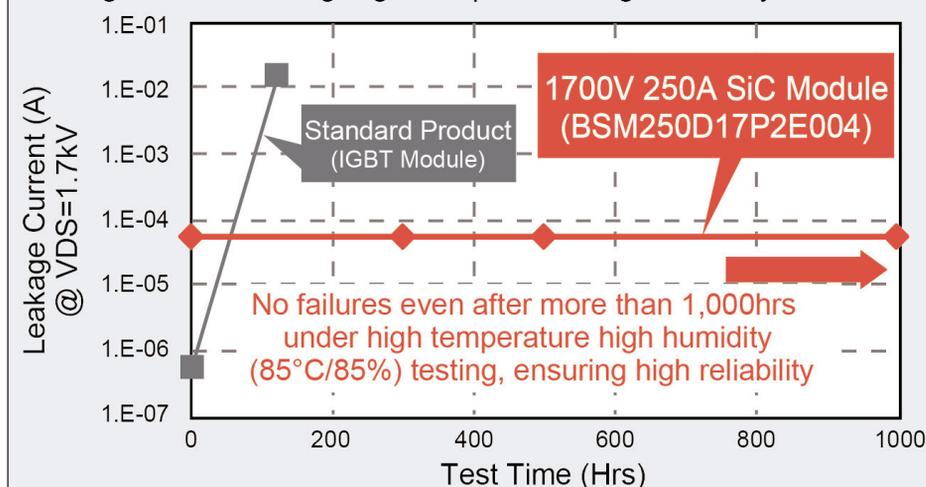
In response, ROHM has been able to achieve high reliability at 1700V, while maintaining the energy-saving performance of its 1200V SiC products, achieving what is claimed to be the first commercialization of 1700V-rated SiC power modules.

The new BSM250D17P2E004 introduces a new packaging method and coating materials to protect the chip from dielectric breakdown and suppress increases in leakage current, allowing the module to pass the HV-H3TRB reliability tests. For example, during this high-voltage, high-temperature, high-humidity reverse bias testing it exhibited no failures when 1360V is applied for more than 1000 hours at 85°C and 85% humidity, unlike conventional IGBT modules that typically fail within 1000 hours due to dielectric breakdown. To ensure the highest level of reliability, ROHM tested the leakage current of the modules at different intervals with the highest level of blocking voltage 1700V.

Incorporating ROHM's proven SiC metal-oxide-semiconductor



Leakage Current During High Temperature High Humidity Bias Testing



field-effect transistors (MOSFETs) and SiC Schottky barrier diodes (SBDs) into the same module and optimizing the internal structure makes it possible to achieve an ON-resistance 10% lower than other SiC products in its class. This translates into improved energy savings and reduced heat

dissipation in any application, says ROHM.

Going forward, ROHM will continue to expand its lineup while offering evaluation boards for easy testing and verification of its SiC modules.

www.rohm.com/products/sic-power-devices/sic-power-module/bsm250d17p2e004-product

Infineon acquires wafering technology firm Siltecta

Cold Split technology to boost Infineon's ramp-up of silicon carbide device production for power semiconductors

Munich-based Infineon Technologies AG has acquired wafering technology start-up Siltecta GmbH of Dresden, Germany for €124m in an agreement with the main shareholder, venture capital investor MIG Fonds.

Siltecta was founded in 2010 and has been growing an IP portfolio with more than 50 patent families. The start-up has developed Cold Split technology for splitting crystalline materials efficiently and with minimal loss of material compared with common sawing technologies. The technology can be applied to silicon carbide (SiC), for which rapidly rising demand is expected in the coming years. SiC products are already used in very efficient and compact solar inverters, and in the future SiC is expected to play an increasingly important role in electro-mobility. Cold Split technology will be industrialized at the existing Siltecta site in Dresden and at the Infineon site in Villach, Austria. The transfer to volume production is expected to be completed within the next five years.

Infineon aims to use Cold Split technology to split silicon carbide wafers, doubling the number of chips

that can be made from one wafer.

"Our system understanding and our unique know-how on thin wafer technology will be ideally complemented by the Cold Split technology and the innovative capacity of Siltecta," says Infineon's CEO Dr Reinhard Ploss. "The higher number of SiC wafers will make the ramp-up of our SiC products much easier, especially regarding further expansion of renewable energies and the increasing adoption of SiC for use in the drive train of electrical vehicles," he adds.

"We are glad to become part of the team of the global market leader in power semiconductors," comments Siltecta's chief technology officer Dr Jan Richter. "Having shown that the Cold Split technology

Cold Split will be industrialized at the existing Siltecta site in Dresden and at the Infineon site in Villach. Transfer to volume production is expected to be completed within the next five years

can be used at Infineon in principle, we will now work together to transfer it to volume production," he adds.

"Since we invested in Siltecta more than eight years ago, we have always believed in the Cold Split technology and the great team," comments Michael Motschmann, general partner of MIG Fonds' administrator MIG AG. "We are very pleased that we found Infineon as a buyer who fits perfectly technologically as well as culturally to the company."

Infineon offers a broad product portfolio of power semiconductors based on silicon as well as silicon carbide and gallium nitride substrates. It is claimed to be the only company worldwide with volume production on 300mm silicon thin wafers, and is positioned to apply the thin wafer technology to SiC products too. It is expected that Cold Split technology will help it to secure a supply of SiC products, especially in the long term. Over time, further applications of Cold Split could emerge, such as boule splitting or application to materials other than silicon carbide, it is reckoned.

www.SILTECTRA.com
www.infineon.com

Littelfuse completes acquisition of silicon carbide diode and MOSFET developer Monolith

Littelfuse Inc of Chicago, IL, USA, which provides circuit protection technologies (including fuses, semiconductors, polymers, ceramics, relays and sensors), has completed the acquisition of start-up Monolith Semiconductor Inc of Round Rock, TX, USA, which develops silicon carbide (SiC) power device technology. Littelfuse began partnering with Monolith in 2015 and has progressively increased its ownership after a series of technical and commercial product release milestones achieved over the last three years.

"Completing the acquisition of Monolith Semiconductor is an important part of our growth strategy as we expand our capabilities to serve the growing power electronics market," says Ian Highley, Littelfuse's senior VP & general manager, Semiconductor Products, and chief technology officer. "Adding silicon carbide technology allows us to evolve our portfolio with strategically relevant and innovative products," he adds. "We are already seeing meaningful design activity for commercially

released products across our regions, with significant interest for industrial and automotive applications."

Littelfuse introduced its first commercial silicon carbide Schottky diode in May 2017, followed by its first commercial silicon carbide MOSFET that October. To date, the firm has released for mass production more than 20 silicon carbide products, with more than 30 more planned in the coming months.

www.monolithsemi.com
www.littelfuse.com

ON Semiconductor partners with Keysight

Keysight Technologies Inc of Santa Rosa, CA, USA has been selected as an electronic design automation (EDA) partner by ON Semiconductor, delivering a design solution for power devices to increase reliability and accelerate time-to-market.

The power device industry is driven by demand for more energy-efficient products, such as power supplies and solar inverters that need greater efficiency and increased power density, notes Keysight. Electric vehicles (EVs) are pushing for more miles per charge and faster charging times. Wide-bandgap materials such as silicon carbide (SiC) and gallium nitride (GaN) are enabling increased efficiency, and will power future applications for high performance and efficiency.

Since power device manufacturers need a reliable design solution for these new materials, Keysight says its Power Electronics Design Bundle

is tailored power electronics engineers, delivering a complete design workflow for power device design.

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

"Keysight's power electronics design solution introduced a new level of accuracy and flexibility in studying design and device interactions, especially in applications based on wide-bandgap power devices," comments Mehrdad Baghaie Yazdi, head of Wide Band Gap Application Engineering at ON Semiconductor. "Keysight's Advanced Design System (ADS) software seamlessly integrates with ON Semiconductor's advanced physical SPICE models and enables

us to study, for the first time, device-environment interaction, providing deep insight into optimal application design from which both our internal test circuits and customers can benefit."

Keysight's power electronics design solutions integrate with an electromagnetic field solver, allowing designers to visualize effects of the design without the need to build and test time-consuming prototypes. This enhances a designer's confidence and accelerates time-to-market, claims the firm.

"Keysight is playing a pivotal role in accelerating the time-to-market for switch-mode power supplies that utilize ON Semiconductor's wide-bandgap devices," says Charles Plott, worldwide design software planning manager for EEs of Electronic Design Automation (EDA) at Keysight.

www.onsemi.com

Mercedes EQ Formula E Team partners on EV powertrain solutions

ON Semiconductor of Phoenix, AZ, USA — which supplies power management, analog, sensors, logic, timing, connectivity, discrete, system-on-chip (SoC) and custom devices — has announced an Official Supplier relationship with Mercedes-AMG Petronas Motorsport and Mercedes EQ Formula E team that will extend their automotive power solutions activities to Formula One and Formula E.

Building on technology already used in the energy recovery pack that controls ignition and injection drivers of the Mercedes-AMG Petronas Motorsport race car (which has won four consecutive Formula One World Constructors' championships and five consecutive Drivers' titles), ON Semiconductor will collaborate with the Mercedes EQ Formula E Team to develop next-generation electric powertrain innovations.

"Powertrain systems within both a Formula 1 and Formula E vehicle not

only possess an increased number of power semiconductors, these semiconductors must meet extremely demanding performance and efficiency requirements, while withstanding the harshest of automotive environments," says David Somo, senior VP corporate strategy, marketing and solutions engineering. "This partnership showcases our full range of power semiconductors and modules in supporting the continuing success of Mercedes-AMG Petronas Motorsport as part of a demanding and dynamic sport."

"Formula E cars see massive power transfers during their running so it's not a simple electrical problem," notes Dave Priscak, VP, global solutions engineering at ON Semiconductor. "Our comprehensive expertise that spans both mechanical and electrical engineering offers full solutions to the innovation of next-generation electric vehicles. We look forward to continuing our work with Mercedes to further

capitalize on this expertise in the development of technological advancements in power devices and electric vehicle technology."

Race cars need technology that can withstand high levels of shock, vibration and temperature. The more efficient the semiconductor, the less power is lost to wasted heat, resulting in better mileage or miles per watt of energy. At the same time, engineers also aim to make their cars' components smaller to save weight and space.

ON Semiconductor power products and solutions include insulated-gate bipolar transistors (IGBTs), high-voltage gate drivers, super-junction MOSFETs, high-voltage rectifiers, high-voltage DC-DC, as well as wide-bandgap (WBG) developments in silicon carbide (SiC) and gallium nitride (GaN) that can provide longer driving range, faster battery charging times and better thermal management in electric vehicles, says ON Semiconductor.

II-VI and Sumitomo collaborate on 150mm GaN-on-SiC HEMT production

II-VI preparing 150mm semi-insulating substrate manufacturing platform and expanding fab in Warren, New Jersey

Engineered materials firm II-VI Inc of Saxonburg, PA, USA has announced a strategic collaboration with Japan's Sumitomo Electric Device Innovations Inc (SEDI), a subsidiary of Sumitomo Electric Industries Ltd, to establish a vertically integrated 150mm wafer fabrication platform to manufacture gallium nitride on silicon carbide (GaN-on-SiC) high-electron-mobility transistor (HEMT) devices for next-generation 5G wireless networks.

The race to deploy next-generation broadband wireless services is driving the development of scalable strategic supply chains with enabling technologies, notes II-VI. It reckons that its expertise in 150mm compound semiconductor manufacturing combined with SEDI's in GaN RF device technology should allow the parties to drive best-in-class performance, greater scale and competitive costs for 5G RF solutions.

"II-VI has invested aggressively to establish a world-class 150mm compound semiconductor manufacturing platform," comments SEDI's corporate director Keiichi Imamura. "Based on rapidly growing market opportunities, it was important to act now to evolve our long-standing commercial relationship into a full strategic relationship. We will leverage II-VI's manufacturing platform to achieve economies of scale to enable us to meet the upcoming global demand for gallium nitride on silicon carbide HEMT devices," he adds.

"This collaboration establishes a differentiated, vertically integrated value-chain solution that spans from substrates through RF modules," says II-VI Inc's president & CEO Dr Chuck Mattera (who describes SEDI as "the market leader in high-performance gallium nitride HEMT products for wireless communications"). "Coupling SEDI's industry-

leading HEMT device technology with our 150mm manufacturing platform will accelerate both companies' wide-bandgap RF product roadmaps, as well as secure a leading technology and market position for many years to come," he believes. "To be ready for the mass-production ramps, we are preparing a 150mm semi-insulating substrate manufacturing platform and expanding our Warren, NJ, device fab to add these core technologies to our growing optoelectronic device fab capability."

II-VI serves the rapidly growing markets for wide-bandgap materials from its facilities in Pinebrook, NJ and Champaign, IL. The 150mm production facility in Warren, NJ should be qualified for GaN-on-SiC HEMT production in mid-2020.

www.iivadvmat.com

www.sedi.co.jp/products/wireless/GaNHEMTsforBaseStationList.html

UnitedSiC launches UF₃C FAST silicon carbide FET series

United Silicon Carbide Inc (USCi) of Monmouth Junction, NJ, USA has launched its UF₃C FAST series of 650V and 1200V high-performance silicon carbide FETs in a standard TO-247-3L package — the UF3C120040K3S (1200V/35mΩ), UF3C065030K3S (650V/30mΩ) and UF3C065040K3S (650V/42mΩ) — offering increased switching speeds and higher efficiency levels than the existing UJC3 Series.

Based on the firm's proprietary cascode configuration, the new series provides higher switching speeds while at the same time offering a 'drop-in' replacement solution for most TO-247-3L IGBT, Si-MOSFET and SiC-MOSFET parts, so upgrades for greater performance and efficiency can be affected without requiring changes to the existing

gate drive circuitry. Turn-on losses can be reduced based on a 50% reduction in Q_{rr} . For high current use, a small, low-cost RC snubber is required, simplifying EMI design.

Applications suitable for use with the UF₃C FAST series include the full range of hard switched circuits such as active rectifiers and totem-pole PFC stages, commonly used in electric vehicle (EV) charging, telecom rectifiers and server supplies.

Built on UnitedSiC's Gen-3 SiC transistor technology, the UF₃C FAST series integrates a faster SiC JFET with a custom-designed Si-MOSFET to produce a combination of normally-OFF operation, a high-performance body diode and easy gate drive of the MOSFET. Compared with other wide-bandgap technologies, the SiC cascode

devices support standard 12V gate drive, and have assured avalanche ratings (100% production-tested).

"UnitedSiC's new FAST SiC FET range is simple to use and offer a great cost-performance option," claims Anup Bhalla, VP engineering. "The range offers design engineers the opportunity to extract even higher levels of efficiency from high-power designs."

Prices range from \$14.50 for the UF3C065040K3S to \$24.50 for the UF3C120040K3S in 1000-unit quantities. Stock is available at Mouser and other local distributors.

Data sheets and a SiC FET user guide are available, including recommended RC snubber values tested by UnitedSiC for optimal performance.

www.unitedsic.com

www.mouser.com/usci

Exagan extends range of G-FET and G-DRIVE power-conversion products for multi-kilowatt server and automotive applications

Gallium nitride technology start-up Exagan of Grenoble and Toulouse, France (founded in 2014 with support from CEA-Leti and Soitec) is extending its market reach by introducing new G-FET power transistors and G-DRIVE intelligent, fast-switching devices with enhanced power capabilities for automotive and server applications.

With the products' drain-source on-resistance ($R_{DS(on)}$) capabilities ranging over 30–65m Ω , the new versions provide enhanced performance and power efficiency for diverse applications including electric vehicles (EV), industrial equipment and data servers.

At the electronica 2018 trade show in Munich, Germany (12–16 November), Exagan demonstrated the implementation of its products for kilowatt-range applications using topologies such as totem-pole power factor correction (PFC) to achieve high conversion efficiency as well as improved power density.

Power supplies for the fast-growing server market are one of the first

power applications to benefit from Exagan's GaN solutions. Global server shipments increased 20.7% year-on-year to 2.7 million units in first-quarter 2018, according to International Data Corp.

Another sector that can benefit from the enhanced products is automotive power electronics, where Exagan says its solutions provide robust performance and simplify design-in at the system level. During the electronica Automotive Conference (eAC), president & CEO Frédéric Dupont gave a presentation 'From Evolution to Revolution:

Disrupting Automotive Power Conversion with GaN' describing how GaN enables significantly smaller, lighter and more cost-effective sys-

New versions provide enhanced performance and power efficiency for diverse applications including EV, industrial equipment and data servers

tem-level power solutions and why this technology is playing a major role in the automotive industry's transition to more EVs.

"Our G-FET and G-DRIVE product lines offer the most comprehensive portfolio of easily integrated GaN solutions for an extensive range of applications spanning consumer, server and automotive markets," claims Dupont. "To work closely with our customers, we recently opened application centers in France and Taiwan focused on delivering the most competitive GaN-based solutions for current and emerging power-conversion needs."

Exagan says that the new GaN products prove its ability to provide multiple products using an established 200mm CMOS manufacturing process while maintaining full control of its proprietary GaN technology. Engineering samples (with associated evaluation boards) are available now.

www.exagan.com/en/products/gfet-family

www.electronica.de

Arrow Electronics expands distribution agreement with Cree's Wolfspeed Division to include Power & RF products

Arrow Electronics Inc has announced an expanded agreement with the Wolfspeed division of Cree Inc of Durham, NC, USA, positioning it as the largest global distributor for Wolfspeed's silicon carbide (SiC) and gallium nitride on silicon carbide (GaN-on-SiC) product portfolio.

"We are pleased to build upon and expand our franchise to include both Wolfspeed's power and RF solutions," says David West, senior VP of global marketing and engineering at Arrow. "This agreement offers our customers a greater range of technology options that

will enable continuous product innovation," he adds.

"Wolfspeed's heritage as a pioneer of GaN-on-SiC technology for RF applications is well established and offers an attractive value proposition to our customers who are evolving the technology marketplace," comments Rafael R. Salmi Ph.D., president of Richardson RFPD (an Arrow Electronics company that specializes in the RF and wireless communications, power conversion and renewable energy markets). "This agreement offers a strategic advantage in that we can now provide the optimal RF power solutions

to meet our customers' diverse needs," he adds.

"Arrow's global sales force enables us to reach more markets and customers quicker and more efficiently through a proven partner solution," says Thomas Wessel, senior VP of global sales & marketing.

In its booth at electronica 2018 in Munich, Germany (13–16 November), Arrow is featuring an Internet of Things (IoT)-connected 150kW off-board charging station that relies upon Wolfspeed's SiC technology.

www.cree.com

www.arrow.com

TI launches ready-to-use 600V GaN FET power stages supports applications up to 10kW

Dallas-based Texas Instruments Inc (TI) has launched a portfolio of ready-to-use 600V gallium nitride (GaN) 50mΩ and 70mΩ power stages to support applications up to 10kW.

The firm says that its LMG341x family enables designers to create smaller, more efficient and higher-performing designs compared with silicon field-effect transistors (FETs) in AC/DC power supplies, robotics, renewable energy, grid infrastructure, telecom and personal electronics applications.

The GaN FET devices provide an alternative to traditional cascade and stand-alone GaN FETs by integrating functional and protection features to simplify design, enable greater system reliability and optimize the performance of high-voltage power supplies. With integrated <100ns current limiting and over-temperature detection, they protect against unintended shoot-through events and prevent thermal runaway,

while system interface signals enable a self-monitoring capability.

Key features and benefits of the LMG3410R050, LMG3410R070 and LMG3411R070 include:

- **Smaller, more efficient solutions:** TI says that its integrated GaN power stage doubles power density and reduces losses by 80% compared with silicon metal-oxide-semiconductor field-effect transistors (MOSFETs). Each device is capable of fast, 1MHz switching frequencies and slew rates of up to 100V/ns.

- **System reliability:** The portfolio is backed by 20 million hours of device reliability testing, including accelerated and in-application hard switch testing. Also, each device provides integrated thermal and high-speed 100ns over-current protection against shoot-through and short-circuit conditions.

- **Devices for every power level:** Each device in the portfolio offers a GaN FET, driver and protection fea-

tures at 50mΩ or 70mΩ to provide a single-chip solution for applications ranging from sub-100W to 10kW.

TI showcased a 10kW cloud-enabled grid link demonstration at the electronica 2018 trade fair in Munich, Germany (13–16 November). Developed jointly by TI and Siemens, the active demonstration uses TI's LMG3410R050 600V GaN FET with integrated driver and protection, enabling engineers to achieve 99% efficiency and up to 30% reduction in power component size compared with a traditional silicon design.

The devices are available now in the TI store in 8mm-by-8mm split-pad, quad flat no-lead (QFN) packaging. The LMG3410R050, LMG3410R070 and LMG3411R070 are priced at US\$18.69, \$16.45 and \$16.45, respectively, in 1000-unit quantities.

www.ti.com/power-management/gan/overview.html

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SAPPHIRE	446	50.8mm	N	
SILICON	500			

Qorvo awarded US Air Force contract to accelerate GaN design, performance and reliability

Qorvo Inc of Greensboro, NC, USA (which provides core technologies and RF solutions for mobile, infrastructure and defense applications) has been awarded a four-year contract by the US Air Force Research Laboratory (AFRL) to develop and implement a physics-based, unified gallium nitride (GaN) modeling framework to accelerate the design of GaN devices.

As the prime contractor on the Engineering Predictable Behavior into GaN Devices Foundational Engineering Problem (FEP) contract, Qorvo will head a team that includes Modelithics Inc, the University of Padua, NI AWR, HRL and the University of Colorado-Boulder.

GaN's superior power density and

ability to deliver higher output power and efficiency — including at millimeter-wave frequencies — make it the semiconductor technology of choice for radar, electronic warfare (EW) and communication systems for defense and commercial applications, says Qorvo.

The firm, which supplies GaN devices to the US Department of Defense (DoD), will lead a group of industry and university organizations to create a single tool that unifies physics modeling and device modeling to provide powerful predictive capabilities. The tool will allow circuit designers to make performance and reliability trade-offs at the design stage, which is not currently possible.

The new capability should signifi-

cantly reduce the number of design-build-test iterations, enhance reliability and achieve reductions in cost and delivery times for capabilities critical to the Air Force, DoD and commercial industries.

"This award enables the Air Force to leverage Qorvo's nearly 20 years of expertise developing the industry's most reliable, highest-performing GaN process," says James Klein, president of Qorvo's Infrastructure and Defense Products business. The new modeling and simulation tool will "accelerate advanced GaN designs for mission-critical applications even as it reduces costs."

Delivery of the final, unified modeling framework is expected in 2022.

www.qorvo.com

GaN Systems launches new products at China's PEAC power electronics conference

At the IEEE International Power Electronics and Application Conference and Exposition (PEAC 2018) in Shenzhen, China (4-7 November), GaN Systems Inc of Ottawa, Ontario, Canada (a fabless developer of gallium nitride-based power switching semiconductors for power conversion and control applications) announced new products and design tools and provided customer demonstrations. They included:

- The GS-065 low-current (4-11A) line which, combined with the EZDrive circuit, eliminates the need for a discrete or integrated driver, making it easy to implement and reduce system costs. This solution for sub-1kW power is suitable for applications including gaming and workstation laptop AC adapters, TV power, LED lighting, and wireless power systems.
- A 50W wireless power amplifier expands the firm's line of solutions for wireless power transfer and charging applications that encom-

pass 100W power amplifier and 300W power amplifier products. The new power amplifier is targeted at lower-power applications in consumer, industrial and automotive markets for items such as handheld electronics, power tools, toys, household, robots, drones and scooters.

- Two PLECS simulation models for 3-Phase Traction Inverter and Single-Phase T-Type 3-Level Inverter designs will be available on GaN Systems' Circuit Simulation Tool. This platform helps power designers to quickly and easily tune parameters to suit their design goals and see the results in real time.

"We continue to listen to our customers and provide the industry-leading solutions they need to be successful whether they are creating high-frequency wireless products or maximizing output in a power system," says Paul Wiener, VP of strategic marketing. "Having the right tools and resources shortens design times and increases

system performance."

Speaker sessions

At the conference, GaN Systems' representatives presented in two industry sessions and one tutorial session:

- 'Opportunities and Design Considerations Tutorial for GaN HEMTs in Industrial and Automotive Applications' by Juncheng (Lucas) Lu;
- 'High Power Density Adapters with GaN' by Leyang Yang;
- 'High Efficiency Wireless Power with GaN' by Tiefeng Shi.

GaN Systems Cup

GaN Systems again sponsored the China Power Supply Society (CPSS) design competition. The GaN Systems Cup is currently underway with top engineering teams participating from leading universities throughout China. Winning teams were announced at the awards ceremony during PEAC on 4 November.

www.cpss.org.cn

www.peac-conf.org

www.gansystems.com/peac2018

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EPC expands Asia Pacific sales and FAE team

To support its accelerating sales growth in Asia, Efficient Power Conversion Corp (EPC) of El Segundo, CA, USA — which makes enhancement-mode gallium nitride on silicon (eGaN) power field-effect transistors (FETs) for power management applications — has expanded the sales and field application engineering (FAE) team in Asia Pacific to support its expanding customer base for DC-DC, light detection and ranging (LiDAR) and wireless power applications, maximize new business acquisition and capture new market opportunities.

VP of sales (Asia Pacific) Darren Shang has over 20 years of experience in multi-national power semiconductor firms, including extensive sales and business development experience. His primary responsibilities at EPC are creating and implementing sales strategies to achieve sales objectives in Asia Pacific.

Shang joined from Taiwan power semiconductor distributors including Pantek Technology Corp (Alltek Group). Previously, he had regional roles in Boston Power, Avago (now Broadcom) and Infineon. In representing EPC, on 30 October Shang supported ITRI's Wireless Power Workshop at Taiwan University in Taipei, at which commercial and academic experts shared practical examples and experiences. EPC demonstrated an eGaN-based large-surface-area wireless power application on site which attracted

engineering participants who are actively contributing to the latest development of wireless power applications.

At the Open Data Center Summit on 16 November in Beijing, China (which featured presentations by Tencent, Alibaba and Baidu), EPC's China sales director Chris Cheung, together with senior FAE manager (China) Henry Qiu, explored the opportunities of working with data-center partners using eGaN technology (which EPC claims is the choice of technology for the latest designs at 48V input).

Cheung has over 10 years of sales experience at International Rectifier (now Infineon). Prior to joining EPC, he worked for a combined nine years for GTC Technology Ltd (managing eGaN product sales opportunities) and ENW Electronics Ltd.

With more than six years of experience in DC-DC power supply design, Qiu has been working with customers in creating design solutions using eGaN devices to optimize circuit performance well beyond silicon FET-based solutions. During his three years at Huawei Technologies Co Ltd in Shenzhen, China, he managed power module projects, adopted eGaN FETs in power supply applications, and is familiar with leveraging the advantages of eGaN technology in customer solutions by incorporating eGaN benefits into DC-DC, wireless power and light detection & ranging (LiDAR) designs.

Shoichi Yasuda joined EPC in October as VP of sales for Japan and Korea. In the past decades, he worked for a range of semiconductor companies, holding positions as a field application engineer (FAE) as well as sales management. Before joining EPC, he worked for Mitsuiwa Corp, where he acquired in-depth knowledge of eGaN products. Yasuda is speaking for EPC at the Techno Frontier 2019 exhibition and conference, to be held at Makuhari, Tokyo on 19 April 2019, where EPC partner & co-founder Robert Beach will be sharing the latest technological developments in gallium nitride.

"Our new sales and FAE members have all come from power electronics companies with solid sales, customer and distribution management experiences in multi-national organizations including strong experiences in ramping power technology sales," says Nick Cataldo, global VP of sales & marketing.

"Each member has a proven track record of supporting customers through combined sales and FAE efforts in shortening customers' product design cycles and time to market," he adds. "Our new Asian team members, together with our regional distribution channels and sales representatives, provide the technical and business support for our customers in 21 regions throughout Asia Pacific".

www.epc-co.com

Integra offers GaN-on-SiC transistor evaluation kits for verifying performance in RF systems

Integra Technologies Inc (ITI) of El Segundo, CA, USA (which makes high-power RF and microwave transistors and power amplifier modules) is offering gallium nitride on silicon carbide (GaN-on-SiC) high-electron-mobility transistor (HEMT) evaluation kits to designers evaluating the technology for their high-power amplifier designs.

Each kit is customized to include a designer's transistor model of choice (partially or fully matched options are available) and includes a test fixture with one transistor fully mounted and tested, and a second spare device. Full RF test results, as tested under key conditions by the Integra technical support team, are also provided as a

reference guideline.

The kits can be borrowed free for 30 days and extended if needed or be purchased to own.

The Application Note 'Handling and Adjustment of Integra Technologies GaN-on-SiC HEMT Evaluation Kits' can be downloaded from Integra's website.

www.integrattech.com



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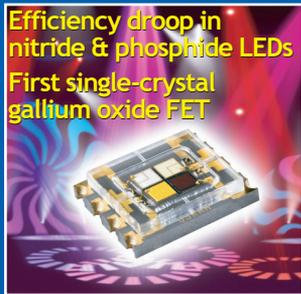
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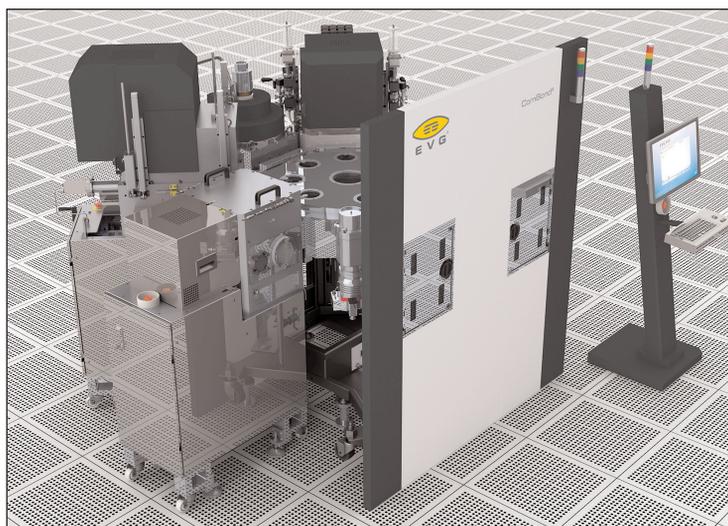
IHP and EVG co-developing low-temperature covalent wafer bonding for next-gen wireless and broadband communication devices

EV Group of St Florian, Austria — a supplier of wafer bonding and lithography equipment for semiconductor, micro-electro-mechanical systems (MEMS) and nanotechnology applications — says that IHP - Innovations for High Performance Microelectronics in Frankfurt (Oder) — a German government-funded research institute for silicon-based systems, highest-frequency integrated circuits and technologies for wireless and broadband communication — has purchased a ComBond automated high-vacuum wafer bonding system for use in developing next-generation wireless and broadband communication devices.

The ComBond features micron-level wafer-to-wafer alignment accuracy and room-temperature covalent bonding, which enables a wide variety of substrate and interconnect combinations for producing engineered substrates, next-generation MEMS and power devices, stacked solar cells, and high-performance logic and 'beyond CMOS' devices. The ability to conduct oxide-free aluminium-to-aluminium (Al-Al) direct bonding at low temperature is a unique capability of the ComBond platform, and is among the new bonding applications that IHP will explore with the system.

Covalent bonding enables wafer-level packaging and heterogeneous integration

Heterogeneous integration through wafer-level-packaging (WLP) — where multiple semiconductor components with different design nodes, sizes or materials are combined into a single package at the wafer level — is key to extending the semiconductor technology roadmap. Metal and hybrid wafer bonding are key process technologies for WLP and heterogeneous integration due to their ability to



enable ultra-fine-pitch interconnections between the stacked devices or components. The continuous drive to higher performance and functionality of these integrated systems requires constant reductions in the dimensions and pitch of the interconnects — which in turn drives the need for tighter wafer bond alignment accuracy.

In addition, for certain WLP applications, Al-Al direct bonding is a promising new method of metal-based bonding due to aluminium's low cost coupled with its high thermal and electrical conductivities. However, conventional Al-Al thermo-compression bonding requires high temperatures and bond forces to provide reliable bonding interfaces — making it incompatible with heterogeneous integration efforts.

"Combining different materials and device components into a single package has taken on greater importance in adding performance and value to electronic devices," says EVG's executive technology director Paul Lindner. "The EVG ComBond facilitates the bonding of nearly 'anything on anything' in wafer form. This provides our customers with a powerful solution for researching new material combinations for future semiconductor

devices," he adds. "Its micron-level alignment capability also makes the EVG ComBond uniquely suited for use in high-volume manufacturing of emerging heterogeneous integration device designs." EVG's Com-

Bond wafer activation technology and high-vacuum handling and processing allow the formation of covalent bonds at room or low temperature for fabricating engineered substrates and device structures. ComBond facilitates the bonding of heterogeneous materials with different lattice constants and coefficients of thermal expansion (CTE) as well as the formation of electrically conductive bond interfaces through a unique oxide-removal process. It maintains a high-vacuum and oxide-free environment throughout the entire bonding process, enabling low-temperature bonding of metals, such as aluminum, that re-oxidize quickly in ambient environments. Void-free and particle-free bond interfaces and excellent bond strength can be achieved for all material combinations, says EVG.

The firm showcased the ComBond — along with its complete suite of wafer bonding, lithography and resist processing solutions for advanced packaging and MEMS applications — at SEMICON Europa 2018 in Munich, Germany (13–16 November).

www.semicon.europa.org
www.ihp-microelectronics.com
www.evgroup.com/en/products/bonding/waferbonding/evg_combond

IGaN and SiTerra demo D-MISHEMT using 200mm GaN-on-Si wafer on foundry CMOS process

Singapore-based IGSS GaN Pte Ltd (IGaN) — which provides proprietary gallium nitride on silicon (GaN-on-Si) epitaxial wafer fabrication services for both power and RF devices — and SiTerra Malaysia Sdn Bhd of Kulim Hi-Tech Park (an 8" wafer foundry offering fabrication and design support services in CMOS logic, high-voltage, mixed-signal, RF, BCD, power and MEMS technologies) have announced results of their recent technology transfer partnership, demonstrating a breakdown voltage of 650V for a D-Mode MISHEMT device using a 200mm GaN-on-Si wafer on a CMOS-compatible fabrication process. The outcome of the exclusive collaboration is the transfer and establishment of a gold-free metallization and CMOS-compatible 200mm GaN-on-Si metal-insulator-semiconductor high-electron-mobility transistor (MISHEMT) fabrication process in SiTerra.

"IGaN aims to offer an innovative one-stop solution, providing 100–200mm GaN-on-Si epiwafer and 200mm CMOS-friendly GaN fabrication processes," says Raj Kumar, chairman & CEO of IGaN, which has exclusive rights to the GaN-on-Si intellectual property of Singapore's Agency for Science, Technology and Research (A*STAR). "This will enable customers in the power semiconductor community currently offering silicon-based power metal-oxide-semiconductor field-effect transistors (MOSFETs) and insulated-gate bipolar transistors (IGBTs) to leapfrog into GaN technology devices, unlocking access to the huge opportunity of the \$12bn power device market using GaN technology," he adds. "We are already engaged in positive discussions with other customers enthusiastic about the potential of our platform, keen to accelerate their access into the rapidly growing GaN market, as our new partnership with SiTerra enables

mass production of this powerful new technology in early 2019."

"With our close partnership with IGaN, SiTerra is committed to deliver the best-yielding process and capacity assurance to fulfil our mutual customers' business expectations," comments SiTerra's Firdaus Abdullah.

GaN devices are used for high-power-density wireless power transfer, allowing higher server power — a capability recently demonstrated at March's IEEE Applied Power Electronics Conference & Exposition (APEC 2018) in San Antonio, TX, USA. Using GaN technology, a high-density on-board charger (OBC) for electric vehicles delivered a three-fold increase in power density at 4kW per litre, compared with a silicon-based charger at 1.3kW per litre. Further demonstrations revealed that GaN transistors can enable wireless charging to be increased from 100W to 1.5kW.

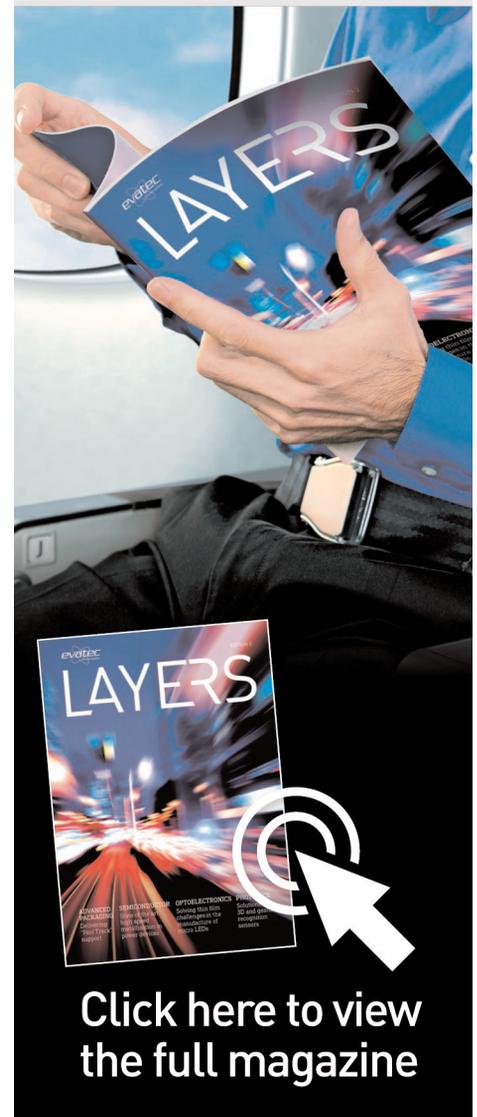
IGaN says that gallium nitride technology can unlock the potential for wireless charging applications far beyond low-power applications such as cell phones and laptops. It also enables greater energy savings and increased power density in data centers, which greatly reduces operating expenditure (OpEx), capital expenditure (CapEx) and total cost of ownership (TCO), with a 50% power density increase achievable utilizing a power supply of the same size.

IGaN and SiTerra are together offering an accelerator to spur the conversion of pure silicon and compound-based technologies into GaN-on-Si. The firms claim that this can favourably impact the bottom line and long-term business competitiveness of both power and RF semiconductor companies that adopt the technology. The efficiency performance figures of GaN-on-Si also show its further potential to minimize power conversion losses, they add.

www.igssgan.com



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AXT grows revenue an above-expected 5.5% in Q3

Softness in LED market to suppress revenue and profit margin in Q4

For third-quarter 2018, AXT Inc of Fremont, CA, USA — which makes gallium arsenide (GaAs), indium phosphide (InP) and germanium (Ge) substrates and raw materials in Beijing, China — has reported revenue of \$28.6m, up 5.5% on \$27.1m last quarter and up 1.4% on \$28.2m a year ago (and exceeding the \$27.5–28.5m guidance).

Of total revenue, revenue from raw material joint ventures (namely the three companies consolidated into AXT's results) was \$5.8m, level with a year ago but up modestly on \$5.5m last quarter as raw material prices remained relatively stable (enabling a contribution to profitability). This has also enabled the seven raw material companies in which AXT has partial ownership (non-consolidated, accounted for using the equity method, and hence contributing to improved profitability) to collectively break even (after Q2 represented their first profit in ten quarters).

Substrate sales were \$22.8m, up on \$21.6m last quarter and \$22.4m a year ago.

InP revenue was again a record, with relative strength in all primary applications, particularly for silicon photonics-based applications such as data-center connectivity as a result of a substantial increase in the volume of global network and data-center traffic that is driving the need for more cost-effective, energy-efficient and high-bandwidth solutions.

"Beyond silicon photonics, PON (passive optical network) applications contributed meaningfully to our record Q3 indium phosphide revenue," says CEO Dr Morris Young. "As expected, PON sales were down from Q2 following a very strong first half and this is likely to continue through Q4."

Germanium substrate revenue was a bit down, following several strong quarters.

GaAs revenue grew, driven by semi-insulating substrates, offset

somewhat by weaker demand in LEDs. "We are beginning to see more meaningful contribution from Android-based 3D sensing," Young notes. "To date, this year our revenue has reached nearly \$1 from 3D sensing programs in Asia."

Of total revenue, 72% came from Asia Pacific (up from 67% last quarter), 11% from North America (up from 8%), and 17% from Europe (down from 25%). One customer reached 10% of revenue and the top five generated about 39%.

Gross margin was 37.1%, down from 40.6% last quarter and 39.5% a year ago. "Our substrate products held their own in terms of gross margin, but our three consolidated raw material companies each had a quarter-to-quarter decline, plus the fact that Q2 had about a 1% incremental upside from the sale of material previously written off account for the change from Q2 to Q3," notes VP & chief financial officer Gary Fischer.

Operating expenses (OpEx) were \$6.3m, cut from \$6.5m last quarter but up from \$5.9m a year ago. "Operating expenses continue to be in line with our run-rate expectations for the year," says Fischer.

Net income was \$3.9m (\$0.10 per diluted share), down from \$4.4m (\$0.11 per diluted share) a year ago but level with last quarter (at the top end of the expected \$0.08–0.10 range).

"Revenue and profitability came in at the high end of our expectations, highlighting demand for our products across a diverse set of applications and our ongoing effort to drive efficiencies in our business," says Young.

Depreciation and amortization was \$1.2m. Capital expenditure (CapEx) was \$12.7m. Due mainly to the new facility and equipment, cash and cash equivalent investments hence fell during the quarter from \$54m to \$42m. This was also partly due to net inventory rising

from \$57m to \$58.7m, of which about 51% was in raw materials, 44% in work in process (WiP) and only 5% in finished goods. The increase in inventory is partly due to the ramp up of AXT's new GaAs and Ge manufacturing manufacturing facilities in Dingxing (being relocated from Beijing).

For fourth-quarter 2018, AXT expects revenue to fall slightly to \$26.5–27.5m, with raw materials flat but substrate revenue typically a bit down. "There's a general softness on the LED side," says Fischer. "Based on the discussion with customers in this space, we expect a softness in our traditional lighting, signage and display applications to persist in Q4," says Young. "In semi-insulating things are a bit soft as well," he adds.

"We remain confident in a gross margin going forward of around 37.5%," says Fischer. "However, in this Q4 we believe we will be lower than that [about 35%] as a result of a drag from the three raw material companies that we consolidate, as well as some year-end inventory adjustments. Net income per share will be \$0.050.07.

"In the tariff list that was released by the US government on 24 September it included wafer substrates that we manufacture and import to the United States. Therefore our Q4/2018 forecast will include approximately \$150,000 for tariffs of 10% charge on the importing wafers into the United States from China," says Fischer. "It has been said that President Trump might raise the rate to 25% in 2019," he adds. "These amounts are not what we would consider to be dramatic hits, nevertheless they are real and will have an impact going forward unless the two countries can sort out and resolve the trade war issues."

"Many of the key applications into which we sell appear to be in the early stages of a large and promising lifecycle," says Young.

"The continued adoption of silicon photonics technology and hyper-center, hyperscale and enterprise data centers, as well as the transition over time to 100G and 400G technologies, will feed the need for indium phosphide for years to come," believes Young. "In addition to data-center connectivity, the current infrastructure upgrade cycle and preparation for 5G in telecommunication applications are providing opportunities in short-haul, long-haul and metro deployments. As another data point for the expected growth in this application, Intel announced in Q3 that it has begun assembling a new portfolio of 100Gb/s silicon photonics transceivers that are optimized to meet the bandwidth requirement and the environment conditions of 5G communication infrastructure," he adds. "The industry move to 5G, along with a ramp in existing network traffic for services such as video streaming, is likely to strain the existing communication infrastructure. As a result it will need to support an expanded spectrum range over time, driving demand for more efficient solutions."

"PON applications should provide significant opportunities for our indium phosphide product over many years. Driving the demand is the ongoing need for faster broadband networks and increasing fiber-to-the-home [FTTH] requirements," adds Young.

Regarding germanium substrate revenue, AXT say that, overall, the satellite industry is expected to continue its positive strength, providing upside opportunities in the quarters to come.

"We are also encouraged to see new emerging applications that could contribute to our growth for years to come," says Young.

"Although the commercialization of the [3D sensing] technology in the Android ecosystem is still in its early stages, we expect that revenue will ramp slowly over the course of 2019 and into 2020, as new devices come to market," says Young. "In addition with the tech-

nology performance of our wafer and the solid progress we are making in relocating our gallium arsenide production line, we're positioning ourselves to expand beyond Android in the coming years," he adds. "Applications such as augmented reality and virtual reality (AR/VR), 5G wireless, LiDAR for autonomous cars, retinal recognition and many others are emerging and will require the performance characteristics adaptability [indiscernible] that offers."

"Most recently we have seen rising demand for gallium arsenide in high-power fiber lasers that supplement traditional cutting, welding and drilling tools for industries, micro fabrication, aerospace and defense applications. The stringent technical specifications for these high-end applications continue to serve to severely limit the number of companies that can provide substrates to meet global demand. And importantly, as demand for these application increases, AXT will be uniquely positioned through our current capacity expansion to accommodate the growing requirement of our customers," says Young.

"As such, the relocation of our GaAs manufacturing line is providing us the opportunity to plan for growth in our industry and to prepare our business to meet increasing customer demand. We continue to make good progress on the new facilities and are pleased by our success to date."

By the end of 2018, AXT expects to have relocated about 60% of its wafer production and to be close to completion by mid-2019. "We are now well underway with customer qualifications including all of our major customers," says Young. "Further, our internal qualification results to date demonstrate consistent specification across our sites, which gives us the confidence that those remaining customers who require qualification will find quality levels that are on par with substrates made from our current facility."

www.axt.com



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IQE reduces 2018 Photonics wafer revenue forecast from 35–50% to 11% after VCSEL customer cuts guidance ...but Wireless revenue to grow 8% rather than 0–5%, and Infrared revenue growth to exceed 5–15% guidance

Epiwafer foundry and substrate maker IQE plc of Cardiff, Wales, UK says that — after a major vertical-cavity surface-emitting laser (VCSEL) chip maker said on 12 November that one of its largest customers had requested a reduction in shipments of 3D sensing laser diodes due for delivery in the December quarter — it now expects revenue of about £160m for full-year 2018, up just 3.5% on 2017's £154.6m.

Photonics demand was facing a later but steeper ramp for VCSELS for consumer products moving into fourth-quarter 2018, a reflection of the 6"-wafer VCSEL inventory overbuild in 2017 being larger and taking longer than expected to be consumed during 2018. With the impact of the VCSEL chip maker's announcement at this critical time, IQE now expects Photonics wafer revenue growth for full-year 2018 (on a constant currency basis) to be about 11% (rather than the guidance of 35–50% given at the end of August) and (based on early initial indications) 2019 revenue growth to return to previously guided levels of 40–60%.

Wireless wafer revenues for 2018 (on a constant currency basis) is now expected to grow at 8%, above the top end of the prior 0–5% guidance range. Wireless demand, especially for gallium nitride (GaN) products, has been strong and capacity was retained through third-quarter 2018, to continue to address demand following the replenishment of inventory channels depleted during second-half 2017. IQE says that the late ramp of Photonics production has also provided an extended opportunity for additional engagement and qualification programs with more than 25 VCSEL chip makers.

Infrared wafer revenue (on a constant currency basis) is also

expected to grow at or above the top end of the compound annual growth rate (CAGR) guidance range of 5–15% for full-year 2018 and remain in the 5–15% range for full-year 2019.

As a result, full-year 2018 adjusted EBITDA (earnings before interest, taxes, depreciation and amortization) is now expected to be about £31m (up from 2017's £37.1m).

"The much reported VCSEL inventory overbuild, following the successful second-half 2017 ramp for a new 3D sensing consumer product application for this technology, took longer to work through the inventory channels than the industry expected," notes CEO Dr Drew Nelson. "It is now clear that some of this inventory likely satisfied product build as late as September and October 2018. This resulted in a steeper and later ramp for VCSEL production in Q4/2018. The impact of an immediate slowdown in shipments of VCSEL wafers will therefore materially impact our expected year-end revenues and profitability," he adds.

Nevertheless, Photonics revenues (on a constant currency basis) from full-year 2016 through to full-year 2018 is still expected to deliver revenue growth of at least 45% (within the guidance range retained for full-year 2019). "We have retained approximately 90% share of the VCSEL epiwafer market that we enjoyed last year and, based on early initial indications, we expect a similar market share in full-year 2019, but with a significantly broader OEM end-customer spread as the technology penetrates many more devices and applications," says Nelson.

"IQE is the premier solution provider for this VCSEL technology, serving the mobile, sensing and datacom applications. We have

demonstrated the three key elements for establishing a pre-eminent position for this high-growth material: technical competence, 6-inch production capability through an aggressive ramp, and finally a commitment to install and qualify significant capacity to meet industry assumptions for future VCSEL demand," he adds. "Our technical leadership is underwritten by more than 25 years' experience with these highly complex structures, and this will be maintained by an unrivalled technology roadmap," Nelson continues.

"The added capacity to be provided by our Newport Foundry is progressing, with 10 reactors now installed and four of which are already engaged in multiple customer qualification activity with some initial volume mass production possible at the very end of the current quarter. The throughput, yield and quality (uniformity) of the qualifications currently underway are very encouraging," Nelson states.

"Our Photonics business is building a wide customer base across multiple chip manufacturers providing VCSELS for a number of different end-market applications including 3D sensing, and this increasing customer diversification will in time produce a better-balanced and more uniformly distributed demand profile," he continues. "I am also delighted by the strong performance of both our Wireless and Infrared business units and the opportunities they face for 2019 and beyond."

"We reiterate our long-term guidance for each of the photonics, wireless and infrared businesses," Nelson concludes. IQE's 3–5 year CAGR forecast is up to 10% for Wireless, 5–15% for InfraRed and 40–60% for Photonics.

www.iqep.com

SMI aiding NSF INTERN program and science exchange programs

Structured Materials Industries Inc (SMI) of Piscataway, NJ, USA — which provides chemical vapor deposition (CVD) systems, components, materials and process development services — says that it is helping graduate research students to develop their careers through internships and collaborative science exchange programs that give interns valuable first-hand experience in cutting-edge technology industries. Interns participating in such programs can expect the following:

- working with industry professionals (research scientists, engineers, etc);
- conducting and observing experience with thin-film depositions in metal-organic chemical vapor deposition (MOCVD) reactors;
- experience with using an application laboratory;
- gaining knowledge of handling/procuring materials for commercial- and government-funded research projects;
- exposure to budget management for government- and commercial-funded research projects; and
- working in an industrial environment.

SMI is active in the US National Science Foundation (NSF) internship program 'INTERN', in which a graduate student works directly with the principal investigator on an NSF-funded project. SMI has hosted Jignesh Vanjaria from professor Hongbin Yu's group at Arizona State University (ASU) where he has worked with SMI research scientist and principal investigator Dr Arul Arjunan on a government-funded project to develop a silicon germanium tin (SiGeSn)-based device.

In addition, SMI is also separately hosting Kuang-Hui Li, a visiting PhD student from professor Xiaohang Li's group at the King Abdullah University of Science and Technology (KAUST) in Saudi Arabia, in a collaborative effort with SMI. Arjunan, Vanjaria and Kuang-Hui Li were recently featured on an NSF internship video that

outlined the NSF program interns working with their non-academic partners.

"We take pride in enabling young researchers by providing them with valuable in-the-field experiences and one-on-one educational lessons with industry professionals," says SMI's president & CEO Dr Gary S. Tompa. "In this instance, our NSF intern is able to work directly under our research scientist on a day-to-day basis and interact with guest/visiting scientists. While at SMI, he is also conducting deposition runs, under the supervision of SMI professionals and gaining insights on practical lab operations; maintaining tools, interacting with vendors operating within a budget and timeline, analyzing results and planning experiments, as well as understanding safety procedures for this government funded project," he adds.

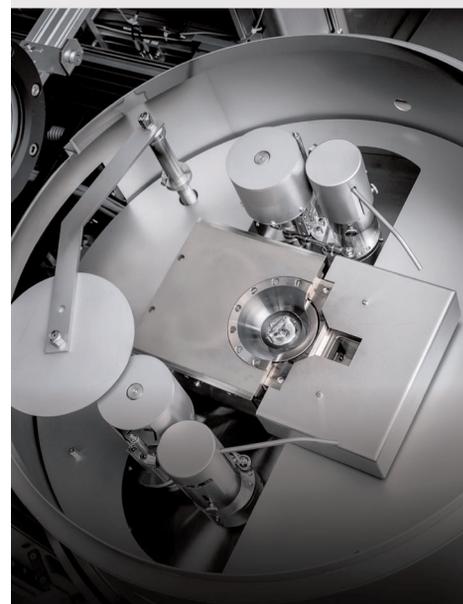
"NSF programs such as INTERN not only help in training the future workforce directly in an industrial environment but also provide an opportunity for universities to foster a much closer collaboration between university and industry for accelerated technology development and commercial introduction," says Dr Hongbin Yu, ASU professor and director of the NSF Industry-University Cooperative Research Center (IUCRC) Center for Efficient Vehicles and Sustainable Transportation Systems. "I have always enjoyed working with students and introducing them to new technologies as well as sharing my 20 years of experience in industry and academic research," states Arjunan. "It is a pleasure working with professor Yu and Mr Vanjaria through the NSF INTERN and other programs," he adds. "We are showing Mr Vanjaria how to optimize material growth for multiple projects. We sincerely hope that the experiences he gained at SMI will transition into other facets of his career."

www.smicvd.com



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MRSI Systems announces HVM3 die bonding demonstration capability in Shenzhen

Mycronic Group's MRSI Systems of North Billerica, MA, USA (which makes fully automated, high-precision eutectic and epoxy die bonding systems) has announced new demonstration capability at the facility of Shenzhen Axxon Automation (a fellow subsidiary of Sweden's Mycronic Group) in the Longhua district, Shenzhen, China. MRSI will be offering local demonstrations (by arrangement) of its MRSI-HVM3 die bonder and also die bonding applications using customer's sample materials.

This offers existing and prospective customers in China the opportunity to review the detailed performance capability of the MRSI-HVM3 in a local setting, supported by MRSI's local application engineers for a quick turn-around of product demonstration and die bonding sample building. The firm says that



The MRSI-HVM3 die bonder.

the MRSI-HVM3 product family delivers high-speed, future-proof high-precision (<math><3\mu\text{m}</math>), and the flexibility for true multi-process, multi-chip, high-volume production. This performance is enabled by dual-head, dual-stage, integrated

'on-the-fly' tool changer, ultrafast eutectic stage, and multi-levels of parallel processing optimizations.

The MRSI-HVM3 is designed for specific applications including chip-on-carrier (CoC), chip-on-submount (CoS) and chip-on-baseplate (CoB) assembly using eutectic and/or epoxy stamping die bonding. This also provides opportunities to discuss with MRSI's local process experts for solutions within the extended product configurations of HVM3e, HVM3P, H3TO and H3LD. These configurations are based on the same design as HVM3 but configured specifically for local top heating, inline conveyor CoB, AOC and gold-box packaging, WDM & EML TO-can packaging and high-power laser diode packaging, respectively.

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EpiGaN orders Aixtron AIX G5+C system to expand large-diameter GaN-on-Si and GaN-on-SiC epi

EpiGaN nv of Hasselt, near Antwerp, Belgium has ordered an AIX G5+C metal-organic chemical vapor deposition (MOCVD) system from Aixtron SE of Herzogenrath, Aachen, Germany to boost its manufacturing capability of large-diameter gallium nitride on silicon (GaN-on-Si) and gallium nitride on silicon carbide (GaN-on-SiC) epitaxial wafers for telecom, power electronics and sensor applications.

To be operational in Q1/2019, the fully automated Planetary MOCVD system features in-situ chamber cleaning and enables configurations of 8x6" or 5x8" epiwafers to be automatically loaded and removed by a cassette-to-cassette wafer transfer module.

"The demand from our global customer base for GaN product solutions is booming. Our key customers are getting ready to launch and scale-up products based on our GaN RF-power technology, which is optimized for 5G broadband network applications," says EpiGaN's CEO & co-founder Dr Marianne Germain.

"With Aixtron's AIX G5+C Planetary

system, EpiGaN will increase its capacity for 150mm and 200mm product solutions to cope with these increasing market demands," she adds. "Aixtron's Planetary system combines excellent on-wafer uniformity and run-to-run performance at the lowest cost of ownership — these attributes are critical to serve our customer base with products of exceptional performance and at the right price point," Germain comments.

"The AIX G5+C will support EpiGaN's demanding requirements for high-quality, cost-effective production of GaN epitaxial wafers as our tool meets the highest standards in terms of uniformity and particle density," says Aixtron's president Dr Felix Grawert.

EpiGaN recently released large-diameter versions of its HVRF (high-voltage radio frequency) GaN-on-Si as well as GaN-on-SiC wafer product families tailored to demanding 5G applications needs. With the new AIX G5+C MOCVD system, the firm expects to quickly scale up and spread its technology solutions to the global market.

www.epigan.com

Edwards opens new service & support facility in Arizona

Edwards Vacuum LLC (a subsidiary of vacuum and exhaust-abatement equipment maker Edwards Ltd of Crawley, UK) has opened a new customer service and support facility in Chandler, AZ, USA to provide rapid service, support and applications training to customers in the southwest region.

"Edwards' vacuum and abatement solutions are integral to manufacturing processes for semiconductors, flat-panel displays, LEDs and solar panels, and the southwest is home to many of our major customers in these industries," says Scott Balaguer, VP & general manager, Semi North America, Edwards. "The

Chandler facility is situated close to our key customers for rapid support and hands-on training," he adds.

"Edwards is well established in the US and we have a long-term commitment to expand our facilities in conjunction with our growth," says Balaguer. "The new Chandler office allows us to grow in a key geography for us. In addition, we recently broke ground on our brand-new Innovation Center and Manufacturing site in Hillsboro, OR, and plan to move in during first-quarter 2019."

Edwards North America has seven sites and over 697 staff in the USA. Chandler will have about 30 staff.

www.edwardsvacuum.com

Web: laytec.de

LayTec's EpiTT FaceT for GaAs laser facet coating is an in-situ spectroscopic metrology tool especially designed for accurate temperature measurement during MBE passivation of GaAs laser facets in conjunction with real-time passivation layer thickness sensing.

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Aixtron's revenue grows 15% in Q3, driven by power electronics, laser and ROY LED applications

Highest order backlog since 2011 leads to further increase in full-year 2018 earnings guidance

For third-quarter 2018, deposition equipment maker Aixtron SE of Herzogenrath, near Aachen, Germany has reported revenue of €63.4m, up 15% on €55.2m last quarter and up 2% on €62.2m a year ago.

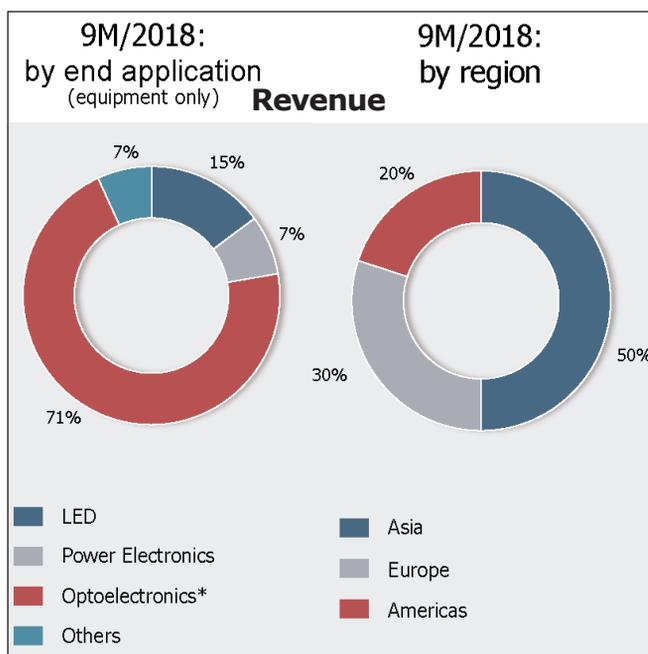
Revenue for the first 9 months of 2018 was €180.9m, up 3% year-on-year from €176.3m. Adjusted for €37.6m revenue from the atomic layer deposition/chemical vapor deposition (ALD/CVD) memory product line that was sold to Eugene Technology Inc in Q4/2017, on a like-for-like basis this was 30% above the prior year's €138.7m.

Gross margin has improved further, from 35% a year ago and 43% last quarter to 44%, due to the higher sales volume, a favorable product and regional mix and the strengthening US\$/€ exchange rate. Gross margin for the first 9 months improved to 43%, up from 30% the prior year (when inventories were being cleared and the product mix was not so good).

Operating expenses were €57.6m in the first nine months of 2018, down 21% on the prior year's €72.5m, although the latter included restructuring expenses of €13.6m from freezing development of product lines for III-V-on-silicon (TFOS) for microprocessor logic. Quarterly operating expenses were cut slightly to €18.9m in Q3, from €19.7m in Q2.

Driven by the good control of operating expenses, the operating result (EBIT) for the first 9 months of 2018 improved to €20.7m, compared with –€19.5m the prior year. This included quarterly EBIT more than doubling from €4.1m in Q2 to €8.7m in Q3 (margin of 14% of revenue).

Likewise, compared with a net loss of –€20.6m the prior year, the first nine months of 2018 saw net income of €27.7m (higher than EBIT because of the recognition of



€4m of deferred taxes in Q3). This was aided by quarterly net income more than tripling from €3.7m in Q2 to €11.7m in Q3 (margin of 18% of revenue).

Operating cash flow has risen from €12.5m in Q2 to €13.9m in Q3, offsetting Q1's outflow of –€21.1m resulting mainly from planned payments related to selling the ALD/CVD product line in Q4/2017. For the first nine months of 2018, operating cash flow was hence €5.4m (down from €56.5m the prior year). After capital expenditure (CapEx) of €2.7m in Q3/2018, total cash flow was therefore €10.7m. Cash and cash equivalents hence rose from €234.7m to €245.4m during the quarter (almost reaching the €246m at the end of 2017). The main changes are an increase in pay inventories and the associated customer deposits (reflecting a strong order backlog for delivery over the next few months) and a reduction in receivables to 45 days outstanding.

Also, with the signing in late October of a joint venture agreement with South Korean organic light-emitting

diode (OLED) supplier IRUJA Co Ltd (involving IRUJA contributing its automation & handling technology for display applications plus some cash, as well as acquiring up to 20% of Aixtron's OVPD-based OLED subsidiary APEVA over the next few years), Aixtron has completed the strategic adaptation of its structure that was initiated in 2017, which has led to sustainable profitability, says president Dr Bernd Schulte.

Order intake (including spare parts and services) in Q3/2018 was €76m, up slightly from last quarter's €75.6m and up 10% on €69m a year ago. Order intake for the first nine months of 2018 was €230.3m, up 16% on €197.9m the prior year.

As in previous quarters, both revenue and order intake in the first nine months of 2018 were driven primarily by continued demand for continued demand for metal-organic chemical vapor deposition (MOCVD) systems for the production of red, orange and yellow (ROY) LEDs (e.g. for displays) and lasers such as vertical-cavity surface-emitting lasers (VCSELs) and edge-emitting lasers (EELs) for applications in 3D sensing and optical data transmission. In Q3/2018 there was also increasing demand for MOCVD systems for power electronics applications — “For the first time, we have more orders on production capacity extensions rather than just for development and for product qualification,” notes president Dr Felix Grawert.

“We were very pleased with the broad distribution of our order intake into applications for red, orange and

yellow LEDs, lasers and power electronics," comments Schulte.

"In this fiscal year, we are benefiting from the increasing market penetration of new display and communication technologies worldwide," says Grawert. "Our MOCVD systems for ROY LEDs and laser applications such as

VCSEL or EEL, which are particularly in demand in the field of 3D sensor technology or optical data transmission, have established themselves as technically leading systems. The growing orders from power electronics are due to the increasing use of components based on gallium nitride (GaN) or silicon carbide (SiC) for energy-efficient communication, automotive energy management, consumer electronics and mobile devices," he adds.

Equipment order backlog has hence risen to €151.9m, up 10% on €138.3m at the end of June and up

53% on €99.2m a year previously, and the highest backlog since 2011. "This gives us good visibility for the remainder of the year and into 2019," comments VP of finance & administration Charles Russell.

Full-year 2018 guidance (given in February) was originally for revenue and orders of €230–260m, gross margin of 35–40%, OpEx of €75m, EBIT margin of 5–10% of revenue, and positive operating cash flow. After first-half 2018, this was revised to revenue of €260m, gross margin of 40% and EBIT margin of 10% (corresponding to EBIT of €26m),

i.e. the upper end of the prior guidance ranges. Guidance for orders was raised to €260–290m.

Now, based on the results for the first nine months of 2018 and internal assessment of the development of demand, Aixtron has further updated its full-year 2018 guidance. The firm still expects revenue of €260m and gross margin of 40%, but it now expects EBIT of €35–40m, orders of €290m (at the upper end of the revised range) and positive total cash flow (not just positive operating cash flow).

www.aixtron.com

(€ million)

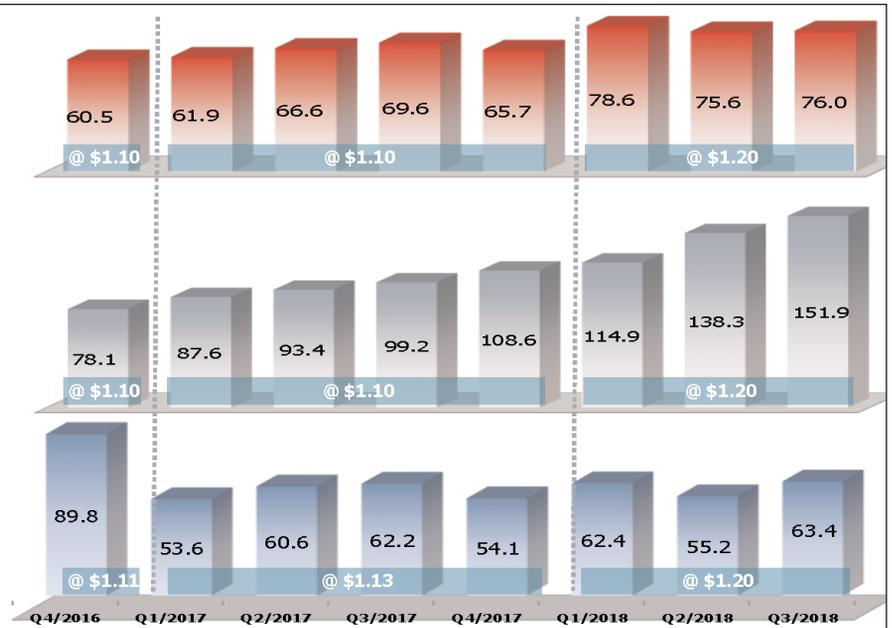
Order Intake
(incl. equipment,
service, spare parts)

Order Backlog
(equipment only)

**Aixtron's 24-month
business development**

Revenues
(incl. equipment,
service, spare parts)

USD order intake and backlog were recorded at the prevailing budget rate (2017: \$1.10/€; 2018: \$1.20/€)
USD revenues were converted at the actual period average FX rate (2017: \$1.13/€; 2018: \$1.20/€)



China's InnoScience orders Aixtron AIX G5+ C MOCVD systems for manufacturing 650V GaN-on-silicon devices

China's InnoScience Technology has ordered multiple AIX G5+ C MOCVD systems, for the development of GaN power devices. All cluster tools will feature a 5x200mm-wafer configuration and be shipped by Q2/2019.

In the scope of the increasing number of applications, Aixtron says that the AIX G5+ C platform can demonstrate its advantages in manufacturing since it allows for scalable processes, tight uniformity and particle control of the epitaxial wafers to enable the highest yield and maximum

throughput at the lowest cost of ownership.

"We have chosen the AIX G5+ C as it has proven to provide excellent thickness and wafer uniformity due to the superior capabilities of the Planetary batch reactor concept," says InnoScience's CEO Jay Son. "The newly acquired systems will enable us to ramp up manufacturing of our high-end products such as 650V GaN-on-Si devices," he adds.

"Market demand for power electronics, especially for GaN-based devices, is picking up speed," notes

Aixtron's president Dr Felix Grawert. "We are pleased that InnoScience leads the way in China and has decided to select this system, which convinces not only by performance but also by making the production of GaN power devices commercially viable."

Founded in December 2015, InnoScience's first fab is located in Zhuhai National Hi-Tech District, where it has established China's first mass-production line for 8" enhancement-mode (E-mode) GaN-on-Si power devices.

www.innoscience.com.cn

Veeco's Q3 revenue down more than expected due to China market softness

SG&A cost reduction to save extra \$20m annually to shrink quarterly operating expenses to \$40m by Q2/2019

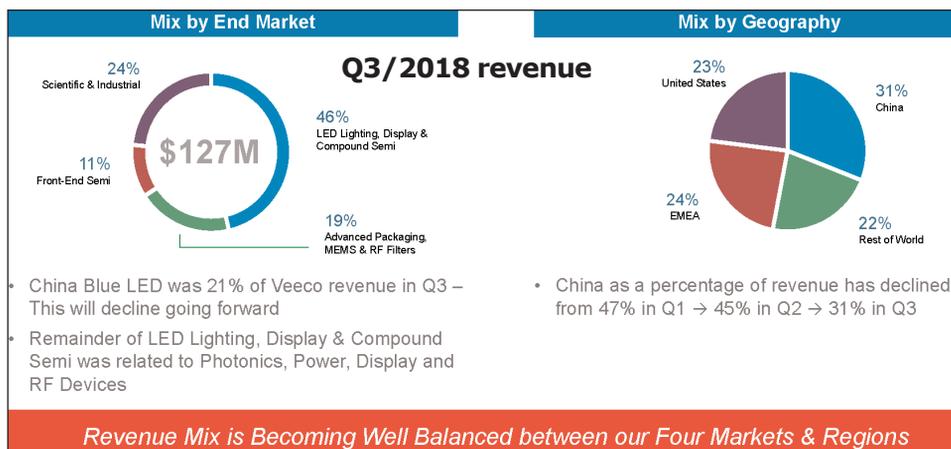
For third-quarter 2018, epitaxial deposition and process equipment maker Veeco Instruments Inc of Plainview, NY, USA has reported revenue of \$126.8m, down 19.6% on \$157.8m last quarter and 1.9% on \$129.3m a year ago. It is also below the \$130–140m guidance range due to market softness in China across all of the firm's businesses, as well as a US foundry [GlobalFoundries] unexpectedly putting its 7nm FinFET program on hold indefinitely.

Geographically, compared with last quarter, China has fallen from 45% to 31% of total revenue, while Europe, Middle East & Africa (EMEA) has grown from 16% to 24%, the USA from 21% to 23%, and rest of the world from 18% to 22%.

Of total revenue, the LED Lighting, Display & Compound Semiconductor segment fell from \$88m to \$59m (from 55% of total revenue to 46%, including blue LED MOCVD systems for China falling from 31% to 21%). Most of this segment's revenue was hence in Compound Semiconductors, including metal-organic chemical vapor deposition (MOCVD) systems for specialty LEDs, automotive, photonics and power electronics applications as well as Precision Surface Processing (PSP) systems for RF device manufacturing.

The Advanced Packaging, MEMS & RF Filter segment — including lithography and PSP systems sold to IDMs and OSATs for Advanced Packaging in automotive, memory and other areas — was level on last quarter at \$25m (rising from 16% to 19% of total revenue).

The Front-End Semiconductor segment (formerly part of the Scientific & Industrial segment, before the May 2017 acquisition of lithography, laser-processing and inspection system maker Ultratech of San Jose, CA, USA) fell back from



\$18m to \$13m (from 12% to 11% of total revenue), which included sales of ion beam etch systems for STT-MRAM manufacturing as well as 3D inspection systems.

Scientific & Industrial revenue (including shipments to data storage and optical coding customers) recovered from \$27m to \$30m (rising from 17% to 24% of total revenue).

Despite being down from 41.2% a year ago, non-GAAP gross margin has rebounded from 35.8% last quarter to 38.2%, exceeding the 36–38% guidance range due to a favorable product mix and lower spending. Operating expenditure (OpEx) has improved further, from \$48.9m a year ago and \$45.7m last quarter to \$40.4m (better than the expected \$43–45m), due mainly to selling, general & administrative (SG&A) expenses being cut further, from \$25.7m a year ago and \$21.9m last quarter to just \$17.6m.

"Gross margin was better than guidance and led to non-GAAP operating income, net income and EPS all coming in at the high end of our guided ranges," says CEO Dr William J. Miller.

Operating income was \$8m, down from \$10.8m last quarter but up from \$4.3m a year ago.

Likewise, net income was \$5.3m (\$0.11 per diluted share), down

from \$7.2m (\$0.15 per diluted share) last quarter but up from \$2.4m (\$0.05 per diluted share) a year ago, and above the midpoint of the \$1–6m (\$0.03–0.13 per diluted share) guidance range.

Operating cash flow was positive, at \$18m (compared with –\$46m last quarter). During the quarter Veeco purchased \$10m of its common stock (1.8% of its outstanding shares) at an average price of \$11.58 per share.

During the quarter, cash and short-term investments rose from \$261m to \$266.3m, due mainly to the reduction in accounts receivable from \$134m to \$91m, and improving days sales outstanding (DSO) from 76 to 64 days. Inventory remained high (\$150m) as Veeco continued to ramp EUV systems-related manufacturing and also to invest in new products for MOCVD. Consequently days of inventory (DOI) rose from 130 to 173 days. Long-term debt was \$284m, representing the carrying value of \$345m in convertible notes.

Order bookings were \$100m, down 24% on \$132m last quarter and 38% on \$162m a year ago, reflecting softness in China across all of Veeco's business.

LED Lighting, Display & Compound Semiconductor orders continued to be weak, as expected (comprising just 13% of bookings), with no orders

for blue LED MOCVD systems.

Advanced Packaging, MEMS & RF Filter orders comprised 11% of bookings, including multiple lithography tools with a large Taiwanese outsourced assembly & test (OSAT) firm that is adding capacity to provide wafer-level advanced packaging applications for their logic customers.

Industrial & Scientific orders comprised 39% of total bookings, remaining strong in data storage as well as in optical coatings systems.

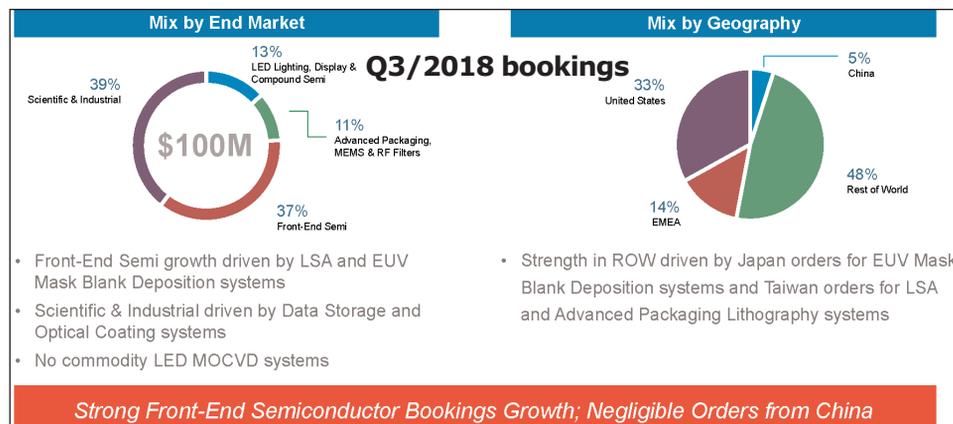
Front-End Semiconductor orders grew strongly to 37% of bookings, including two extreme ultraviolet (EUV) mask blank deposition systems for Japan and a laser spike anneal (LSA) system for leading-edge applications at a market leader in Taiwan.

Driven by the latter, orders from the rest of the world (including Japan and Taiwan) rose to 48% of bookings, the USA comprised 33% and EMEA 14%, while China fell to just 5%.

Order backlog hence fell further during Q3/2018, from \$305m to \$276m. Typically, more than two-thirds of backlog turns into revenue in the subsequent two quarters. However, less than half of the Q3 ending backlog is expected to turn into revenue in Q4/2018 or Q1/2019, primarily due to the EUV systems (which typically ship with a lead time of 10–12 months).

For fourth-quarter 2018, Veeco expects revenue to fall to \$85–105m, partly due to revenue from blue LED MOCVD system sales to China being negligible (compared with 21% in Q3 — and, going forward, Veeco expects the proportion of overall revenue from China to decline significantly). Compared with the previous outlook, Q4 is weaker due to push-outs of non-MOCVD products for China-based customers as well as the US foundry's unexpected discontinuation of its 7nm program.

Q4 gross margin should be 36–38%. Product mix is shifting away from low-margin blue LED MOCVD systems for China, but this is being offset by the overall decline



in business volume, preventing Veeco from achieving its previously stated goal of 40% gross margin by Q4. "We continue to target 40% gross margin or higher as volume picks up," says chief operating officer & chief financial officer Sam Maheshwari.

OpEx should be \$41–43m, the midpoint of which is an improvement after adjusting Q3's OpEx for a one-time credit of \$2.2m.

Veeco expects an operating loss of \$10–3m and a net loss of \$11–4m (\$0.25–0.09 per diluted share).

"Some of our prior plans have been impacted for various reasons," notes CEO Bill Miller.

"The first was our forecast to grow full-year 2018 revenue over 2017. Given our current visibility, full-year 2018 revenue will be slightly lower than the \$556m pro-forma 2017 revenue of the combined Veeco and Ultratech. The revenue shortfall was driven by a US foundry's decision to put its 7nm FinFET program on hold. We are also seeing broader China softness across all of our businesses," he adds.

"The second was our plan to exit 2018 with 40% gross margin. Our cost-reduction efforts and improved product mix have helped gross margin. However, lower Q4 revenue and the resulting under-absorption has more than offset the benefits."

"Third was our plan to release a tool for the VCSEL market in the second half of this year. We are engaged with customers under a new VCSEL platform and have demonstrated many key requirements for VCSEL manufacturing, but commercial availability will be

delayed at least three months as we optimize our technology."

Based on its backlog and current visibility, Veeco sees Q1/2019 sales tracking slightly above Q4/2018. It also expects OpEx to continue declining towards the \$40m targeted by end-Q2/2019.

"We remain encouraged by our growth prospects in compound semiconductor, advanced packaging and front-end semiconductor," Miller says. "We are working on many promising initiatives in Front-End Semiconductor and Compound Semi which offset the declining commodity LED business, but this transition will take time. Therefore, we have begun to take proactive measures to reduce expenses in such a way that we preserve our innovation capability and position Veeco for growth when our markets regain traction."

"We announced \$15m in annualized OpEx synergies when we acquired Ultratech. A few actions are still outstanding and we expect to complete them by early Q1/2019," notes Maheshwari. "We recently initiated additional expense reduction efforts to align our cost structure to the current business conditions. These new actions are projected to save an additional \$20m annually to bring our quarterly non-GAAP operating expenses to \$40m by Q2/2019. These expense reductions are being implemented primarily in SG&A [selling, general & administrative] with a minimal impact to our R&D and new product development efforts [in laser anneal, MOCVD and lithography]."

www.veeco.com

Veeco and ALLOS technical collaboration completes another phase towards 200mm GaN-on-Si micro-LED production

Reproducibility of ALLOS' 200mm GaN-on-Si epi technology on Veeco's Propel MOCVD reactor demonstrated for consumer electronics customers

Epitaxial deposition and process equipment maker Veeco Instruments Inc of Plainview, NY, USA and IP licensing & technology engineering firm ALLOS Semiconductors GmbH of Dresden, Germany have completed another phase of their mutual effort to provide gallium nitride on silicon (GaN-on-Si) epiwafer technology for micro-LED production.

The purpose of their most recent collaboration was to demonstrate the reproducibility of ALLOS' 200mm GaN-on-Si epiwafer technology on Veeco's Propel metal-organic chemical vapor deposition (MOCVD) reactor when producing epiwafers for many prominent global consumer electronics companies.

"To bring micro-LED technology into production, simply presenting champion values for a single metric is insufficient. It is essential to achieve the whole set of specifications for each wafer with excellent repeatability and yield," comments Peo Hansson Ph.D., senior VP & general manager of Veeco's Compound Semiconductor business unit. "This successful joint effort reaffirms the power of combining Veeco's superior MOCVD expertise with ALLOS' GaN-on-silicon epiwafer technology to provide customers a novel, proven and reliable approach to accelerate micro-LED adoption," he adds.

Sorting and binning are standard methods to achieve wavelength consistency for conventional LEDs. But micro-LEDs are too small and numerous to be sorted and binned, so the uniformity of the epitaxial deposition is even more critical. The most important success factor for turning the promise of micro-LED displays into mass-production reality

is to achieve extremely good emission wavelength uniformity, which eliminates the need to test and sort individual micro-LED chips, say the firms.

Depending on the application and mass-transfer approach, the target requirements of the industry are between $\pm 1\text{nm}$ and $\pm 4\text{nm}$ bin (min/max) on the epiwafer. Through this collaborative project, Veeco and ALLOS say they have further improved the critical wavelength uniformity, with the best wafer having a standard deviation of just 0.85nm (an industry first on a production system).

"Veeco and ALLOS validated

To bring micro-LED technology into production, simply presenting champion values for a single metric is insufficient. It is essential to achieve the whole set of specifications for each wafer with excellent repeatability and yield.

The most important success factor for turning the promise of micro-LED displays into mass-production reality is to achieve extremely good emission wavelength uniformity, which eliminates the need to test and sort individual micro-LED chips

wafer-to-wafer reproducibility with an average wavelength standard deviation for all wafers of 1.21nm and the peak wavelength within a $\pm 0.5\text{nm}$ range," says ALLOS' CEO Burkhard Slischka. "With these results we made another significant leap towards the $\pm 1\text{nm}$ bin goal on an epiwafer," he adds. "Our technology is already available on 200mm wafer diameter, which enables the use of low-cost and high-yield silicon lines for micro-LED chip production. Additionally, we have a clear roadmap to enable 300mm."

Innovators in display technology are focusing on micro-LEDs as the next significant technological shift, say the firms. The market for micro-LED displays could reach 330 million units by 2025, according to research firm Yole Développement. This optimism is fueled by the promise of micro-LED technology (sub- $100\mu\text{m}$ edge length), which is considered to be the critical enabler to achieving the ultimate display with much lower power consumption. However, development of such displays has been hindered by high material costs and low yield and throughput of micro-LED mass-transfer technology. Veeco and ALLOS say that their joint technical effort effectively addresses these challenges as they continue to work with customers to further improve GaN-on-Si epiwafer and micro-LED mass-transfer technology.

Veeco and ALLOS showcased details of their achievements on 12 November at the International Workshop on Nitride Semiconductors (IWN 2018) in Kanazawa, Japan.

www.iwn2018.jp

www.veeco.com

www.allos-semiconductors.com

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EVG and Plessey partner on GaN-on-Si monolithic micro-LED technology for AR applications

Plessey of Plymouth, UK is collaborating with EV Group of St Florian, Austria — a supplier of wafer bonding and lithography equipment for semiconductor, micro-electro-mechanical systems (MEMS) and nanotechnology applications — to bring gallium nitride on silicon (GaN-on-Si) monolithic micro-LED technology to the mass market. Micro-LEDs comprise the key optical technology for next-generation augmented reality (AR) applications.

Plessey has purchased a GEMINI production wafer bonding system from EVG, enabling it to bond its GaN-on-Si micro-LED arrays to the panel's backplane at the wafer level with the high level of alignment precision necessary to enable very small pixel dimensions.



EVG's GEMINI automated production wafer bonding system for 200mm wafers.

EVG's patented SmartViewNT Automated Bond Alignment System technology is suitable for Plessey's requirements because it allows face-to-face alignment of the wafers with very high precision.

A maximum level of automation and process integration is achieved via the GEMINI automated production wafer bonding system. Wafer-to-wafer alignment and wafer bonding processes up to 300mm for volume manufacturing are all performed in one fully automated platform.

"The modular design of the GEMINI system is ideal for our requirements," comments Plessey's VP of engineering John Whiteman. "Having the pre-treatment, clean, alignment and bonding enabled within one system means higher yield and throughput in production. The excellent service provided by EVG has been critical to bringing the system online quickly and efficiently," he adds.

www.plesseysemiconductors.com/products/microleds

Thermco opens second UK manufacturing facility Expansion to support increased demand for flagship horizontal thermal reactors and chemical wet-benches

Thermco Systems (a division of Tetreon Technologies Ltd that makes equipment for the semiconductor, power devices, MEMS, LED and photovoltaic sectors) has announced its expansion into a second manufacturing facility, close to its existing UK facility in Washington, West Sussex.

Acquisition of the new plant is part of Thermco's planned growth strategy, implemented to support increased demand for its flagship range of horizontal thermal reactors and chemical wet-benches.

The new facility follows the firm's recent acquisition of CSD Epitaxy Inc of Fremont, CA, USA (which makes the Epi-pro epitaxy batch reactor) and its new strategic association with Hitachi Kokusai Semiconductor Europe GmbH of Erkrath, Germany.

Founded in 1962 and having the largest installed base of over



30,000 horizontal diffusion furnaces worldwide for the semiconductor market, Thermco says that, as a result of these developments, its customers can now benefit from an increased range of semiconductor solutions across Europe, North America, Canada, Russia, China and other Asian locations.

These solutions now include: horizontal and vertical atmospheric and low-pressure chemical vapor deposition (LPCVD) thermal reactor

furnaces; batch epitaxy reactors; chemical wet-benches; epitaxy reactors and batch ashers; four-point probes and other metrology equipment; and next-generation backward compatible control systems and gas cabinets.

"It's been a very exciting year for Thermco in

which we've seen our order book go from strength to strength and the business grow considerably," comments Thermco's managing director Andrew Conning. "Our acquisition of CSD Epitaxy in California and the strong relationship we've built with Kokusai in Europe give us improved capability and capacity to meet our customers' needs and deliver high-quality engineered solutions."

www.thermosystems.com

Pfeiffer Vacuum opens new North American headquarters building in Nashua, NH

Pfeiffer Vacuum of Asslar, Germany (which provides high-tech vacuum solutions for the semiconductor, industrial, coating, analytical and R&D markets) has opened a new two-story, 27,000ft² building in Nashua, NH, USA that will be home to its North American headquarters for administration, sales, product management, marketing and customer care.

In parallel, the former 24,000ft² administration building has been converted into a Service Center of Excellence, bringing together under one roof all service activities for the major part



Pfeiffer Vacuum's new facility in Nashua, NH, USA.

of the Pfeiffer Vacuum product portfolio. Automated cleaning and test equipment is being utilized, resulting in fast repairs. This joins

work environment for our staff," says Daniel Saelzer, president of Pfeiffer Vacuum Inc.

www.pfeiffer-vacuum.com

the service center in Austin, Texas (which has a strong presence in the semiconductor industry).

"With the completion of the two facilities, Pfeiffer Vacuum will be able to better support our valued customers throughout North America, while at the same time providing a modern, best-in-class

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Nitride Semiconductors forms subsidiary Micro Nitride to make micro UV-LED chips for displays

Luminous efficiency for μ UV-LEDs + RGB phosphor doubles with strained-layer superlattice in both n and p layers

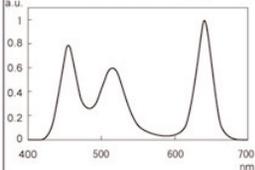
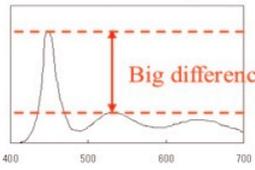
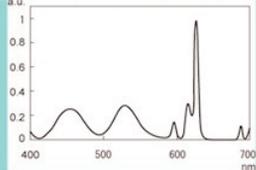
Nitride Semiconductors Co Ltd (spun off from Japan's Tokushima University in 2000 and claims to have developed the first highly efficient ultra-violet light-emitting diode), says that on 1 November it is establishing the subsidiary Micro Nitride Co Ltd to develop, make and sell micro UV LED chips for display applications. With capital of ¥50m plus a capital reserve of ¥50m, total capitalization will be ¥100m.

In recent years, self-emissive displays typified by organic light-emitting diodes (OLEDs) have been adopted for smartphones and the like but, due to their short lifetime and durability against heat, the development of micro-LED displays is becoming active, says the firm.

Currently, there are two methods for realizing micro-LED displays: three-LED type using red, blue and green LEDs, and the blue-LED-excitation type, with blue LEDs exciting red and green phosphors.

Regarding the three-LED type, it is impossible to produce micro red chips because the material is fragile. Also, it is difficult to mount LED chips of different colors with different structures in high density. Their current and voltage reaction speeds are different, so control of each chip becomes complicated, says Nitride Semiconductors.

By comparison, the micro blue-LED-excitation method can integrate all mounted LED chips into blue μ LEDs, so the difficulty of mounting decreases and the current and

	3LED type	Blue+RG type	UV+RGB type
Luminescent spectra			
Merits	<ul style="list-style-type: none"> • Good color balance 	<ul style="list-style-type: none"> • Easy mass production • Easy control drives 	<ul style="list-style-type: none"> • Easy mass production • High efficiency • Good color balance • Easy control drives
Problem	<ul style="list-style-type: none"> • Difficulty of mass production • Complicated control drives 	<ul style="list-style-type: none"> • Poor color balance • R/G low efficiency • Low synchronization • Blue bigger scatter 	<ul style="list-style-type: none"> • Cost?

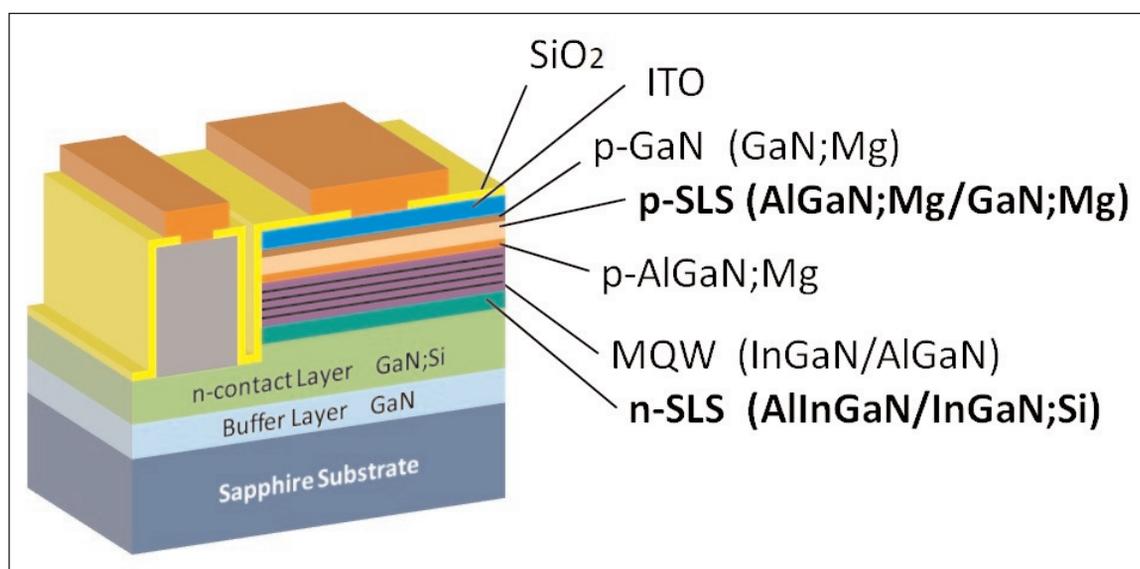
voltage can also be unified. However, the blue light is emission whereas the red light and green light are excitation, so there is a time lag in reaction speed. Also, there is another problem that the color reproducibility is low due to the low luminance of red and green as a result of the blue excitation.

The company says that these problems can be solved by μ UV-LEDs + RGB phosphor. It found that luminous efficiency is doubled when fabricating μ UV-LED chips

with a strained-layer superlattice (SLS) structure in both the n and p layers (for which a patent is pending).

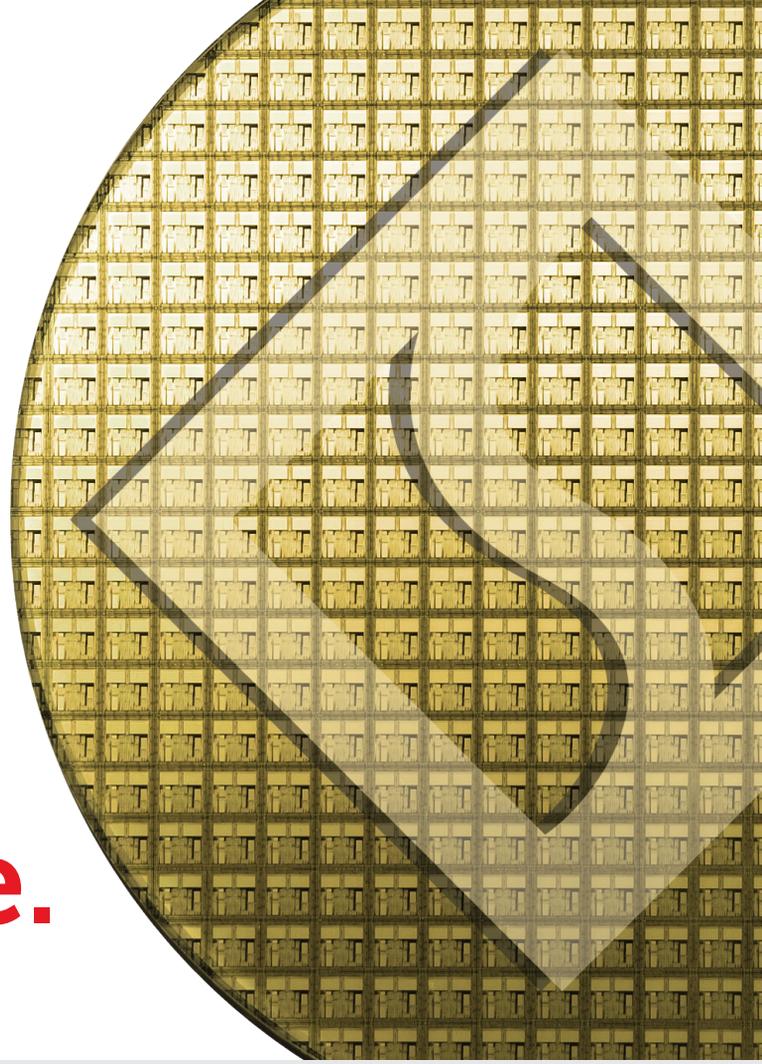
The reason is that, since the distance for current diffusion is short, the light emission recombination increases and the internal quantum efficiency improves. Also, since the distance from the light-emitting layer to the outside becomes short, the external quantum efficiency improves.

www.nitride.co.jp





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Seoul Semiconductor expands litigation against LED TV distributor, asserting infringement of 19 LED patents

South Korean LED maker Seoul Semiconductor Co Ltd has expanded its patent infringement litigation filed on 31 August in the United States District Court for the Eastern District of Texas against big-box consumer electronics retail firm Fry's Electronics Inc.

In its amended complaint, Seoul asserts that top brand televisions being sold in Fry's stores infringe 19 patents covering backlight lenses, backlight modules, LED chips, LED packages and phosphors, as well as WICOP (wafer-integrated chip-on-PCB) technology that enables LED chips to be directly soldered onto printed-circuit boards.

Seoul's backlight lens patents relate to a new concept of lens technology for manufacturing thin and light TVs. This patented technology was developed jointly with optical expert Dr David Pelka and included what Seoul claims was substantial R&D investment in optical lenses. Seoul consequently has about

160 related patents in this area.

Seoul says that its backlight module patent enables significant improvement in the color gamut of LCD displays by using KSF phosphors. Co-developed with Mitsubishi Chemical Corp over many years, the related technology has been widely incorporated in most mobile phones and increasingly applied in LCD TVs too, says the firm.

The WICOP patents enable LED chips to be soldered to a PCB without an LED package. Seoul says that other companies may be attempting to imitate its patented technology, describing it as a CSP (chip-size package) requiring a sub-mount between a PCB and an LED. Protecting its patented technology has led Seoul to expand its infringement claims in the litigation against Fry's.

Seoul says that, to safeguard its LED backlight technology and other protected inventions, it has actively

enforced its patent rights and sent cease-and-desist letters against suspected infringers. As a result, the United States Federal Circuit Court of Appeals issued a decision on 19 November that one of its competitors willfully infringed its LED lens and backlight module patents. The appellate court also found that that Korean LED package company Lumens Co Ltd supplied TV makers with LED backlight bars incorporating infringing products.

"We hope that our commitment for technology innovation would inspire young entrepreneurs and small businesses," said Sam Ryu, Seoul's vice president of IT Business. "Protecting that technology against infringement is a cornerstone of our business and sends an important message to the market and other innovators who would follow in Seoul's footsteps – that hard work and innovation will be respected."

www.SeoulSemicon.com

AquiSense collaborates with US EPA and Washington University to develop UV LED disinfection

Nikkiso Group company AquiSense Technologies LLC of Erlanger, KY, USA (which designs and manufactures water, air and surface disinfection systems based on UV-C LEDs) has announced a Cooperative Research and Development Agreement (CRADA) with the United States Environmental Protection Agency (US EPA) and Washington University.

Through the CRADA partnership, AquiSense is working with US EPA researchers at the National Homeland Security Research Center (NHSRC) and the Department of Energy, Environmental and Chemical Engineering in the School of Engineering and Applied Science at Washington University in St. Louis in order to design, fabricate and test an integrated water treatment sys-

tem incorporating ultraviolet light-emitting diode (UV LED) disinfection and filtration technologies. The integrated device will target higher flow rates and more challenging water qualities than currently available

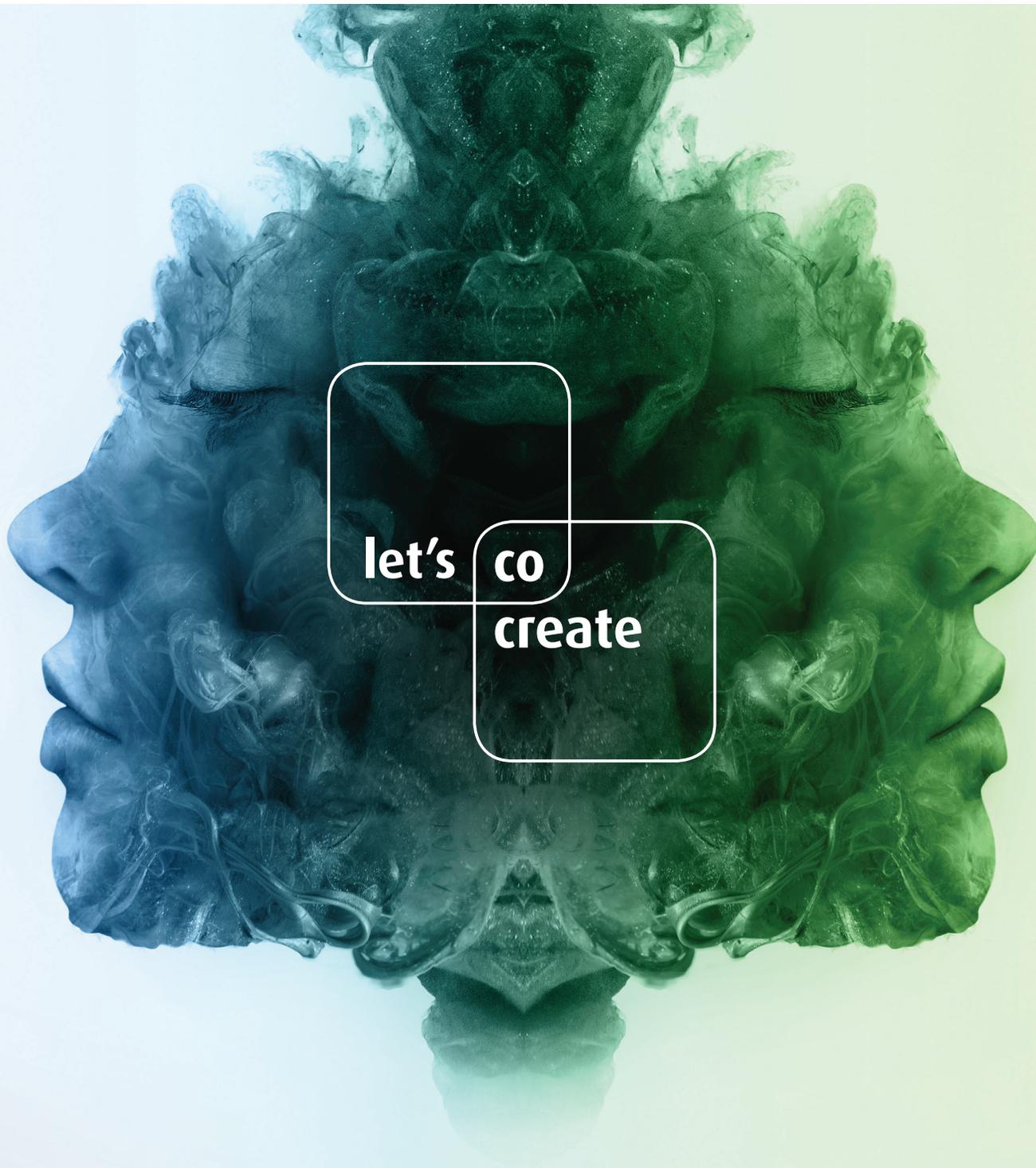
The development agreement showcases patented AquiSense technology and allows the expansion of UV LED disinfection technology to new application areas including small community water and wastewater systems and a variety of industrial solutions

commercial systems. The NHSRC is particularly interested in rugged and quickly deployable emergency water treatment systems capable of providing safe water following natural and man-made incidents.

The development agreement "showcases patented AquiSense technology and allows the expansion of UV LED disinfection technology to new application areas including small community water and wastewater systems and a variety of industrial solutions," says CEO Oliver Lawal. "Our UV-C LED technologies will be optimized for more challenging water treatment scenarios."

www.aquisense.com

www.epa.gov/homeland-security-research



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Lumileds launches LUXEON SunPlus 2835 line for maximizing crop yield

Lumileds LLC of San Jose, CA, USA has introduced the LUXEON SunPlus 2835 line of LEDs, which provide the color options and high photosynthetic photon flux (PPF) needed to maximize plant growth rate and crop yield of a variety of plants and vegetables.

Growers can select specific color points or design a customized spectrum using what is claimed to be the only LEDs specifically engineered for horticulture applications. The LED's compact 2.8mm x 3.5mm footprint allows minimal spacing between plants and lighting so that higher crop yield can be realized in interweaving canopy or vertical farm applications, says the firm. The LEDs are offered off-the-shelf or configured in the Lumileds Matrix Platform for faster time to market of lighting fixtures.

Growers can choose a specific color point using LUXEON SunPlus



2835 Purple or Horticulture White LEDs, or design a spectrum using the LUXEON SunPlus 2835 Deep Red, Far Red, Lime and Royal Blue emitters.

Horticulture White provides a suitable broad spectrum for growing many different crops. In tests, Horticulture White produced red leaf lettuce with significantly greater nutrient levels than RGB LEDs, claims Lumileds.

LUXEON SunPlus Purple LEDs are made with a customized phosphor

solution designed to provide the maximum PPF output in the Deep Red and Royal Blue range of the spectrum. "We are seeing great demand for Purple LEDs in vertical farms," says product line director Jennifer Holland. "When the Purple LEDs are combined with Lime, a white color point is achieved, enabling ease of visual inspection and harvest."

The LUXEON SunPlus 2835 Series LEDs are said to solve an industry challenge by matching polarity across all of the colors in the product range, simplifying the PCB layout and system design. Emitters are binned at 120mA (25°C) but can be driven at up to 480mA for greater lumen output and fewer LEDs per fixture. Lumileds claims to be the only supplier that bins all its horticultural LEDs by PPF.

www.lumileds.com/products/horticulture-leds/luxeon-sunplus-

Samsung expands horticulture LED lineups for greenhouse and vertical farming

South Korea's Samsung Electronics Co Ltd has launched new horticulture LED lineups, including full-spectrum packages and modules as well as color (monochromatic) LEDs. Optimized for lighting in greenhouses and vertical farming (growing crops in vertically stacked layers, in controlled, indoor environments), the new LEDs are said to provide a broader spectrum of light for healthier plant growth, enhanced farming environments and reduced lighting system costs.

Encompassing a continuous range of wavelengths from blue and green to red, full-spectrum light creates a light blend suitable for horticultural uses. Samsung says that, compared with narrow-spectrum lighting, its full-spectrum-based LEDs encourage healthier and more balanced plant growth by stimulating photosynthesis, enhancing plant immunity and

increasing nutritional value. Additionally, the LEDs can help to improve the overall farming environment by enabling growers to observe plant conditions more easily and spot diseases (like damping-off) at an earlier stage under bright white light. As high-efficiency and cost-effective alternatives to higher-priced red LEDs, full-spectrum LEDs can help to lower the costs of a grower's entire lighting system, it is reckoned.

"Samsung's full-spectrum-based horticulture LEDs present a new way of using LED lighting to improve plant cultivation at reduced system costs," claims Un Soo Kim, senior VP of the LED business team. "We plan to further expand our horticulture offerings by integrating the latest in smart LED lighting technology, including Samsung's leading sensor and connectivity solutions."

In addition to its full-spectrum white LEDs, Samsung has added blue, red and far-red LEDs to its horticulture family to offer an extensive variety of wavelength combinations and meet the different design needs of horticulture lighting manufacturers.

Built on Samsung's market-proven LED technologies, the new full-spectrum and color LED lineups feature a high degree of reliability, making them suited to withstanding high temperatures and humidity levels as well as agricultural chemicals used in greenhouses and vertical farming, it is claimed.

Samsung's horticulture LED packages are now in mass production for lighting manufacturers and growers worldwide. The modules will become available in first-quarter 2019.

www.samsung.com



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Lumileds and Melexis demo LUXEON IR LEDs operating up to 40MHz, enabling 940nm & 850nm TOF applications up to 3 meters

High-frequency operation of infrared light sources is rapidly gaining interest for various time-of-flight (TOF) applications in automotive, industrial and consumer segments. Due to the fast switching requirements of these applications, mostly vertical-cavity surface-emitting lasers (VCSELs) are being considered. However, VCSEL technology has drawbacks including mass volume availability, required eye-safety measures and high cost. Now, LED maker Lumileds LLC of San Jose, CA, USA has demonstrated that LUXEON IR Domed and LUXEON IR Compact LEDs can be suitable alternatives to VCSEL technology for TOF applications operating at high frequencies up to 40MHz.

To demonstrate this, engineering teams from Lumileds and Melexis NV of Ypres, Belgium (which provides automotive semiconductor sensors) have developed an evaluation kit that allows the operation up to 40MHz of LUXEON IR LEDs, whose intrinsic properties result in a clean and repeatable response

curve required for TOF operations.

"The illuminator evaluation kit developed by Lumileds reduces the rise and fall times of the light pulses to 6ns, which is a factor of four over other similar LED devices," says Erno Fancsali, director CPAT (Customer Program Application Team) EMEA (Europe, Middle East and Africa) at Lumileds. "This is enabled by optimizing the combination of improved peak current response of the LUXEON IR LEDs, the PCB design and boost electronics. The illuminator card enables an LED-based TOF system with accuracy and range comparable to VCSEL-based solutions, while reducing the overall system cost," he adds.

"This breakthrough in high-frequency operation of LUXEON IR LEDs enables new TOF applications previously limited by cost or eye-safety constraints," says LUXEON IR Family senior product manager Wouter Schrama. "This development will help to bring affordable and eye-safe distance measurements to a much broader range of

products such as driver monitoring systems, logistics navigation, gesture recognition systems and drones." The Lumileds LED illuminator is available in 60°, 90° and 150° fields of view and for 850nm and 940nm, by request. "The joint evaluation kit with Melexis can help our customers reduce their development time significantly and enable them to successfully enter the market," Schrama adds.

"The Lumileds solution pairs well with our new Automotive QVGA TOF chipset and will help accelerate the adoption of TOF systems, at an affordable cost point; the performance of the system in terms of range and accuracy provides a compelling value proposition for the emerging TOF systems," reckons Melexis' product marketing manager Gualtiero Bagnuoli.

Lumileds and Melexis have reported the results in a whitepaper that can be downloaded from the Lumileds website.

www.lumileds.com/uploads/788/WP35-pdf
www.melexis.com

Lumileds launches LUXEON 2835 Line of 12 colored mid-power LEDs

Lumileds has launched the LUXEON 2835 Color Line, a mid-power line of 12 colors that achieves what is claimed to be the best performance in its class.

The flux and efficacy of the phosphor-converted and direct-color LEDs are said to enable flawless color mixing for the rapidly growing markets of color-tunable lamps and architectural and entertainment lighting. Color mixing is achieved using the same technology that characterizes every Lumileds color LED offering. "The new LUXEON 2825 Line contains LEDs with matching focal lengths, which enables minimal halos and

superior color mixing in all color applications," says LUXEON Color Family product manager Anthonie Chong.

The LUXEON 2835 Color Line includes Red, Green, Blue, Royal Blue, Cyan, Red-Orange, Deep Red, Far Red, PC Amber, Lime, Mint and White (3000K/80 CRI, 4000K/80 and 5700K/70), all specified at 120mA and 25°C. The unique LUXEON Lime LED enables the highest efficiency white lighting designs whereas the LUXEON Mint and Red-Orange LEDs can be combined to achieve the warm candle-light (2200K) ambiance desired by restaurants and other

venues, says Lumileds. Examples of the performance include output of 77lm for LUXEON 2835 Lime and 48lm for the PC Amber LED (120mA drive current).

The firm says that system designers are finding the LUXEON 2835 Color LEDs simpler to integrate due to the same polarity for all colors in the product family. Some competing products switch the anode/cathode locations on the LED, complicating printed circuit board (PCB) layout and system design. "Matched polarity for all 12 colors simplifies the design process," says Chong.

www.lumileds.com/products/

Everlight demonstrates smart automotive products at electronica 2018

At electronica 2018 in Munich, Germany (12–16 November), Taiwan-based Everlight Electronics Co Ltd demonstrated not only its latest automotive, infrared and lighting products but also modules such as an ADB matrix headlamp, a mini/smart multi-array rear lamp, and an infrared heartbeat smart-watch.

Everlight's ADB matrix intelligent LED headlamp can automatically turn off the light source in the region to avoid interference from high beam when the CCD sensor detects an oncoming vehicle. 24 LEDs of the EVL-EL ALFS 1x1 (EU) series (2.0mm x 1.6mm) were used, where 245lm can be provided for a single LED at the 700mA operating current. Due to a combination of smart control, fisheye lens, control module, guide prism in special arrangement and CCD, the headlamp can be more accurate on identification and lighting. The products comply with ECE R112 class B Driving Beam and were jointly designed and developed with all OEMs involved.

The new Mini Rear Lamp is manufactured with fine-pitch display components from Everlight that meet 27.63 pixels per inch. It implements an adaptive rear lamp system and flexibly adjusts the displayed figures and texts to provide a clearer quality of image and to conform to all requirements of a rear lamp.

The smart multi-array rear lamp uses Everlight's Smart Multi Series (3.5mm x 3.5mm x 0.8mm) and a built-in drive and control ICs to achieve the information delivery and a diversified figure display most conveniently. The technology can be used to design rear lamps, brake lamps and turning lamps.

The new Mini Rear Lamp provides a priority solution for rear lamps due to the visual effect combined with and performance quality.

www.everlight.com

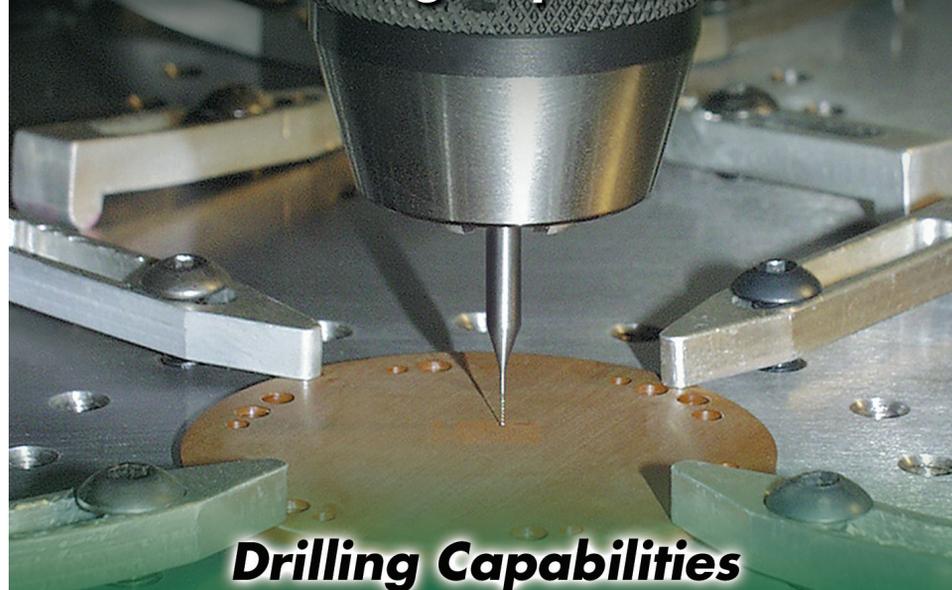
Smart multi-array rear lamp



Smart Multi Series LED

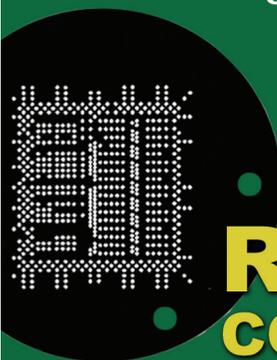


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Osram launches long-life Osconiq S3030 LED for professional mid-power lighting

With the market for LED lighting progressing rapidly and demand growing for professional components with long lifetimes and robustness, Osram Opto Semiconductors GmbH of Regensburg, Germany has launched the Osconiq S3030 LED, designed to meet professional demands in general lighting applications and characterized by long life, high performance and reliability.

As Osram's entry into the professional mid-power market, the Osconiq S3030 is suitable for use in outdoor and industrial lighting, offering durability even in extreme operating conditions. The individual components provide flexibility in forward voltage and luminous flux with an exceptional lifetime of 75,000 hours even at high temperatures. Together with an optimized phosphor, lead frame and chip

design, the Osconiq S3030 raises luminous efficiency to 146lm/W. The 0.2W applications are especially suitable for linear lighting and fluorescent tube replacement.

"We have succeeded in developing an LED that is ideal for professional lighting solutions in outdoor, indoor and industrial applications," says Wong Kum Yih, marketing manager for General Lighting. "With high-grade materials such as the proven Osram-designed sapphire chip and robust silicone, we have taken the stability of LED lighting to the next level," he adds. "In addition to outstanding lifetime values, our customers also benefit from superior quality and improved performance."

The Osconiq S3030 comes in two versions — a color rendering index (CRI) of 70 or 80 — with a power rating of 1.0W at 6V and luminous

flux of 138–148lm. The footprint of both versions is comparatively small at 3.0mm x 3.0mm x 3.0mm. The color temperature ranges over 2700–6500K. A beam angle of 120° and the extremely low thermal resistance of around 8.9K/W make the LED suitable for outdoor lighting.

As well as the technical improvements, the Osconiq S3030 features professional-grade materials such as high-quality long-life packaging subcomponents and proprietary coatings. These materials have been validated by extensive robustness testing under extreme overload conditions. Also, the EMC (epoxy molding compound) lead-frame material provides the basis for much longer life and better reliability than conventional PPA and PCT materials, it is reckoned.

www.osram-os.com

Osram adds more powerful and efficient edge-emitting laser for automotive LiDAR

After developing pulse laser diodes for automotive applications for over 15 years, Osram Opto Semiconductors GmbH of Regensburg, Germany has added the more powerful and more efficient SPL DS90A_3 to its portfolio for light detection and ranging (LiDAR) systems, increasing the range of applications.

LiDAR systems are an integral part of driving assistance systems, such as lane assist and emergency braking systems in autonomous or semi-autonomous vehicles. The propagation time of very short light pulses is used to determine the distance between the vehicle and objects in its vicinity. When a laser pulse hits a person or an object it is reflected and captured by a detector. From the time between the emission of the laser beam and its detection it is possible to calculate the distance to the object. The safety system can then decide



whether, for example, the vehicle should brake or drive around the person or object.

The firm's latest edge-emitting laser scans the vicinity of the car with an infrared laser beam across a particular angle segment. The system uses the scans to create a high-resolution 3D map of the environment. This enables the technology to react to any traffic situation without losing valuable seconds. A car traveling at a speed of 50 miles per hour, for example,

covers about 22m each second, so every extra second that drivers take to react can have consequences for them and other road users.

The new SPL DS90A_3 laser can be operated at high currents up to 40A and achieves a typical output power of 125W. It is suitably qualified for use in automotive applications and offers long life and high efficiency, says the firm. Its compact dimensions allow for flexible system design within the vehicle.

"With this new laser we have succeeded in taking one of the key technologies for autonomous driving another step forward," says Andreas Bauer, marketing manager for Lasers. "Thanks to the higher output, the LiDAR system can reliably detect even small and poorly reflecting objects at big distances and take the necessary action in critical driving situations."

www.osram.com

VCSELs enabling progress in biometric applications such as mobile 3D sensing, says Osram

Opto component makers complementing infrared technology portfolios with vertical-cavity surface-emitting lasers

Since many key technology advances in mobile devices (including smartphones, tablets and wearables) are based on the ubiquitous use of light, including not only visible light (such as display lighting or flash applications) but also invisible infrared light (for example for gesture recognition, iris scanning or facial recognition), vertical-cavity surface-emitting laser (VCSEL) technology can play a role in this development, says optoelectronics component maker Osram Opto Semiconductors GmbH of Regensburg, Germany.

Biometrical user identification methods are currently the most reliable and secure access options. They are an alternative to complex password management tools for mobile device security, access control and, increasingly, authentication for mobile payments and other transactions. The need for these solutions is driven by users increasingly managing all aspects of their digital lives via their smartphone and other mobile devices, which accelerates the development progress, says Osram Opto.

Biometrics make use of human characteristics such as specific structures within the iris, facial features or fingerprints. Sensors identify these characteristics and compare them with previously stored biometrical data. To function reliably in mobile devices, infrared light is required to illuminate the target area. This technology was already being used in access control systems, with most countries using it for immigration purposes. But with the growing miniaturization of infrared LED technology, adoption in mobile and consumer devices has been accelerating. Now VCSEL technology is complementing the portfolio of solutions, enabling use of these applications in a wider market.

VCSEL technology opening up new applications fields

VCSEL technology has previously been used for data communications, but recently a multitude of application opportunities in different markets has been identified. Since light radiates vertically from the surface of the chip (rather than from the edge of the chip in edge-emitting laser diodes), surface emitters feature lower production costs than edge emitters and superior beam quality but lower output power. As a surface-mountable component, a VCSEL combines the characteristics of a LED with those of a laser. The technology can also be used as a VCSEL array — composed of several hundred or even thousand VCSELs — for example, a chip with 500 apertures of 1mm x 1mm, glued and bonded like a normal LED.

VCSEL technology is a good choice for applications such as smartphones, drones and augmented reality/virtual reality (AR/VR) devices where high-speed modulation is an advantage, says Osram Opto.

3D sensing applications such as facial recognition

(especially for consumer devices) are viewed as key market drivers. Market research firm LEDinside forecasts that the global infrared laser projector market for mobile 3D sensing will grow from \$246m in 2017 to about \$1953bn in 2020.

Existing solutions for mobile 3D sensing include structured light and time of flight (ToF). One of the most recent smartphone models uses structured light, with its dot projector producing several ten thousand dots of infrared (IR) light on the face before the infrared camera receives the reflected light to create a 3D facial landscape.

Additional applications include autofocus and proximity functions in cameras (especially smartphone cameras). 3D sensing is also being integrated with AR and VR for smart glasses or future smartphones and other mobile devices, including drones.

Due to its broad range of advantages such as a very small footprint, relatively low cost, optical efficiency, low power consumption, wavelength stability and high modulating rates, VCSEL technology could be key to the wider adoption of applications such as 3D sensing in the mass market, reckons Osram Opto.

Although the technology offers many advantages compared with existing technologies, it is not the best solution for all segments, the firm acknowledges. It should therefore be viewed as an expansion of infrared and other light-based technologies. To help clients choose the most suitable solution for each application, leading providers of optoelectronics components are complementing their infrared technology portfolios with VCSELs, notes Osram Opto.

www.osram.com/os/applications/biometric-identification/index.jsp

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Philips Photonics ships billionth VCSEL

Production capacity to double in next 18 months

Philips Photonics of Ulm, Germany — a wholly owned business of Royal Philips of Eindhoven, The Netherlands that provides vertical-cavity surface-emitting laser (VCSEL) technology for datacom, consumer and industrial applications — has shipped its billionth VCSEL. This follows two years of significant growth in demand for VCSEL technology, driven by trends such as the introduction of proximity sensing and 3D facial recognition technology in consumer smartphones.

Since its establishment in 2000 as ULM Photonics GmbH and its acquisition by Philips in 2006, the facility in Ulm has grown significantly. The last expansion (to double production capacity) was completed in early 2018. Now, the firm plans to double production capacity again at its Ulm facility within the next 18 months.

Philips Photonics was the leading partner of the €23m, three-year

project VIDaP (VCSEL Pilot Line for Illumination, Datacom and Power Applications), which was jointly sponsored by the German Federal Ministry of Education and Research (BMBF) and the European Union, and executed under the umbrella of the European program ECSEL (Electronic Components and Systems for European Leadership). Completed in September 2017, VIDaP has enabled industry to standardize the design, manufacture and testing of VCSEL technology, matching the same standards as other high-volume semiconductor components. Philips' role in the project has enabled the business to grow beyond traditional VCSEL applications such as optical data transmission and thermal industrial processes, while also supporting new technology applications such as consumer facial recognition and LiDAR (light detection and ranging) for autonomous vehicles. Philips Photonics reckons that it is uniquely

positioned to serve the full spectrum of traditional and emerging VCSEL applications.

"Through continuous investment in our business, from research and development to quality manufacturing processes, we have been able to meet the rapidly growing global demand and cement our position as a European industry leader for VCSEL technology," says Philips Photonics' general manager Joseph Pankert. "We are seeing very strong levels of interest from the consumer electronics sector, and we expect this to continue in the coming years as more manufacturers adopt facial recognition technology in their new smartphone models."

The VCSEL market is forecasted to rise from several hundred million dollars currently to \$3.5bn in 2023, driven largely by sharp growth in consumer electronics technology applications.

www.photonics.philips.com

Lextar's first VCSEL products for 3D depth-sensing

At the biannual electronica 2018 show in Munich (13–16 November), vertically integrated LED firm Lextar Electronics Corp of Hsinchu Science Park, Taiwan launched its first portfolio of vertical-cavity surface-emitting laser (VCSEL) products for 3D depth-sensing applications, including gesture recognition, people detection, facial recognition and driver fatigue detection.

Lextar's VCSEL PV88M component series is mainly applicable to light source emission in the 3D depth-sensing module, providing products with various wavelengths, brightnesses and package sizes, and beam-angle selection (from 45° to 100°). The series can be applied to many kinds of sensing systems based on customer demand.

As for gesture recognition, users

can gesture to control a vehicle control system, such as adjusting audio volume, selection from the menu, and answering/hanging up phone calls.

In terms of facial recognition, the series (which is capable of reading faces and telling humans from photos) can be applied typically to security systems.

For human detection applications, the series can recognize humans and detect human height, and is suitable for senior/children monitoring, senior fall detection, or people counting in a mall.

In addition, in driver fatigue detection applications, products can detect reactions of fatigue, including closed eyes and nodding, to enhance driving safety.

According to Lextar, existing mainstream 3D sensing includes

stereo vision, structured light, and ToF (time of flight). By adopting ToF measurement, VCSELs — with advantages such as fast scanning, long distance, high efficiency and high resistance to ambient light — have gradually become a major factor in the 3D sensing market. Lextar says that, by developing VCSELs, it has entered the supply chain of the world's top mobile phone makers, and has already begun to deliver products.

Also at electronica, Lextar is debuting its I-Mini Square module for automotive tail lamp application. Not long after announcing its mini-LED display technology in August, the firm has applied its latest mini-LED technology to automotive tail lamps, which can hence display dynamic images smoothly.

www.lextar.com

MIRPHAB offering firms design, production and business planning for developing mid-IR devices for chemical sensing and spectroscopic applications

The European Commission project MIRPHAB (Mid InfraRed PHotonics devices fABrication for chemical sensing and spectroscopic applications), which is creating a pilot line to fabricate mid-infrared (MIR) sensors by 2020, is accepting proposals from companies that want to develop and prototype new MIR devices that operate in gas and liquid media. Companies can submit proposals for possible matching funds.

Funded by the Photonics Public Private Partnership, the MIRPHAB project brings together 18 leading European organizations and is coordinated by Grenoble-based CEA-Leti (a micro/nanotechnology research institute in the technology research branch of the French Alternative Energies and Atomic Energy Commission, CEA).

The project produces MIR photonic devices via assembled and/or packaged devices for laser-based, analytical MIR sensors and expert design for sensor components that are fabricated on the pilot line. The platform is organized so that development of novel sensors and sensing systems is based on MIR

integrated optic components and modules already incorporated in MIRPHAB's portfolio.

The aim of the MIRPHAB pilot line is to provide each customer with a unique chemical spectroscopic system by combining sources, photonic circuits and detectors in standard packaging.

"European industry requires more efficient control processes to gain greater productivity and operational efficiency, and this project will deliver the devices required to improve those processes," says project coordinator Sergio Nicoletti at CEA-Leti. "MIRPHAB also will develop new sensor technology that provides novel analytical tools for companies to help improve people's overall quality of life via environmental monitoring (e.g. to measure VOC [volatile organic compounds]), food quality control (e.g. food spoilage or adulteration) and fast clinical diagnoses (e.g. provide cancer cells images)," he adds. "These are some of the areas where MIR sensors will play an increasingly significant role."

In addition to providing device-design services for customers, the

MIRPHAB team will help them develop sound business cases and strong business plans to commercialize their new devices. Potential cost-and-performance breakthroughs will be shown for reliable MIR sensing products based on building blocks provided by MIRPHAB. MIRPHAB will also act as a sustainable source of key components for new and highly competitive MIR sensors, and will support their market introduction, while strengthening the competitiveness of European industry.

Mid-infrared light interacts strongly with molecular vibrations as each molecule gives a unique absorption spectrum that provides a simple solution for sensing. The sensors' reduced size and flexible design make them suitable candidates for integration into existing equipment for in-line/on-line detection.

The MIRPHAB team hosted a booth at the Sensors USA 2018 event in Santa Clara, CA, USA (14-15 November).

www.idtechex.com/sensors-usa
www.mirphab.eu
www.leti.fr

CST Global appoints R&D Programme Manager

III-V optoelectronic foundry Compound Semiconductor Technologies Global Ltd (CST Global) of Hamilton International Technology Park, Blantyre, near Glasgow, Scotland, UK has appointed Dr Tiina Delmonte as Research & Development Programme Manager, involved in next-generation technology projects in the UK and European Technology Consortium Programme; customer-specific, foundry-based development projects; and production improvement projects for CST Global standard products.



"I am implementing a Stage Gate approach to new product development, which is known to achieve efficient, flexible, transparent, through-life product development," says Delmonte. "It links in with our ISO 9001:2015 certification and approval process and helps us to continually develop commercially viable products using industry best-practice, project management processes," she adds.

"I will train and mentor other staff in project management and identify new program, process and project opportunities."

Prior to her appointment, Delmonte worked in program management and in analysis and research engineering roles at Doosan Babcock, Doosan Power Systems and BAE Systems.

Delmonte has a MSci degree in Physics and Electronic Engineering from the University of Glasgow and an EngD in Photonics from Heriot-Watt University.

www.CSTGlobal.uk

Marktech Optoelectronics joins AIM Photonics

Marktech Optoelectronics of Latham, NY, USA, a designer and manufacturer of standard and custom optoelectronics components and assemblies — including UV, visible, near-infrared (NIR) and short-wavelength infrared (SWIR) emitters, detectors, indium phosphide (InP) epiwafers and other materials — has announced its membership of AIM Photonics.

The American Institute for Manufacturing Integrated Photonics is an industry-driven, public-private United States Department of Defense (DoD)-led engineering technology consortium, spearheaded by the State University of New York Polytechnic Institute (SUNY Poly). It focuses the specialty expertise of its member base in order to capture critical global manufacturing leadership mindshare. It further recognizes the importance of

integrated photonics as a technology essential to national security, and one that is well positioned to provide a significant return-on-investment to the US economy. Through its partnerships with small-to-medium-sized industry manufacturers, academia and service providers, AIM Photonics seeks to emulate the same 40-year successes that have already been achieved within the electronics industry, applying key lessons, processes and best practices to the emerging photonic integrated circuit (PIC)

Marktech looks forward to reaffirming this commitment on a larger and more visible scale, while directly lending our vast R&D expertise to the evolving US PIC technology

sector. As part of that commitment, AIM Photonics offers practical access and technology on-ramps to various industry, government and academic communities. In doing so, it is creating a widely accessible and inherently flexible national PIC manufacturing infrastructure, which can effectively meet market challenges with practical, innovative solutions.

“Throughout Marktech’s nearly 35-year history, our unwavering commitment to the advancement of the photonics sector has been well demonstrated,” says CEO Mark Campito. “By joining AIM Photonics, Marktech looks forward to reaffirming this commitment on a larger and more visible scale, while directly lending our vast R&D expertise to the evolving US PIC technology roadmap.”

www.aimphotonics.com

Marktech introduces InGaAs/InP broadband PIN photodiodes for high-speed communications, autonomous vehicles, industrial controls, LiDAR and wearables

Marktech Optoelectronics of Latham, NY, USA, a designer and manufacturer of standard and custom optoelectronics components and assemblies — including UV, visible, near-infrared (NIR) and short-wavelength infrared (SWIR) emitters, detectors, indium phosphide (InP) epiwafers and other materials — has announced the global market introduction of the Model MTPD1346D-xx series of InGaAs/InP broadband PIN photodiodes, designed to effectively convert broadband light into photocurrent in the VIS-SWIR range.

In addition to their low noise, high sensitivity and high-speed response, they feature wide standard spectral ranges of 0.6–1.7 μ m (1.7 μ m material), low dark current and high efficiency (typically 0.6A/W), says the firm. Standard Model MTPD1346D-xx series broadband PIN photodiodes are



Marktech Optoelectronics’ new InGaAs/InP photodiode.

offered in active area sizes of 0.1–3.0mm. Each is packaged within a hermetically sealed, 3-pin TO-46 metal can with flat lens cap, and with the choice of either through-hole or surface mounting.

Small-to-medium-sized quantities of standard broadband PIN photodiodes are typically available with 24-hour shipment from stock via Marktech’s longtime distribution

partner Digi-Key Corp. In addition, the photodiodes may be integrated, together with Marktech’s SWIR emitters, as a single, compact package. Such custom and hybrid designs may be produced in as few as 6–8 weeks from customer prototype approvals.

The MTPD1346D-xx series InGaAs/InP broadband PIN photodiodes are designed to support a diverse array of applications, particularly where high-speed performance, high data rates, low dark current, small capacitance and smaller active area sizes are required. Typical applications include aerospace, automation, autonomous vehicles (AV), high-speed communications, industrial controls, light detection and ranging (LiDAR), medical, material and chemical analysis, security and wearables.

www.marktechopto.com

Device consortium wins Eurostars program funding for €1.2m MISCA project

CSC, ICS and VTEC collaborate on Monolithically Integrated Detector Solutions for Next Generation Communications Applications

A UK-Netherlands consortium has been awarded a two-year, €1.2m project by Eurostars — a joint program between EUREKA and the European Community — to develop next-generation photodetector solutions for ultra-high-speed datacom applications.

The Compound Semiconductor Centre Ltd (CSC) — a joint venture founded in 2015 between Cardiff University and epiwafer foundry and substrate maker IQE plc of Cardiff, Wales, UK — will deliver project MISCA (Monolithically Integrated Detector Solutions for Next Generation Communications Applications) in collaboration with University of Manchester spin-off Integrated Compound Semiconductors (ICS) Ltd (which designs and makes RF, sensing and optical devices)

and VTEC Lasers and Sensors of Eindhoven, The Netherlands, which was founded in 2011 and designs and produces devices for the communications, sensing and Internet of Things (IoT) markets.

“The project aims to drive a radical improvement in component performance via advances in semiconductor materials integration and will result in a new European source of high-performance detector products for fiber-optic data-communications applications,” says project lead and CSC director Dr Wyn Meredith.

“The rapid growth of the high-speed optical transceiver market is an exciting opportunity for ICS as the demands of the 100G/200G/400G optical transmission markets require a deep understanding of RF compo-

nent design to complement high-quality optoelectronic device manufacture,” comments professor Mohamed Missous, founder & CEO of ICS (which supplies fabricated wafers, die and fully packaged components for the communications, defence and automotive industries).

“The Eurostars program is specifically aimed at enabling agile SMEs to collaborate across Europe, and gives VTEC a great opportunity to collaborate with like-minded companies in the UK to extend our value chain,” notes VTEC CEO Dr Jan Mink. “We see great potential in using semiconductor component integration to enable a new class of low-power-consumption, high-performance detector products.”

www.compoundsemiconductorcentre.com

Sofradir elected to Photonics21 board of stakeholders

Sofradir of Palaiseau near Paris, France, which develops and makes infrared (IR) detectors for military, space, scientific and industrial applications, has been elected to the board of stakeholders (BoS) at Photonics21, the European Technology Platform (ETP) representing the European photonics community. The BoS is the main decision-making body of the platform.

Photonics21 aims to establish Europe as a leader in the development and deployment of photonics technologies in applications fields such as ICT, lighting, industrial manufacturing, life science and safety as well as in education and training. The ETP Photonics21 coordinates photonics research and innovation priorities and provides input to the European research framework program Horizon 2020.

As board member, Sofradir will support Photonics21 BoS' role in defining and prioritizing the photonics research and innovation

roadmaps to be proposed to the European Commission for funding. It will raise awareness of infrared and thermal imaging within the European photonics sector as well as their potential for application in a cross section of industries.

Sofradir's representative Patrick Abraham (private and public partnership manager at Sofradir) was one of 39 candidates elected. He has almost 30 years' experience in a diverse range of photonics applications from fiber-optics communication to infrared imaging and in forging strong relationships within the photonics R&D community in Europe. He has experience with the H2020 (Horizon 2020) and ECSEL (Electronic Components and Systems for European Leadership) collaborative projects and Private and Public Partnership (PPP) development. Skills include promoting and managing innovation as well as having a clear understanding of academic and industrial needs.

“Photonics is a key enabling technology across a wide range of industries. It is therefore essential that European players in the private and public sectors actively coordinate efforts on making the European photonics sector strong,” says Sofradir's chief strategy officer David-Billon Lanfrey. “Through this it will be capable of harnessing these innovations to bring viable solutions for addressing societal challenges, such as climate change, disease detection and efficient food production in Europe and beyond.”

Abraham will act as an ambassador for infrared and thermal imaging by raising awareness of this technology within the European photonics community. Stakeholder board members are appointed for four years. Sofradir remains within Work Group 5 for Security, Metrology and Sensors, where it has been a member since 2014.

www.sofradir.com
www.photonics21.org

POET's revenue grows over 20% in Q3/2018

For third-quarter 2018, 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 sensing and datacom markets — has reported revenue of \$907,044, up 20.6% on \$752,198 last quarter and 26.8% on \$715,420 a year ago. Revenue primarily comprises sales of Denselight's photonic sensors for test & measurement applications plus non-recurring engineering (NRE) revenue.

"We are making solid progress in expanding sales of our sensing product lines and improving our development and operational capabilities across the board," says CEO Dr Suresh Venkatesan. During the quarter, POET's issued patents rose to 60 (with 12 applications pending).

Gross margin has risen further, from 51.3% a year ago and 57.5% last quarter to 58.3%.

Net loss before taxes has risen from \$3,688,590 (\$0.01 per share) a year ago and \$4,687,492 (\$0.02 per share) last quarter to \$5,013,759

(\$0.02 per share). However, Q3's net loss included non-cash stock-based compensation of \$1,149,095 and depreciation and amortization of \$640,517 versus \$1,063,773 and \$659,820, respectively, last quarter and \$1,088,170 and \$559,334, respectively, a year ago.

Capital investment in plant, equipment and patents has risen further, from just \$65,754 a year ago and \$1,139,259 last quarter to \$1,554,648. Cash reserves are \$5.9m.

At the end of Q3/2018 the backlog of orders (for delivery in Q4 and subsequent quarters) was \$903,614. This does not include orders announced on 12 November, some of which should be recognized in Q4.

"We remain on track for introducing Optical Interposer-based products in first-half 2019, now to include both receive-only and transmit-receive solutions," says Venkatesan. "We are most excited about the opportunities resulting from our recently announced orders from data and telecoms industry leaders, as they represent significant customer engagements with meaningful near-term and long-term growth

potential. These customers were won over by the benefits of POET's Optical Interposer solutions to reduce cost and power consumption while at the same time improving performance. We will provide increasingly integrated components to these customers, beginning with lasers and detectors on the Optical Interposer platform, and we expect multiple versions of these components to be included in our customers' product offerings," he adds. "Our ability to deliver disruptive cost reductions to our customers for production contracts, enabled by our innovative Optical Interposer technology, was key to winning these orders," continues Venkatesan. "We are working with more highly strategic customers than ever before, positioning us for growth and the realization of our strategic objectives."

POET estimates that revenue will rise to \$8–10m for full-year 2019. Gross margin should rise as the ratio of NRE to product sales grows. NRE typically contributes higher gross margin, as existing engineering and operational resources are not allocated to individual projects.

POET receives first orders for Optical Interposer Solutions

POET has received its first orders for Optical Interposer-based solutions from global communications firms targeting datacoms (a new served market for the firm's products).

They include sales and development contracts worth over \$3m to purchase existing device prototypes, to develop and provide increasingly integrated optical engine components or to systematically address specific customer integration requirements under paid development programs.

These represent a material increase in the overall revenue run-rate and should be fulfilled by mid-2019. POET's revenue for first-half 2018 was \$1,425,427, entirely from sales of light source products for the sensing market.

The Optical Interposer platform enables co-packaging of electronics and optics in a single chip-scale package (CSP). Incorporating the firm's dielectric waveguide technology, it reduces coupling and transmission losses below levels found in conventional and silicon photonics (SiPh)-based devices and allows passive optical alignment as well as automated wafer-scale pick&place assembly and test. The result is reduced manufacturing costs, lower power consumption and often smaller form factors compared with other approaches, allowing customers to produce highly differentiated products across a range of photonics applications.

"We introduced the Optical Interposer in January of this year

and have now received multiple orders from datacom and telecom industry leaders," says CEO Dr Suresh Venkatesan. "The Optical Interposer enables manufacturers of conventional and silicon photonics transceiver modules to reduce costs and, in some cases, to cost-effectively transition from 100G to 400G products using a common platform architecture," he adds. "We expect these current orders to lead to the inclusion of more of our Optical Interposer technology in current and future products, including 400G transceivers for datacom and low-cost devices targeted at the high-growth market for 5G cellular and next-generation access networks."

www.poet-technologies.com

EFFECT Photonics completes Series-B financing round

Funding to accelerate ramp of tunable SFP transceiver production and development of future technology

EFFECT Photonics b.v. — a spin off from the Technical University of Eindhoven (TU/e) in The Netherlands that develops DWDM optical system-on-chip components using indium phosphide (InP)-based multi-channel photonic integrated circuits (PICs) for mobile networks and data-centers — has completed its series-B funding round, led by Innovation Industries.

The funding round will accelerate the ramp of its tunable SFP production line and the development of future technologies. EFFECT addresses the need for low-cost, wavelength-tunable optical transceivers with industrial temperature specification to be deployed within the next-generation 5G mobile infrastructure. The global market demand for optical transceivers is expected to grow from \$6bn in 2017 to \$12bn by 2023 (according to Lightcounting).

Fifth-generation wireless communication (5G mobile) should enable interconnectivity with many differ-

ent devices such as:

- HD-streaming smartphones;
- driverless and intelligence assisted vehicles;
- HD and 'always on' security cameras; and
- augmented reality and virtual reality (A/VR).

This in turn will accelerate the adoption of the Internet of Things (IoT) interconnecting computing devices and machines without the need for human-to-human or human-to-computer interaction. The number of connected devices in 2017 was 20.35 billion (worth over \$1bn annually) and is expected to rise to 51.1 billion connected devices by 2023 (according to market research firm Statista).

"We are experiencing now in photonics what we saw in the electronics integration revolution last century. There the birth of the integrated circuit enabled the mass deployment of powerful solutions," comments EFFECT's CEO James Regan. "We integrate all of the opti-

cal functions into a single chip and combine it with low-cost, non-hermetic packaging and automatic tuning. Thus DWDM, the proven solution for core and metro networks, is now simple, cost-effective and scalable enough for 5G infrastructure rollouts around the world," he adds.

"This funding also allows us to really push forward with our next-generation technology program to bring even more powerful optical systems to the edges of the network," says chief technology officer Boudewijn Docter.

"We are delighted to be a part of EFFECT Photonics, who are at the forefront of developing optical transceivers with its photonic integrated circuits targeted at high-growth markets such as 5G and fuelling the adoption of IoT-enabled devices," comments Nard Sintenie, partner at Innovation Industries.

www.effectphotonics.nl
www.innovationindustries.com/companies

VLC Photonics issues report on silicon photonic foundries

Backed up by its long-term relationship with all the major photonic integrated circuit (PIC) manufacturers, PIC design house VLC Photonics of Valencia, Spain (which has experience with various material platforms including silicon photonics, indium phosphide, silicon nitride, PLC and polymer) has compiled some of its technical knowledge into a report detailing 35 international foundries and six foundry brokers involved in silicon photonics technology. On its 170+ pages (with 650+ public references), the 'Silicon Photonics Foundry Report' provides an analysis of the different foundries' capabilities, facilities, equipment, processes, component libraries, and previous and on-going works.



"The idea came a few years ago when we realized that we were often discussing with our customers the same specific information regarding the capabilities of the different foundry providers," says CEO Iñigo Artundo. "By consolidating this into a report, our goal is to help other companies and

researchers to quickly and precisely identify which foundries are best suited to fulfil their requirements".

The report draws on research combined with a decade of experience to deliver comprehensive, factual and organized information, facilitating decision making and long-term planning. "This report conveys all the necessary information to face the difficult choice for the most adequate manufacturer in the short term but also for the long run," believes Artundo.

The report has been fully released both in electronic pdf and printed version, and is now available for online purchase at the company's website, where a free sample is also available for download.

www.vlcphotonics.com

II-VI to acquire Finisar for \$3.2bn

\$150m of run-rate cost synergies targeted within 36 months of close

Engineered materials and optoelectronic component maker II-VI Inc of Saxonburg, PA, USA has agreed to acquire fiber-optic communications component and subsystem maker Finisar Corp of Sunnyvale, CA, USA in a cash and stock transaction with an equity value of about \$3.2bn.

Under the merger agreement (unanimously approved by the boards of directors of both firms), Finisar's stockholders will receive, on a pro-rated basis, \$15.60 per share in cash and 0.2218x shares of II-VI common stock, valued at \$10.40 per share based on the closing price of II-VI's common stock of \$46.88 on 8 November. The transaction values Finisar at \$26 per share (about \$3.2bn in equity value), representing a premium of 37.7% to its closing price on 8 November. Finisar shareholders will own about 31% of the combined company.

The firms reckon that the merger will unite two industry leaders with complementary capabilities and cultures to form a photonics and compound semiconductor company capable of serving the broad set of fast-growing markets of communications, consumer electronics, military, industrial processing lasers, automotive semiconductor equipment and life sciences. Together, they will employ over 24,000 people in 70 locations worldwide.

"Disruptive megatrends driven by innovative uses of lasers and other engineered materials present huge growth opportunities for both of our companies," reckons II-VI Inc's president & CEO Dr Vincent D. Matterna Jr. "In communications, materials processing, consumer electronics and automotive, we expect that the combination with Finisar will allow us to leverage our combined technology and intellectual property in indium phosphide (InP), gallium arsenide (GaAs), silicon carbide (SiC), gallium nitride (GaN), SiP and diamond to achieve

faster time to market, cost and scale. Together, we believe that we will be better strategically positioned to play a strong leadership role in the emerging markets of 5G, 3D sensing, cloud computing, electric and autonomous vehicles, and advanced microelectronics manufacturing."

"Our companies both have a long history of focusing on innovation, breakthrough solutions and competitive follow-through by manufacturing high-quality products," Matterna continues.

"The combination of our state-of-the-art technology platforms, deep customer relationships, great assets and amazing talent will enhance our ability to hit market windows that won't stay open for long," believes Finisar's CEO Michael Hurlston.

"This combination will accelerate our collective growth and will take advantage of the technology, products and manufacturing expertise that Finisar has uniquely developed over the course of its 30 year history," he reckons. "The growth potential for the combined company is substantial."

Strategic rationale

As a combined company, II-VI and Finisar aim to continue to leverage their commercialization of complex technologies to maximize value through vertical integration and manufacturing scale, complementing each other at all levels of the value chain, including in the following strategic areas:

- **Optical Communications:** The combined firm will provide a full line and scalable supply of high-performance Datacom transceivers, products based on coherent transmission technology and ROADMs (reconfigurable optical add/drop multiplexers). It will market products into next-generation undersea, long-haul and metro networks, hyperscale datacenters and in 5G optical infrastructure.

- **Platform for 3D sensing & LiDAR:** Combined optoelectronics technology

based on GaAs and InP laser design platforms, together with one of the world's largest 6" vertically integrated epitaxial growth and device fabrication manufacturing platforms, should enable faster time to market for a greater number of opportunities in 3D sensing and LiDAR.

- **Access to larger markets:** The broad portfolio of differentiated engineered materials, including GaAs, InP, SiC, GaN and diamond, together with a critical mass of optoelectronic, optical and integrated circuit device design expertise and related intellectual property, should give access to larger markets in RF devices for next-generation wireless and military applications, as well as power electronics for electric cars and green energy.

- **Maximizing value creation through vertical integration:** Deep vertical integration of core technologies ranging from engineered materials to high value-add solutions, enabled by differentiated components, should provide the combined firm with a foundation to capitalize on a broad range of emerging opportunities while making the overall markets more competitive.

Enhanced financial performance

In addition to the strategic benefits, it is reckoned that the merger will:

- **Accelerate revenue growth:** On a pro-forma basis, combined annual revenue is about \$2.5bn. The combined broad base of talent, technology and manufacturing is expected to enhance the ability to address near-to medium-term opportunities and accelerate revenue growth.

- **Provide synergy potential:** The combined firm expects to realize \$150m of run-rate cost synergies within 36 months of closing. Synergies should be achieved from procurement savings, internal supply of materials and components, efficient R&D, consolidation of overlapping costs and sales & marketing efficiencies.

- **Strengthen earnings accretion:** The transaction is expected to drive

accretion in non-GAAP earnings per share for the first full year post-close of about 10%, and more than double that thereafter.

II-VI intends to fund the acquisition with a combination of cash on hand from the combined companies'

balance sheets and \$2bn in funded debt financing. The transaction is expected to close in the mid-2019 (subject to approval by each firm's shareholders, anti-trust regulatory approvals and other customary closing conditions). Mattera will

continue to serve as president & CEO of the combined company, and three Finisar board members will be appointed to the II-VI board (which will expand to 11 directors).

www.finisar.com

www.ii-vi.com

II-VI Inc to expand manufacturing footprint in China as it inaugurates Asia Regional Headquarters

On 5 November, II-VI Inc held an inauguration ceremony (attended by corporate and regional executive leaders as well as a delegation of local municipal government officials) for its new II-VI Asia Regional Headquarters as the firm prepares to expand its manufacturing footprint in Fuzhou, China in order to meet increasing global demand.

II-VI says that, as carriers worldwide ramp up their investments in 5G wireless infrastructure and drive

increased demand for innovative products that enable optical access architectures for next-generation wireless networks, it will add over 300,000ft² of space in two new buildings in Fuzhou to expand production of its 5G optical product portfolio.

"We are currently experiencing rapidly growing demand for II-VI's differentiated and best-in-class optical technology that is enabling 5G optical access architectures

across multiple deployments beginning in Korea, Japan and North America," says Sunny Sun, president of II-VI Inc's Photonics Segment. "II-VI is committed to a multi-year investment of up to \$50m to expand our manufacturing operations," he adds. "In Fuzhou, China we will establish our II-VI Asia Regional Headquarters in anticipation of the long-term growth driven by global deployments of next-generation wireless connectivity."

Finisar's quarterly revenue recovers further Targeted model for operating margin achieved earlier than expected

For its fiscal second-quarter 2019 (ended 28 October 2018), fiber-optic communications component and subsystem maker Finisar Corp of Sunnyvale, CA, USA has reported revenue of \$325.4m, down 2% on \$332.2m a year ago but up 2.5% on \$317.3m last quarter due to increased sales of wavelength-selective switches (WSS) and vertical-cavity surface-emitting laser (VCSEL) arrays for 3D applications.

On a non-GAAP basis, despite being down from 30.3% a year ago, gross margin was also up from 27.5% last quarter to 28.3% (above the expected 28%), due primarily to favorable product mix and continued focus on reducing manufacturing overhead.

Operating expenses (OpEx) have been cut from \$74.6m (22.5% of revenue) a year ago and \$68.3m (21.5% of revenue) last quarter to \$63.6m (19.5% of revenue, already within the targeted

operating model range of 18–20%). This was despite facility start-up costs rising from \$7.6m last quarter to \$11.4m, since R&D expenses have been cut from \$63.1m to \$52.7m. "We were able to accelerate the process of improving efficiencies and reducing relative operating expense levels faster than expected," notes CEO Michael Hurlston.

Due to the combination of higher revenue, better gross margin and lower OpEx, operating income rose from \$18.8m (operating margin of 5.9% of revenue) last quarter to \$28.6m (8.8% margin, exceeding the expected 7–8%) — and above the \$25.9m (7.8% margin) a year ago.

Likewise, net income has risen from \$21.3m (\$0.18 per diluted share) last quarter to \$30.6m (\$0.26 per diluted share, exceeding the expected \$0.19–0.25), and above the \$26.1m (\$0.23 per diluted share) a year ago.

During the quarter, cash, cash equivalents and short-term investments rose by \$11m, from \$1.159bn to \$1.17. This was despite higher-than-typical capital expenditure from continued progress on the new 700,000ft² fabrication plant in Sherman, Texas (purchased in late 2017) for VCSEL arrays for 3D sensing applications (to expand Finisar's manufacturing capacity for VCSELs using 6-inch wafers, compared with 4-inch wafers at the firm's existing VCSEL fab in Allen, Texas), as well as construction and fit out of the third building at the firm's manufacturing site in Wuxi, China.

Due to its proposed acquisition by the engineered materials and optoelectronic component maker II-VI Inc of Saxonburg, PA, USA (announced on 9 November), Finisar has not provided forward guidance for fiscal third-quarter 2019.

www.finisar.com

NeoPhotonics' Q3 revenue up 15% year-on-year to \$81.7m Free cash flow positive as losses slashed

For third-quarter 2018, 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 \$81.7m, up 1% on \$81.1m last quarter and 15% on \$71.1m a year ago, driven by strong demand in both the Americas and China.

High-Speed Products (for data rates of 100G-and-above) comprised 84% of total revenue (down slightly on the record 86% of last quarter). "We saw some mix changes, including an increase in certain passive products that are often used in 100G-and-above networks, but are not classified as High Speed," notes chairman & CEO Tim Jenks.

Shipments to China comprised 56% of revenue (in-line with 57% last quarter), while the Americas grew to 28% of total revenue (up from 22%) and the rest of the world (RoW) shrank to 16% (down from 21%), as certain customers shifted contract manufacturing locations. In particular, shipments to western customers were up slightly, driven by demand for the firm's leading high-speed products used in data-center interconnect (DCI) as well as metro deployments.

"Demand in China remained strong due to continuing domestic deployments as well as exports outside of China, despite trade tensions and uncertainties about new tender timing," says Jenks.

Largest customer Huawei Technologies (including its affiliate HiSilicon Technologies) contributed 47% of total revenue (up from 43% last quarter). Including the other 10%-or-more customers (at 28%), the next four customers comprised 42% (down from 47%, due mostly to inter-period fluctuations among China customers).

On a non-GAAP basis, gross margin has recovered further, from 20.1% last quarter to 24%, due to the

continued strength in demand combined with increasing volume growth across various product lines. Specifically, product margin was 32%, up three percentage points quarter-over-quarter due to improved costs and a mix shift toward higher-margin products. This was offset by 8% in cost-of-sales charges, consisting mainly of about six points of inventory revaluation, excess inventory write-downs and other manufacturing charges plus two points of under-absorption (excess capacity) charges, largely in the firm's externally modulated laser (EML) fab in Japan (for which yield issues have been overcome, but demand is still lighter than desired).

Operating expenses (OpEx) were \$22.1m (27% of revenue), up slightly on \$21.8m last quarter but cut from \$24.7m (34.7% of revenue) a year ago, and lower than expected as the firm met customer non-recurring engineering (NRE) milestones.

Net loss has been cut further, from \$10.9m (\$0.25 per diluted share) a year ago and \$6.3m (\$0.14 per diluted share) last quarter to just \$2.1m (\$0.05 per diluted share).

Cash generated from operations was positive, at \$13.5m, an improvement from negative \$1.1m in cash used in operations last quarter and -\$25m a year ago. Capital expenditure (CapEx) was \$4m. Free cash flow was hence about \$10m (compared with -\$3m in free cash outflow last quarter).

During the quarter, cash and cash equivalents, short-term investments and restricted cash fell by \$2.9m to \$64.7m after repayment of \$18.6m of debt.

Net inventory was \$57m, down \$4m from last quarter due to strong demand and the loss of two days of production in China because of Typhoon Mangkhut. This resulted in 82 days of inventory on-hand, slightly below the targeted 90 days.

"We saw stable demand in China across the vast majority of our high-speed product lines which,

when coupled with the resumption of orders from ZTE supply chain partners, signals a solid demand environment going forward," says Jenks. "We continue to monitor the US and China trade situation closely. We do see some customer actions that suggest potential securing of supply, both from NeoPhotonics and other key players in the industry. We are closely tracking customer shipments as well as their purchases to help mitigate strategic inventory buying. We continue to view the larger risk to be the broader macro-economic picture."

For fourth-quarter 2018, due to continued solid demand in the Americas, additional domestic build outs in China, plus the resumption of shipments to ZTE and its supply chain partners (helping to mitigate continuing under-utilization in the EML fab), NeoPhotonics expects revenue to rise to \$87-92m.

Gross margin should be 24-28%, despite product margins falling a couple of points due to the initial impact of price reductions. With OpEx of \$23m, earnings per share should range between a net loss \$0.08 to a net profit of \$0.02.

"Over the last year, our focus has been on returning to profitability and we believe our results and outlook demonstrate that we are having success," comments Jenks. However, cash flow could be slightly negative: "We're a little light on inventory at the moment," notes chief financial officer Beth Eby. "We're trying to get some of our finished goods inventory built back up," she adds.

"Chinese New Year and annual pricing negotiations in Q4 will mean that revenue and margins will be lower in Q1," says Eby. "As in 2018, margins will recover through the year [as the firm both ramps through the year and gets cost reductions through], but current tariff rules will result in added charges on components that we make in the US and supply to our factories in China. This will result in cost of goods sold

(COGS) increasing approximately 1 percentage point for as long as the tariffs remain in place,” Eby adds. “We also expect R&D to be up slightly through the year, as we increase investments on next-generation products.”

“We have also remained focused on execution to extend our leadership position in the high-speed digital optoelectronics market with 400–600G-and-above solutions for data-center interconnects as well as telecom, and on silicon photonics innovations,” says Jenks.

“Our currently available suite of 64Gbaud high-speed optical components for coherent systems, including receivers, modulators and ultra-narrow-linewidth tunable lasers, are being used by multiple major customers to develop systems with 400Gb/s- and 600Gb/s-per-wavelength transport capacity,” says Jenks. “Such system developments by leading OEMs, several of whom use our products, were the focus of much publicity at the European Conference on Optical Communications trade show (ECOC) last month in Rome, Italy,” he adds.

“At ECOC, we also highlighted our next generation of coherent products, which reduce the size of coherent optics approximately in half, while featuring the highest performance levels that are required for 400Gb/s- and 600Gb/s-per-wavelength transmis-

sion. Our coherent optical sub-assembly (COSA) integrates our 64Gbaud coherent driver-modulator with our 64Gbaud coherent receiver in a very compact form factor,” continues Jenks. “Similarly, our Nano ultra-narrow-linewidth external-cavity tunable laser again cuts the size approximately in half, while featuring industry-leading linewidth and low phase noise and with low electrical power consumption,” he adds. “We demonstrated these next-generation high-speed optics products in operation at the OFC conference last March, both individually and incorporated into a compact 400G pluggable module.”

“On the line side, our currently shipping CFP-DCO coherent module completed another major customer qualification. And we see strength in our Multicast Switch product line trends, with demand in both telecom and data-center applications, as this product line offers a scalable and cost-effective solution for managing fiber densification in data centers.”

For shorter-reach data-center and client-side applications, NeoPhotonics sees increasing demand for its EML lasers and its laser sources for silicon photonics-based transceiver modules. In addition to its 28Gbaud EML lasers, NeoPhotonics has introduced a full suite of 53Gbaud components for single-wavelength 100G PAM4-based

transceiver modules, including an uncooled, non-hermetic EML laser, along with 53Gbaud drivers, detectors and trans-impedance amplifiers (TIAs). For silicon photonics-based modules, NeoPhotonics offers non-hermetic continuous-wave laser light sources as well as drivers for silicon modulators, and it is now receiving orders for 100G-per-wavelength applications.

“With returning strength in demand for our core products and our successes thus far with multiple customers for our highest-speed product introductions, we are enthusiastic about the opportunities we see in 2019 and beyond,” Jenks says. “Industry trends continue to move in our favor, notably through the push to even higher speeds such as 400G, 600G and beyond as well as the adoption of coherent architectures in metro and metro-edge markets, which we believe places NeoPhotonics in an advantageous position. Similarly, industry momentum toward fully contentionless networks continues to build both in telecom and certain data-center applications, which we expect to drive growth of multi-cast switches over multiple years. And we are actively engaged to extend the application of our coherent product suite to adjacent markets such as cable TV and LiDAR for autonomous vehicles.”

www.neophotonics.com

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Lumentum's quarterly revenue rises 45.6% year-on-year to \$354.1m, driven by telecom and fiber-laser demand

For its fiscal first-quarter 2019 (ended 29 September 2018), optical and photonic optical component and subsystem maker Lumentum Holdings Inc of Milpitas, CA, USA has reported revenue of \$354.1m, up 17.6% on \$301.1m last quarter and 45.6% on \$243.2m a year ago, driven by strong telecom and fiber-laser demand, along with 3D sensing expansion across multiple customers and their products. "We saw new record revenues in ROADMs [reconfigurable optical add-drop multiplexers] and fiber lasers," notes president & CEO Alan Lowe.

Optical Communications segment revenue was \$310.1m (87.6% of total revenue), up 26.6% on \$244.9m (81.3% of total revenue) last quarter and up 49.2% on \$207.9m a year ago. Of this:

- Telecom revenue was \$142.9m, up 7% on \$133.1m last quarter (and up 29% on \$110.4m a year ago), due largely to transport products, with 10% or higher sequential growth in each of the ROADM, pump laser and optical amplifier product lines (with ROADMs exceeding \$70m).

- Datacom revenue was \$34.2m, down 24% from \$45.2m a year ago and down slightly on \$34.5m last quarter. "We continue to be selective in our sales of this margin-challenged product area while we develop our next-generation 100G and 400G products," says Lowe.

- Industrial & Consumer revenue was \$133m, up 72% on \$77.3m last quarter and up 154% on \$52.3m a year ago, driven by an earlier-than-planned ramp of 3D sensing diode laser products into a broader array of models and device types at customers compared with last year.

Commercial Lasers segment revenue was \$44m (12.4% of total revenue), up 24.6% on \$35.3m a year ago but down a larger-than-expected 21.7% on the record \$56.2m (18.7% of revenue) last quarter. Record revenue for kilowatt-class

fiber lasers was up 24% sequentially (benefitting from capacity expansions and further ramping volumes for the firm's newest fiber-laser product to meet strong customer demand). However, this was outweighed by a sharp drop in sales of other laser products, primarily solid-state lasers for semiconductor manufacturing and consumer electronic applications. These are usually seasonally soft in fiscal Q1 and Q2 (since manufacturers typically install laser-based equipment capacity in the spring and summer in anticipation of the annual fall consumer electronics cycle and holiday season), but this year Lumentum is seeing larger-than-normal seasonal declines, perhaps related to overall market softness (as reported by some of the firm's larger peers).

On a non-GAAP basis, gross margin has risen from 34% a year ago and 37.2% last quarter to 40.3%, driven by an increased mix of higher-margin telecom and 3D sensing products as well as overall higher volumes.

Specifically, Optical Communications gross margin has grown from 34.8% last quarter to 40.3%, driven by the higher mix of Industrial & Consumer revenue (e.g. 3D sensing, which is higher than the segment-average gross margin), improvements in telecom margins (from the greater mix of higher-margin products such as ROADMs and pump lasers) and lower average manufacturing cost (due to the higher volumes).

Commercial Lasers gross margin was 40.2%, down from 47.9% last quarter (due to the significant increase in fiber lasers in the revenue mix plus lower volumes of non-fiber laser sales) but up from just 30% a year ago.

Operating expenses were \$57.9m up from \$54.1m a year ago but cut from \$58.5m last quarter (and cut from 22.2% of revenue a year ago and 19.4% to 16.4%).

Driven primarily by gross margin expansion, combined with leverage

over operating expense, operating income has grown from \$28.6m (operating margin of 11.8% of revenue) a year ago and \$53.6m (17.8% margin) last quarter to \$84.7m (23.9% margin).

Likewise, net income has grown further, from \$27.8m (\$0.43 per diluted share) a year ago and \$61.6m (\$0.95 per diluted share) last quarter to \$85.8m (\$1.31 per diluted share).

Capital expenditure (CapEx) was \$31.1m. During the quarter, cash and short-term investments rose by \$22.8m from \$711.5m to \$734.3m.

Net inventory fell \$17m sequentially as Lumentum consumed significant levels of 3D sensing inventory.

For fiscal second-quarter 2019, Lumentum expects Telecom revenue to be driven by continued growth for transport products. Commercial Lasers should be flattish quarter-on-quarter, but this is expected to be the bottom (as fiber-laser demand is continuing to be quite strong, and a new product pipeline from the firm's ultrafast products will be introduced next year that should drive new design wins for both Lumentum and its customers). In contrast, Datacom revenue will be down 20–30%, as the firm is again forgoing certain unprofitable (lower-margin) customer opportunities (although this should be the low point as the firm introduces its low-cost CWM4 module later in the quarter and gets traction through calendar 2019.).

"In the second quarter, based on investment decisions made quarters ago, we expect additional production capacity to come online, particularly in our ROADM product line," says Lowe. "The strong demand for our telecom products is spread across a broad customer base and is driven by an increase in global demand for next-generation optical networks," he adds. "In addition to an increase in the number of networks being built globally, we believe our growth in ROADMs is also driven by a funda-

mental shift in how optical networks are built. There is no practical way to accomplish that needed network capacity and agility, other than incorporating increasing numbers of even more advanced ROADMs.”

Lumentum has also increased its industrial diode pump capacity in its factory in Thailand. “These industrial diode pump lasers are at the heart of our fiber laser as well

as those of our external pump customers,” notes Lowe.

“Our strategic investments in differentiated products targeting growth markets reliant on photonics have proven successful and position us well for the years to come,” believes Lowe.

Regarding its acquisition (announced on 12 March) of Oclaro Inc of San Jose, CA, USA (which provides

components, modules and subsystems for optical communications), Lumentum has received approval under the USA’s Hart–Scott–Rodino (HSR) Antitrust Act, and Oclaro stockholders approved the transaction at their meeting in July. The merger is subject to certain other closing conditions (including anti-trust regulatory approval in China).

www.lumentum.com

Lumentum reduces December-quarter revenue, operating margin and earnings guidance

Major customer for 3D sensing laser diodes requests reduction in shipments of orders scheduled for delivery this quarter

Based on a recent customer development, Lumentum has updated its business outlook for its fiscal Q2/2019 (to end-December).

Compared with the prior guidance (given on 1 November) guidance has been reduced for revenue from \$405–430m to \$335–355m (compared to fiscal Q1’s \$354.1m), for non-GAAP operating margin from 28–30% to 23–25% (versus Q1’s 23.9%) and for net income per diluted share from \$1.60–1.75

to \$1.15–1.34 (versus Q1’s \$1.31).

“We recently received a request from one of our largest Industrial & Consumer customers for laser diodes for 3D sensing to materially reduce shipments to them during our fiscal second quarter for previously placed orders that were originally scheduled for delivery during the quarter,” says president & CEO Alan Lowe.

Lumentum cited Apple as contributing 30% of its revenue in fiscal

full-year 2018. Since Lumentum supplies 3D sensing laser diodes to Apple for the front-facing camera of its newer iPhone models (enabling FaceID and augmented reality functions), the announcement led to a slide in Apple’s share price following a report that it is pausing a boost in production of the new iPhone XR smartphone (launched in September), increasing speculation that iPhone demand is weakening approaching the holiday season.

Oclaro quarterly revenue rebounds by 9% to \$131.7m, aided by resuming shipments to ZTE

For fiscal first-quarter 2019 (ended 29 September 2018), Oclaro Inc of San Jose, CA, USA (which provides components, modules and subsystems for optical communications) has reported revenue of \$131.7m, down 15.4% on \$155.6m a year ago but rebounding by 9% from \$120.9m last quarter, driven mainly by the recovery of shipments to China’s ZTE Corp (previously a greater-than-10% customer) after the US Department of Commerce’s removal of export sanctions imposed in April.

Despite the quarter-to-quarter revenue growth, non-GAAP gross margin fell further, from 40.6% a year ago and 37.7% last quarter to 34.9%, due mainly to a weaker product mix driven by increased sales of certain

100G Datacom modules that are being wound down. “Even so, we delivered strong operating results,” says CEO Greg Dougherty.

Operating expenses were \$34.2m, up from \$31.5m a year ago but cut from \$35.9m last quarter.

Operating income was \$16.8m (operating margin of 12.8% of revenue), down from \$34.6m a year ago but up from \$15.7m last quarter.

Likewise, net income was \$14.4m (\$0.08 per diluted share), down from \$34.5m (\$0.20 per diluted share) a year ago but level with \$14.6m (\$0.08 per diluted share) last quarter.

During the quarter, cash, cash equivalents and short-term investments rose by \$18.8m from \$323.1m to \$341.9m.

Oclaro has not provided guidance for fiscal second-quarter 2019 due to its pending acquisition (announced on 12 March) by Lumentum (which makes photonics products for optical networking and commercial lasers for industrial and consumer markets) for \$1.8bn.

“While we wait for the Lumentum merger to close, which we believe remains on track to occur in calendar year 2018, we remain a leading innovator of new products,” says Dougherty. “We recently announced several new products for next-generation deployments, including 600G components, DCO modules at 100G and 200G, and 400G PAM4 data-center transceivers,” he adds.

www.oclaro.com

Infinera PDK for Synopsys' OptSim Circuit PIC design tool

Synopsys Inc of Mountain View, CA, USA — which provides electronic design automation (EDA) software, semiconductor IP and services for chip and electronic system design — says that, in conjunction with Rochester-based consortium AIM Photonics (American Institute for Manufacturing Integrated Photonics, an industry-driven public-private partnership advancing the USA's photonics manufacturing capabilities), the process design kit (PDK) of Infinera Corp is now available for Synopsys' OptSim Circuit tool.

Part of a key investment by AIM Photonics, the addition of the Infinera PDK to OptSim Circuit enables users to schematically capture, simulate and verify InP-based PIC designs with Infinera's PDK building blocks, and then send the completed circuit design to Infinera for physical implementation, verification and fabrication using its InP PIC process. This capability gives designers, for the first time, access to Infinera's platform for InP-based PIC manufacturing.

One of the challenges faced by photonic foundries and PIC designers

is the disconnect between the pace of technological advances in the industry and the readiness of the photonic design automation (PDA) infrastructure. AIM Photonics member Synopsys says that it is driving the advancement of PIC technologies with its PIC Design Suite, comprising the OptSim Circuit and OptoDesigner tools, which offers a seamless PIC design flow with photonic-aware physical layout capabilities enabled by support for foundry-specific PDKs. PDKs provide a crucial link between photonic circuit simulation and layout tools by supporting efficient design concept verification, signoff checks and mask generation, the firm adds.

"Infinera's PDK helps OptSim Circuit users design and deliver large-scale InP-based PICs more efficiently," says Tom Walker, group director of R&D for Synopsys' Photonic Solutions. "OptSim Circuit users can quickly build and analyze complex PICs using the Infinera PDK, evaluate PIC performance at the system level to demonstrate that it meets or exceeds client specs, and clearly communicate the results to product

development teams and customers."

"Enabling Infinera's PDK use on the OptSim Circuit simulation provides a valuable tool for foundry users," states Fred Kish, senior VP, Infinera Development and Engineering.

"This milestone enhances Infinera's unique capability to deliver an InP-PIC foundry kit supported by advanced simulation software, to further the proliferation of PIC technologies in many diverse applications," he adds.

Infinera's new PDK "complements AIM Photonics' numerous offerings by providing yet another platform for the efficient creation and fabrication of InP-based PIC designs," comments Dr Michael Liehr, CEO of AIM Photonics and VP for Innovation & Technology at SUNY Polytechnic Institute. "This effort supports advanced manufacturing in the critical, burgeoning PIC sector, and it lends further credence to the value of partnering with AIM Photonics to enable these cutting-edge capabilities."

www.aimphotonics.com

www.infinera.com

<http://optics.synopsys.com/rsoft>

Telia Carrier and Infinera demonstrate first 600G transmission

Infinera Corp of Sunnyvale, CA, USA, a vertically integrated manufacturer of digital optical network systems incorporating its indium phosphide (InP)-based photonic integrated circuits (PICs), and Telia Carrier of Stockholm, Sweden (said to be the world's number-one Internet backbone) have announced the first real-time transmission of 600Gb/s wavelengths in a live production network.

This was achieved using the latest generation of Infinera's Infinite Capacity Engine. The ICE5 600G technology, including 64 QAM (quadrature amplitude modulation) and 69Gbaud operation, also sets the foundation for ICE6, which is on track to deliver 800G.

The trial achieved 600G single-wavelength transmission from Palo

Alto to San Francisco across Telia Carrier's production network, which is built on Infinera's FlexILS platform (claimed to be the industry's most widely deployed flexible grid open line system). Infinera says that the trial illustrates that Telia Carrier's deployed FlexILS network is ready for next-generation transponders operating at 600G and beyond, enabling Telia to continue scaling capacity to meet customer demand for the foreseeable future.

"Working together, our companies have a strong history of optical performance leadership, stretching back to the world's first terabit super-channel trial almost seven years ago," notes Mattias Fridström, chief evangelist at Telia Carrier.

"Infinera's 600G technology can be

readily deployed across our existing FlexILS networks, helping us to increase fiber capacity while satisfying our customers' growing capacity requirements," he adds.

"Infinera continues to deliver optical engine innovation on a rapid cadence," says Infinera's chief technical officer Parthi Kandappan. "Our ICE4 optical engines are delivering industry-leading performance in deployed networks from metro data-center interconnect to subsea, and this 600G trial showcases the next step function in ICE performance, leading toward 800G wavelengths and beyond in the future."

Infinera aims to deliver commercial products capable of 600G per wavelength in early 2019.

www.teliacarrier.com

Fraunhofer ISE-led CPVMatch project sets module efficiency record

Four-junction solar cells combined with achromatic lenses yields 41.4% for a 122cm² module

In the €4.95m European Union (EU)-funded project CPVMatch (which lasted for 42-month, from May 2015 to October 2018), a consortium of nine research institutes and industry partners in Germany, Italy, Spain and France (coordinated by Fraunhofer Institute for Solar Energy Systems ISE in Freiburg) has achieved record solar energy conversion efficiency of 41.4% for a photovoltaic module. This was done by optimizing both the multi-junction solar cells as well as the interplay between the cell and the module optics to better exploit the potential of concentrator photovoltaic (CPV) technology.

High-concentration photovoltaic (HCPV) systems provide the highest solar energy conversion efficiency and thus correspondingly low use of resources, especially in regions with high direct normal irradiance. In HCPV modules, III-V compound semiconductor multi-junction solar cells comprise several thin subcells stacked on top of each other to convert the solar irradiance more efficiently. Optical lenses concentrate the incoming sunlight onto the miniature solar



HCPV module with record 41.4% efficiency.

cells. The modules are mounted on a two-axis tracking system that follows the sun's path during the day.

The CPVMatch project's focus was industrial implementation of the highest-efficiency CPV modules and hence reducing the gap between research results and industry production.

"In CPVMatch, we have addressed all production steps for concentrator modules, starting from the materials, through cell fabrication and production systems, and up to the challenges facing module manufacturing," says Dr Gerald Siefer, project head and group leader of III-V Cell and Module Characterization at Fraunhofer ISE.

The project partners have achieved two main results. By using innovative cell architectures for multi-junction solar cells with new materials, processes and manufacturing equipment, the researchers were able to optimize the production of four-junction solar cells. They were also able to improve the design of high-concentration modules, primarily by modifying the optics and making use of achromatic lenses. The combination of four-junction solar cells with achromatic lenses has led to the new record efficiency of 41.4% for a 122cm² module.

The results "pave the way for further efficiency increases in the concentrator technology," says Fraunhofer ISE's director Dr Andreas Bett. "Photovoltaics is booming worldwide, and we see great potential for this particularly efficient module technology," he adds. "It significantly decreases the use of resources for energy conversion per unit area and thus contributes to more sustainability."

www.cpvmatch.eu
www.ise.fraunhofer.de

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NREL outlines where thin-film solar technologies can be flexible

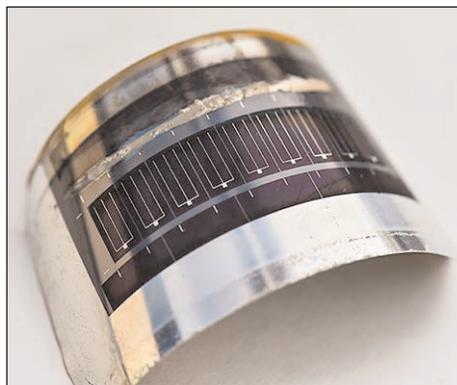
Lower limit for lightweight PV device determined to be 300–500g/m²

Despite rigid silicon solar panels dominating the utility and residential markets, opportunity exists for thin-film photovoltaic and emerging technologies notable for being lightweight and flexible, reckons the US Department of Energy's National Renewable Energy Laboratory (NREL).

Thin films such as cadmium telluride (CdTe) and copper indium gallium selenide (CIGS), along with perovskites and other new technologies, could be ideal for generating the electricity needed for unmanned drones, portable chargers and building facades, according to the paper 'Increasing Markets and Decreasing Package Weight for High Specific Power Photovoltaics' (Nature Energy, vol3 (November 2018) p1002), which discusses the opportunities and challenges inherent in widespread adoption of these ideas.

"We explore the limits behind power-to-weight ratios and how this can generate value for emerging players in photovoltaics to enable them to reach gigawatt scale without having to directly compete with silicon solar panels," says Matthew Reese, lead author of the paper, which was co-authored by Stephen Glynn, Michael Kempe, Deborah McGott, Matthew Dabney, Teresa Barnes, Samuel Booth, David Feldman and Nancy Haegel.

Silicon panels constitute 95% of the global solar market, generating electricity for utilities, residences and businesses, but the researchers identified applications that must consider value propositions beyond the standard value triad of cost, efficiency and reliability used for conventional photovoltaic (PV) panels. Flexibility and portability are important factors, with the performance of the technology quantified in terms of watts per kilogram.



This lightweight CIGS photovoltaic cell, on flexible stainless steel, was made by Matthew Reese and his team at NREL. Photo by Dennis Schroeder/NREL

The researchers identified three high-value markets, each with a potential to cumulatively generate a gigawatt (GW) of electricity — at a price above \$1 a watt — over the next 10 years:

- **Aerospace and unmanned aerial vehicles (UAVs)** — Powering satellites is driven by extremely high launch costs; whereas there is an increasing desire to keep drones aloft for very long periods. For both of these applications, limited space makes efficiency and weight critical and cost secondary. A key player in this market is III–V PV but, while highly efficient, it is also too expensive for many applications.
- **The lower limit for a lightweight PV device is 300–500g/m². Below that would reduce reliability, durability and safety. A lightweight module on the lower side of that range could generate more than a kilowatt of electricity from something that weighs as little as a six pack of soda**

- **Portable charging** — Making it easy for one person to install or move a portable charger is driving the need for PV technology that's efficient and flexible. Finding the correct balance between those requirements and cost could put millions of units into service by the military, disaster relief workers and recreational users.

- **Ground transportation** — The integration of PV in electric vehicles (EVs) will compete with electricity coming from the grid, but the addition could extend the driving range. The PV would have to use smaller panels and be flexible enough to conform to the contours of the roof.

The researchers identified these markets as smaller but significant and ones that will pay a premium for the added value of the technology being lightweight to support initial, low-scale production. As production increases, lower costs will follow.

The NREL team determined that the lower limit for a lightweight PV device is 300–500g/m². Below that would reduce reliability, durability and safety. A lightweight module on the lower side of that range could generate more than a kilowatt of electricity from something that weighs as little as a six pack of soda (specifically, pairing this bound with a 15%-efficiency thin-film or 35%-efficiency III–V module would yield specific powers up to 500W/kg or 1167W/kg, respectively). Conventional modules, even without the additional weight from the mounting equipment, might require 150–200 pounds to generate this much power.

Funding for the work came in part from the US Office of Naval Research (ONR) and in part through NREL's Laboratory Directed Research and Development initiative.

www.nature.com/articles/s41560-018-0258-1.epdf
www.nrel.gov

NASA sends Ascent Solar's lightweight thin-film CIGS to International Space Station

Ascent Solar Technologies Inc (ASTI) of Thornton, CO, USA says that its ultra-lightweight thin-film photovoltaics have been selected by the NASA Marshall Space Flight Center (MSFC) to participate in the Materials International Space Station Experiment (MISSE-X) launched aboard the NG CRS-10 mission.

NASA is evaluating ASTI's flexible, ultra-lightweight, monolithically integrated photovoltaics (PV) based on the copper indium gallium diselenide (CIGS) for various missions, including CubeSats and future missions to the moon and Mars. Actual in-flight experience is invaluable for evaluating new technologies, and NASA's selection of ASTI's PV is a critical path for entering the challenging space market, says the firm. MISSE-X represents the 10th of a series of experiments deployed onto the International Space Station (ISS) for an extended period of time to evaluate new materials, coating and other components in actual flight conditions, and are then retrieved and returned to earth for evaluation. Since 2001,

the MISSE project has tested 4000 material samples and specimens — from lubricants and paints to fabrics, container seals and solar cell technologies — to demonstrate their durability in the space environment. MISSE-X was launched on 17 November from the NASA Wallops Flight Facility in Virginia, for docking at ISS on 19 November.

"Our flight on MISSE-X represents a significant milestone towards the acceptance of our flexible, lightweight, monolithically integrated CIGS in the challenging and very discriminating space market," says Dr Joseph Armstrong, chief technology officer and founding team member of Ascent Solar. "Actual flight experience is crucial for these markets, and MISSE X allows us to demonstrate our monolithically integrated flexible CIGS for the first time," he adds. "The experiment will be attached onto the space station for a year or more and will be returned to earth for further evaluation. NASA MSFC has been working with us for several years on the development of our product for this

challenging market, and the micro-modules developed for MISSE-X are a compact version of our normal space products that were designed to fit within the MISSE-X form factor."

The new 0.5-inch x 2-inch micro-module has six solar cells monolithically integrated in series but has all of the standard features of ASTI's other larger modules. It is hence suitable for evaluating ASTI's product in flight experiments that are typically space-limited. At this size, NASA can include several ASTI samples to be exposed to the same space conditions with different protective space coatings.

"Developing a PV module capable of integrating into a deployable array for CubeSats and future exploration missions puts us in a very unique position in the industry to answer the needs of these future markets," reckons Ascent's president & CEO Victor Lee. "This is a significant milestone for the company in our pursuit of the specialty, high-value PV market."

www.nasa.gov/mission_pages/station/research/experiments/2984.html
www.AscentSolar.com

Midsummer named Sweden's 19th fastest-growing technology firm

Midsummer AB of Järfälla, near Stockholm, Sweden — a provider of turnkey production lines as well as flexible, lightweight copper indium gallium diselenide (CIGS) thin-film solar panels for building-integrated photovoltaics (BIPV) — has been ranked 19th on the list of Sweden's 50 fastest-growing technology companies in 2018, according to the Technology Sweden Fast 50 list of audit and consulting firm Deloitte, which lists the 50 fastest-growing technology companies in Sweden each year. With compound growth of 1072% over the last four years, Midsummer's annual revenue was SEK115m (\$12.8m; €11m) in 2017.

Deloitte's Technology Fast 50 is based on criteria such as rapid growth, ownership of patented technology, major investments in technology research, and certain minimum levels of revenue and the number of years during which the business has been operating. Midsummer has been ranked on this growth list three times before: in 2011, 2012 and 2014. In 2012, Deloitte named Midsummer as the fastest-growing Technology and Cleantech Company in the entire Europe, Middle East & Africa (EMEA) region.

"Being included on these prestigious lists shows that our investment in

research and development is on the right track," says CEO Sven Lindström. "Our goal is for our technology to remain market leading in the segment of lightweight, flexible solar panels, and for the company to grow at least as fast at the entire rapidly expanding segment," he adds. "With lightweight, flexible solar panels, we create a solar energy market that was previously unavailable and where we will be the world's leading supplier."

Midsummer claims that its DUO system is the world's most widely distributed manufacturing tool for flexible CIGS solar cells.

www.midsummer.se

Mini-LED adoption driven by high-end LCD displays and narrow-pixel-pitch LED direct-view digital signage

Adoption is characterized by incremental innovations and limited investment but also supply chain disruption, says **Yole Développement**.

Interest in micro-LEDs has grown exponentially since Apple acquired technology startup Luxvue in 2014. All major display makers have now invested in the technology and other semiconductor or hardware companies such as Intel, Facebook Oculus or Google have joined in, notes the report 'MiniLED for Display Applications: LCD & Digital Signage' by market research and strategy consulting firm Yole Développement.

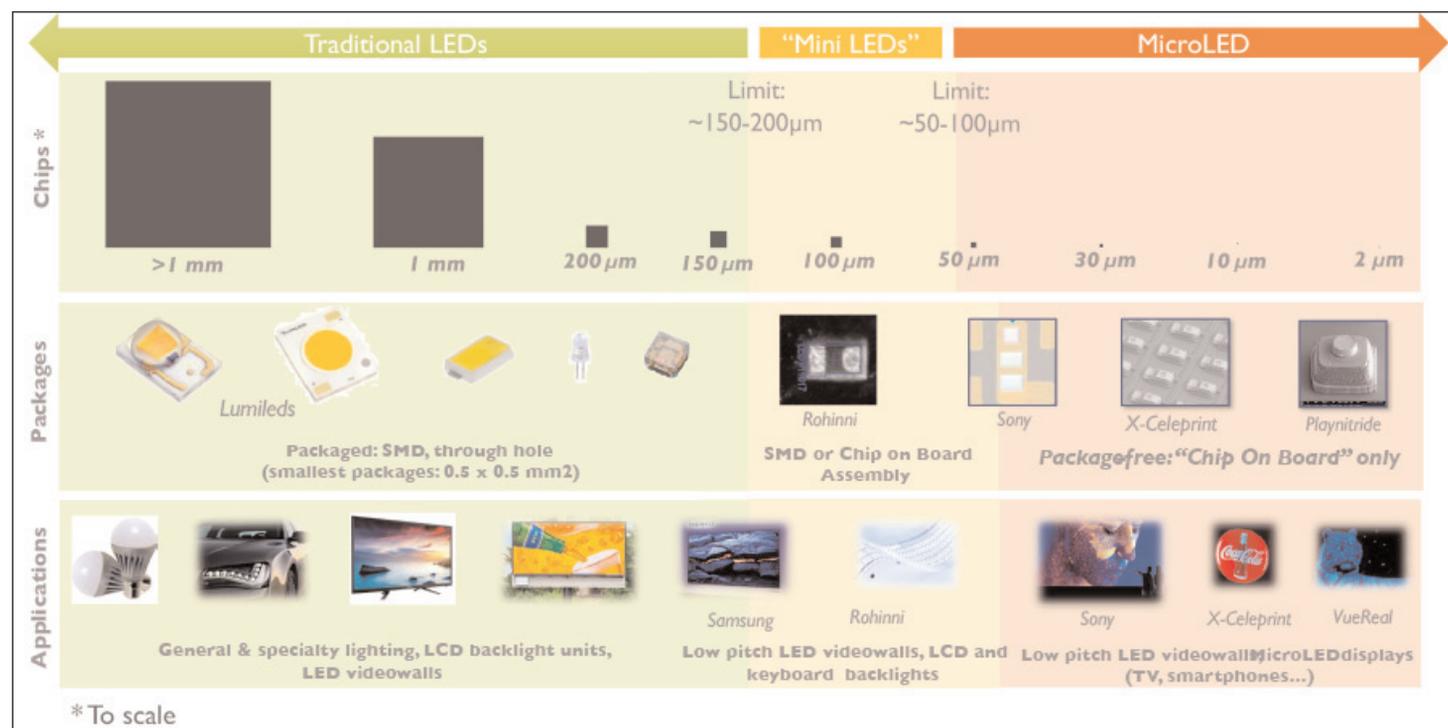
Amid this flurry of activity, a new term emerged in early 2017: mini-LED. The technology is often described as a stepping stone, bridging the technology and application gap between traditional LEDs and micro-LEDs. However, there is no commonly accepted definition of either term. Building on a consensus from the many companies surveyed, micro-LEDs are typical below 50µm along their sides, although the bulk of the

activity is skewed toward the smaller dimensions, typically in the 3–15µm range. By default, mini-LEDs fill the size gap between micro-LEDs and traditional LEDs.

But apart from their size, there is clear differentiation between micro-LEDs and mini-LEDs in terms of technology and manufacturing infrastructure requirements and applications.

While micro-LEDs require major technology breakthroughs in assembly and die structure, as well as a significant overhaul of the manufacturing infrastructure, mini-LED chips are just scaled-down traditional LEDs, and can be manufactured in existing fabs with no or little additional investment.

On the application side, the promise of micro-LEDs lies in the realization of disruptive, high-pixel-density self-emissive displays, while mini-LEDs can be used to



LED landscape as of 2018.

upgrade existing liquid-crystal displays (LCDs) with ultra-thin, multi-zone local dimming backlight units (BLU) that enable form factors and contrast performance close to or better than organic light-emitting diodes (OLEDs).

On the business-to-business side, mini-LEDs are promising for the realization of cost-effective, narrow-pixel-pitch LED direct-view displays used in digital signage applications such as in retail, corporate and control-room applications.

In this dynamic ecosystem, Yole's new report provides analyses of mini-LED technologies in two major display applications: high-performance liquid-crystal display (LCD) and narrow-pixel-pitch light-emitting diode (LED) direct-view-display digital signage.

In terms of applications, the advantages of mini-LEDs are two-fold:

(1) they bring new strength to LCD players in the battle against organic light-emitting diodes (OLEDs), and (2) they enable increased LED adoption for digital signage, says Yole.

Mini-LED adoption first driven by high-end LCD displays

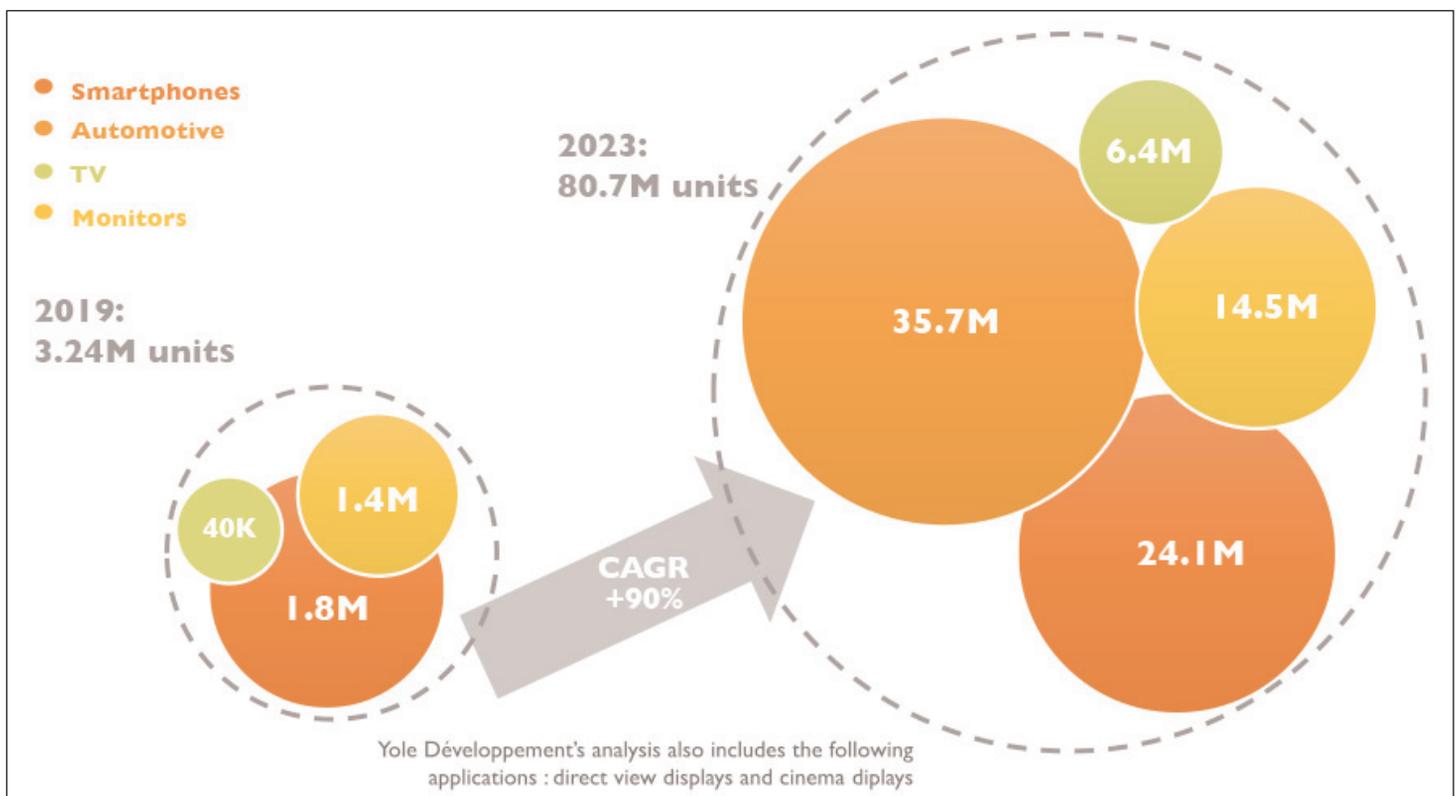
For smartphone applications, mini-LEDs are facing a strong incumbent in OLEDs, as the latter's cost-to-performance ratio has already gained them a strong position in high-end/flagship segments. OLEDs are expected to further increase their share and become dominant as the number of suppliers and global capacity rise dramatically over the next five years and cost continues to drop.

However, mini-LEDs have a card to play in various small-to-mid-size high-added-value display segments, where OLEDs have been less efficient at overcoming their weaknesses such as cost, lack of availability and longevity issues such as burn-in or image retention. For example, in high-end monitors for gaming applications, mini-LEDs could bring excellent contrast, high brightness and thin form factors at lower cost than OLEDs.

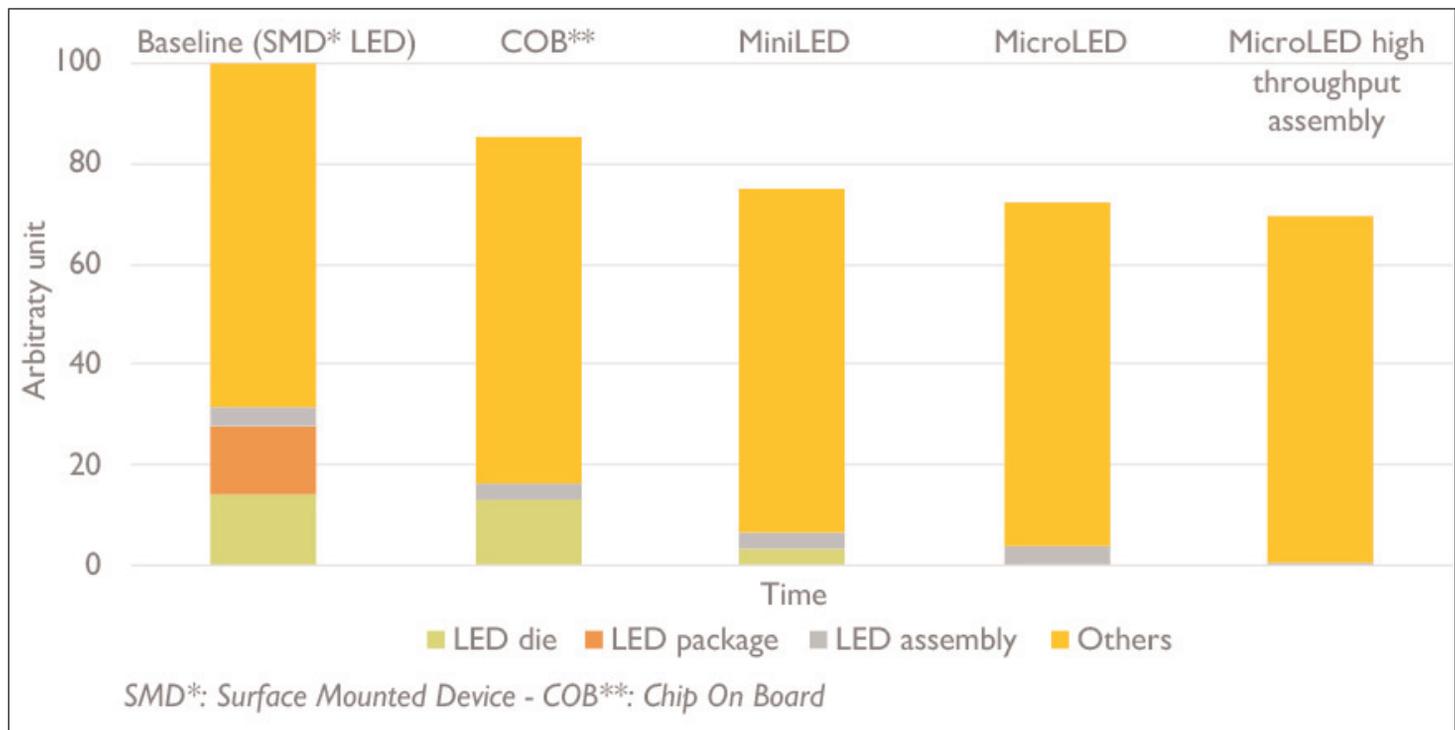
"The automotive segment is especially compelling, first because of its strong growth potential in terms of volume and revenue, and also because mini-LEDs can deliver on every aspect auto-makers are aspiring to: very high contrast and brightness, lifetime, conformability to curved surfaces and ruggedness," says senior market & technology analyst Eric Virey PhD.

Regarding the last point on ruggedness, mini-LED-based LCDs offer significant benefits over OLEDs since they only use proven technologies, LED backlights and liquid-crystal cells - not much different from already established LCDs. Automakers therefore do not have to make a leap of faith and hope that the new technology will meet the demanding lifetime, environmental and operating temperature specifications that they require.

On the TV side, mini-LEDs could help LCDs to bridge the gap and regain market share versus OLEDs in the highly profitable high-end segments. "This opportunity is all the more enticing to panel and display makers that have not invested in OLED technologies and see the potential to extend the lifetime and profitability of



Adoption potential of mini-LEDs — by application.



Cost reduction path for narrow-pixel-pitch mini-LED-based direct-view display from 2019 to 202x.

their LCD fabs and technologies,” notes technology & market analyst Zine Bouhamri PhD.

For direct-view LED displays, mini-LEDs used in conjunction with a chip-on-board (COB) architecture could enable higher penetration of narrow-pixel-pitch LED displays in multiple applications, increasing the serviceable market, says Yole. Die size will evolve continuously toward smaller dimensions, possibly down to 30–50µm in order to reduce cost, forecasts the firm. Adoption in cinema is still highly uncertain, but even modest adoption rates would generate very significant upsides, it adds.

Incremental innovations and limited investments — but supply chain disruptions

In contrast to micro-LEDs (which require sizable investments), mini-LEDs can easily be manufactured by established LED chip makers in existing fabs without major investment, even though they might require new equipment to enable cost-effective assembly. Yet they have the potential to create major disruptions by essentially eliminating LED packaging companies from the LCD as well as the large LED video-wall digital signage supply chains. For many major LED packagers, those applications represent a significant fraction of their revenue. The most exposed are reacting quickly by either moving up the supply chain and offering full mini-LED backlight modules (such as Refond and Lextar) or by developing innovative packages that still allow them to surf the mini-LED wave. For example, companies such as Harvatek or Nationstar’s new ‘4-in-1’ surface-mount device (SMD) packages allow LED direct-view display makers to alleviate a critical obstacle

for mini-LED adoption: the need to re-tool and transition from an SMD to a direct die bonding assembly philosophy.

Mini-LEDs should benefit chip makers by increasing their available market. Some are trying to cash in on the opportunity and move up the supply chain by offering mini-LED packages and/or BLU modules. For example, Epistar is spinning off but keeping control of its mini-LED activities.

A remaining question is how fast equipment makers will develop a new generation of mini-LED-specific assembly tools that will help to speed up adoption by reducing manufacturing costs. Key attributes for such tools are much higher throughput and the ability to handle smaller dies (100µm or smaller). Various routes are being investigated, including the upgrade of traditional die assembly technology or more disruptive processes inspired from the vast body of work and technologies being developed for micro-LEDs. First to market is Kulicke & Soffa, which recently introduced a tool co-developed with startup Rohinni.

The availability of tools capable of efficiently handling smaller dies will in turn enable LCD and LED direct-view display makers to further reduce cost by reducing the die size to the smallest level required for each individual applications, says Yole.

Ultimately, for most of the targeted segments, mini-LEDs offer performance close to the incumbent technologies like OLEDs for high-end consumer displays and SMD LEDs for narrow-pitch digital signage. Cost will therefore be a major driver or showstopper for adoption, expects Yole. ■

www.i-micronews.com/report/product/miniled-for-display-applications-lcd-and-digital-signage.html

Towards ultraviolet optoelectronic systems on silicon substrates

Mike Cooke reports on III-nitride semiconductor on silicon technologies enabling photonic on-chip data transfer and improved material quality for higher-efficiency photon emission and detection.

Crystal nitrides of metals from the group-III column of the Periodic Table of elements — aluminium (AlN), gallium (GaN) and indium (InN) — exhibit conduction-valence bandgaps covering the range of near- and mid-ultraviolet (UV) photon energies from 3.1eV up to 6.2eV with corresponding limit wave-

lengths of 400nm and 200nm.

Electron transitions between the conduction and valence bands can hence emit and detect UV radiation in these ranges and the production of functioning devices on various substrates have been demonstrated for over 20 years, and have resulted in commercial applications.

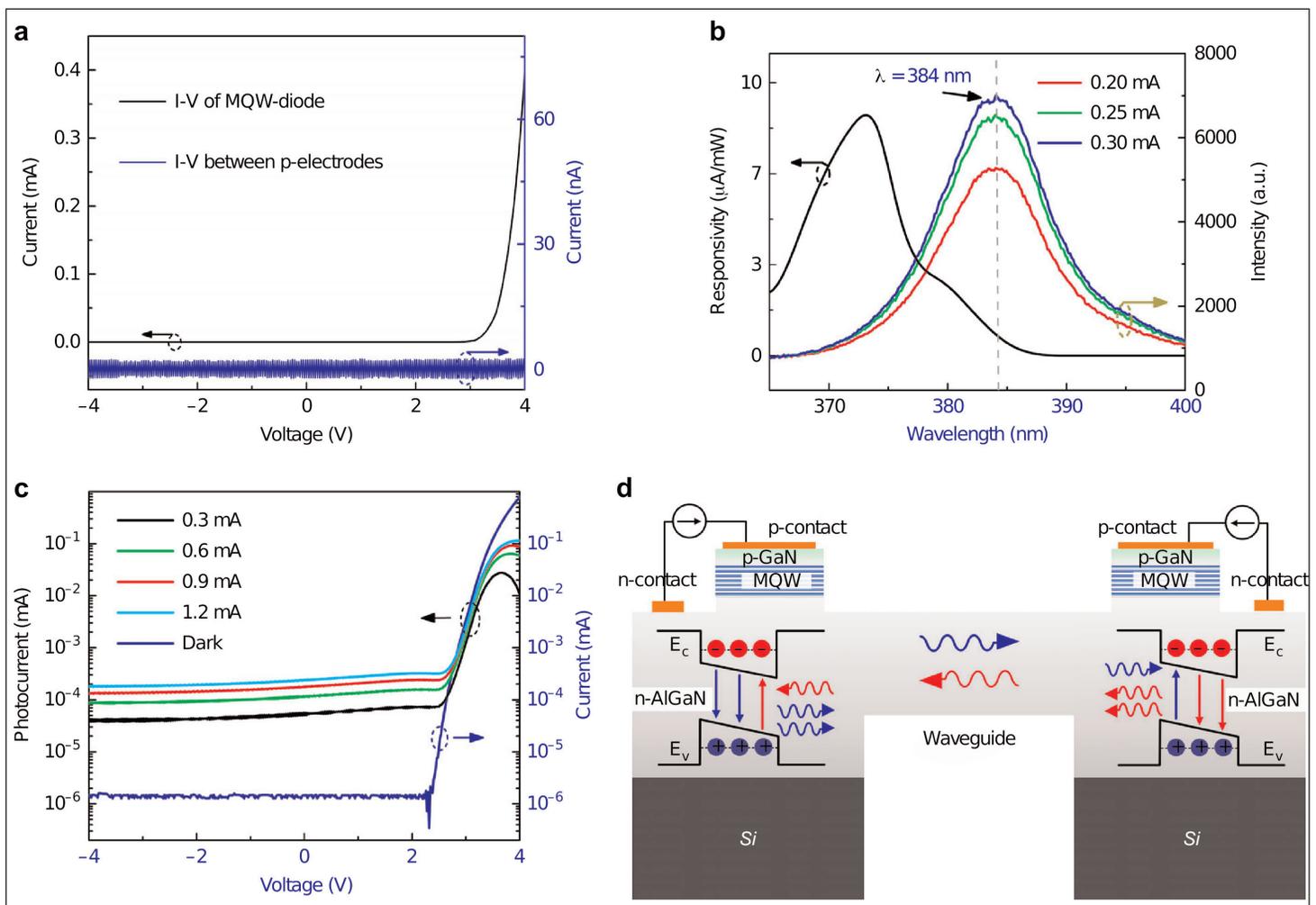


Figure 1. Optical & electrical performance of monolithic multi-component system. (a) Measured current-voltage I-V curves. (b) Electroluminescence spectra and spectral responsivity of ring MQW-diode. (c) Induced photocurrent at circular MQW-diode as function of injection current of ring MQW-diode. (d) Schematic of full-duplex light communication of monolithic multi-component system using identical MQW-diodes.

Growth on silicon, rather than much more expensive sapphire or silicon carbide (SiC), would significantly reduce production costs. Also, silicon is available in larger-diameter formats for mass production. Another advantage of silicon is potential integration with smart driving and signal-processing circuitry based on mainstream CMOS electronics.

The drawback of growth on silicon is lower-quality material that reduces device efficiency. In particular, epitaxial AlGaIn layers are generally strained due to lattice-constant ($\sim 19\%$) and thermal expansion ($\sim 50\%$) mismatching with silicon. Strain is relieved by the generation of defects and dislocation structures in the atomic lattice that form efficiency-sapping leakage paths and non-radiative recombination centers. More efficient UV-emitting devices, enabled by improved material quality, would enhance performance and cost effectiveness of laser printing, high-capacity data storage, white lighting, water purification and sterilization.

Here we report on attempts to use III-N semiconductor on silicon technology for on-chip optical data transfer, more efficient photo-detection, and to improve material quality for UV light-emitting diodes (LEDs).

Monolithic systems

Nanjing University of Posts and Telecommunications in China has been working on monolithic near-UV optoelectronic combinations of InGaN multiple quantum well (MQW) diodes connected by waveguides on silicon [Yongjin Wang et al, *Light: Science & Applications*, vol7, p83, 2018]. The diode devices were able to both generate and detect light signals encoding an audio stream in a real-time full-duplex set up. This builds on work reported earlier this year in collaboration with Nagoya University in Japan [Chuan Qin et al, *Appl. Phys. Express*, vol11, p051201, 2018; reported in Mike Cooke, *Semiconductor Today*, p96, May/June 2018].

The researchers comment: "The self-generated photocurrent opposes a change in the injection current that produced it, indicating that self-absorption may be associated with the efficiency droop phenomenon of light-emitting diodes under high-injection conditions." On the application side, they see "great potential for diverse applications, such as UV sensing, curing, sterilization, and on-chip power monitoring" from monolithic multi-component systems.

A buffer of step-graded aluminium nitride (AlN) and

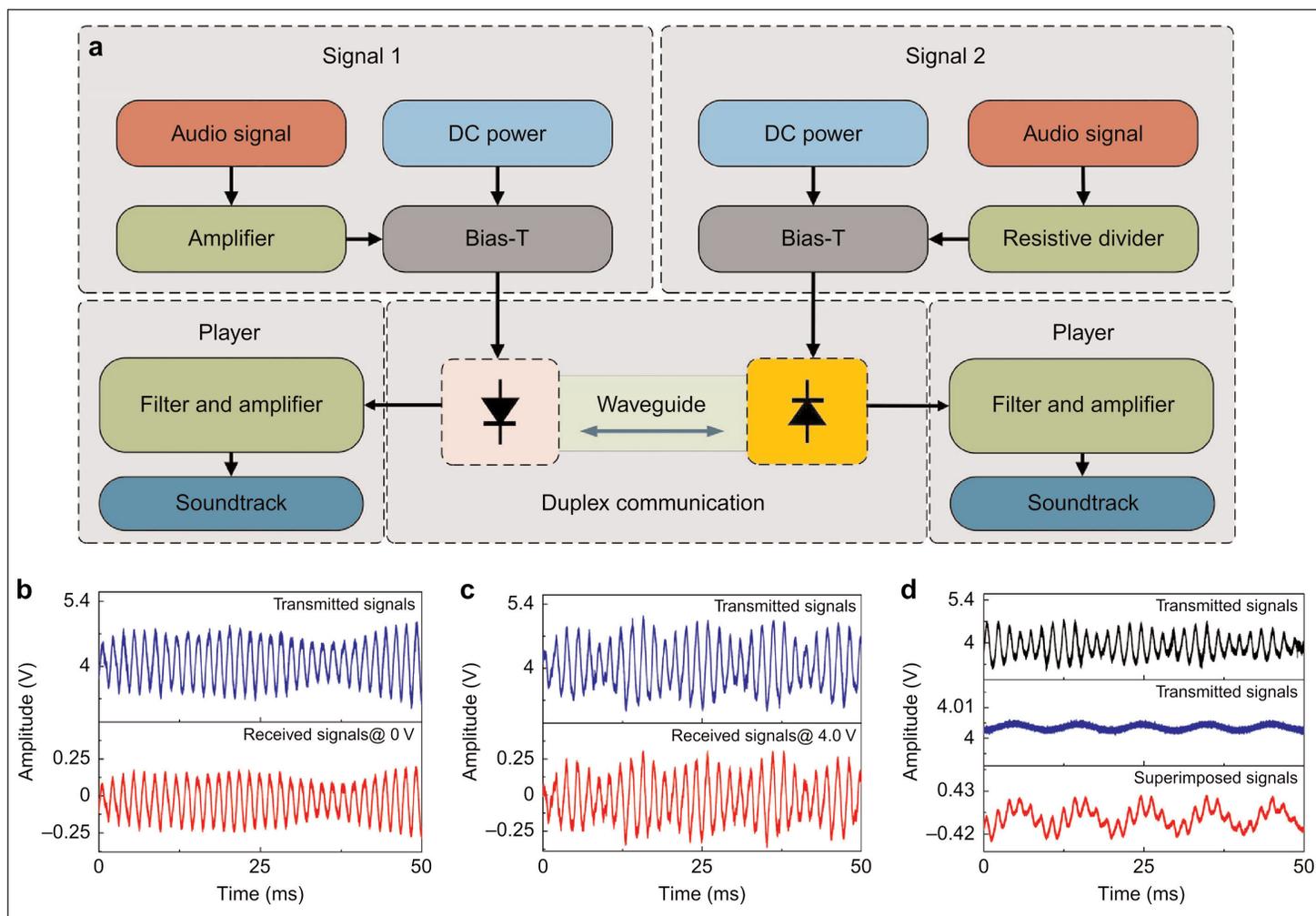


Figure 2. Full-duplex audio communication using monolithic multi-component system. (a) Schematic. (b) Audio signals received at circular MQW-diode with zero bias. (c) Audio signals received at circular MQW-diode with bias voltage of 4.0V. (d) Superimposed signals under simultaneous emission-detection condition.

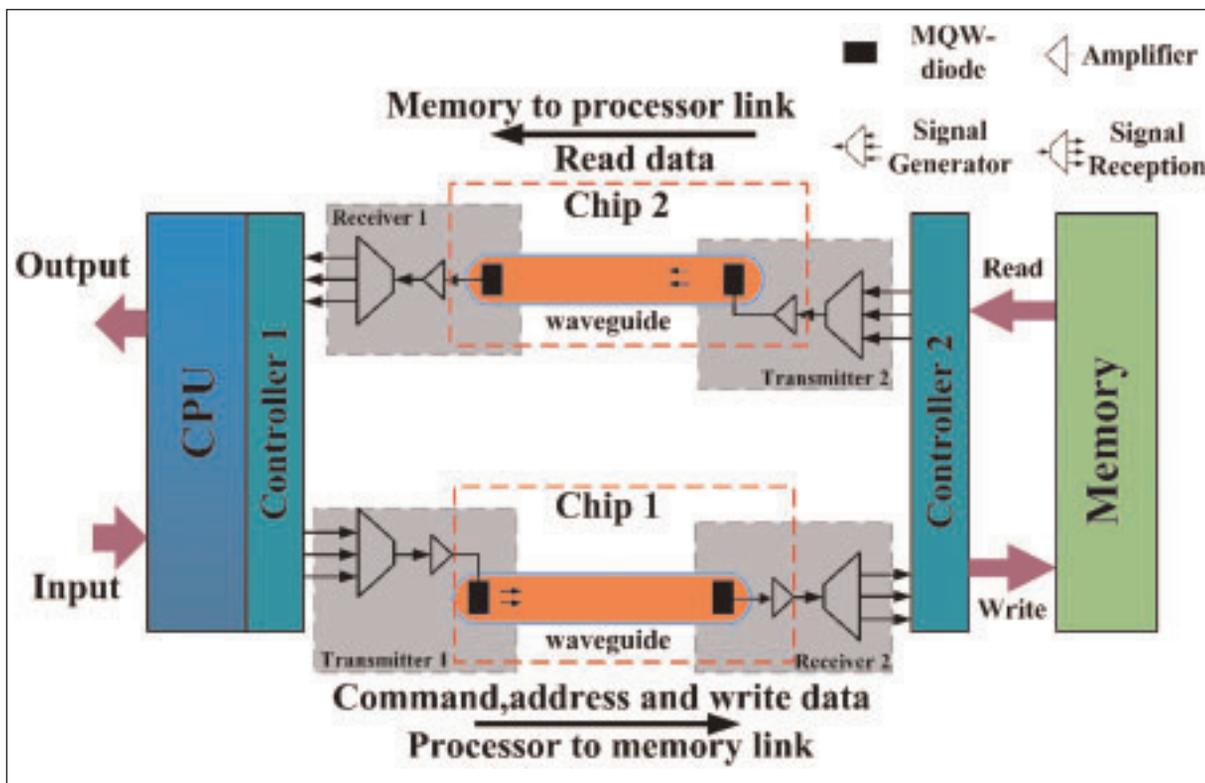


Figure 3. Schematic of optical communication between processor and memory via monolithic multi-component system.

aluminium gallium nitride (AlGaN) layers was grown on (111) Si. Then, a thick n-Al_{0.05}Ga_{0.95}N layer was followed by a superlattice of 30 pairs of In_{0.02}Ga_{0.98}N/Al_{0.10}Ga_{0.90}N. The active light-emitting region consisted of five InGaN QWs separated by Al_{0.10}Ga_{0.90}N barriers. The indium content of the 3nm-thick wells is described as "low". The p-side of the device was completed with 80nm p-Al_{0.05}Ga_{0.95}N and 10nm p-GaN contact.

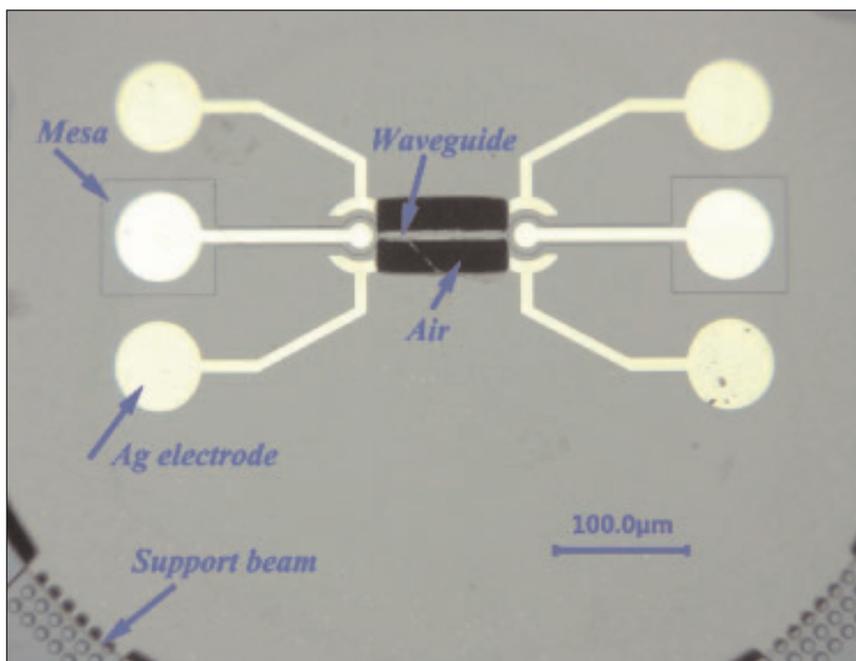


Figure 4. Optical microscopy image of monolithic multi-component system.

The material was fabricated into two diode devices connected by a 8µm-wide 130µm-long suspended waveguide. The p-electrodes were circular with 120µm diameter. One of the electrodes was of ring form to allow the devices to be distinguished for easy identification. The n- and p-electrodes were nickel/silver. The large difference in refractive index between the III-nitride material and air confined the light

to the plane of the waveguide. The waveguide suspension was achieved by locally removing the silicon substrate using back-side etching. Without the silicon removal, the light would be heavily absorbed across the III-N/silicon interface. The refractive index of silicon is in fact higher than that of III-N materials.

The ring diode had a turn-on voltage of 3.0V, emitting radiation with a dominant peak around 384nm (Figure 1).

Removal of the silicon substrate from under the diode shifted the emission wavelength due to changes in the stress built into the material. The researchers found a 40nm overlap of the wavelengths of the emission spectrum and response spectrum of the circular (non-ring) detecting diode.

The researchers used the devices to achieve full-duplex audio communication — i.e. each device was simultaneously a transmitter and receiver (Figure 2). The bias voltage was 4.0V and there was additional driving circuitry to enable encoding and decoding of the signals.

The researchers have also used the technology for microprocessor-memory communication [Yongjin Wang, Appl. Phys. Express, vol11, p122201, 2018]. The optical links enabled microprocessor read/write from/to memory operations (Figure 3). The suspended waveguides were 8µm wide and 100µm long.

The researchers linked two ATmega328 chips with one of the chips sending read/write instructions to the other's 2kbyte SRAM at a rate of 1200 baud, using two separate optical links for the read and write functions.

The team also carried out experiments towards merging the two optical links into one (Figure 4). The 'transmitter' and 'receiver' were variously biased and modulated at megahertz speeds. The team plans to code the phase of the separate signals for two-way signal transfer: "Using the self-interference cancellation method, the received signals are obtained by subtracting the transmitted signals from the superimposed signals." There is also an expected trade-off where the modulation rate increases with decreasing electrode size.

Microwire arrays

South China Normal University and Peking University in China have developed UV metal-semiconductor-metal (MSM) detectors based on GaN microwire arrays on (100) silicon [Dexiao Guo et al, ACS Photonics, published online 1 November 2018].

The researchers claim superior performance compared with most reported GaN nano/microwire- or thin-film-based UV detectors. The team sees application potential for future photoelectronic and on-chip optoelectronic integrated systems. The (100) orientation of silicon is preferred for high-speed and low-power CMOS electronics.

The researchers used a top-down technique for creating horizontal microwires that should enable better repeatability in manufacturing compared with bottom-up growth methods that suffer from random placement, and uneven diameter or curvatures, of vertical wires. Further, the technique avoids the need for complicated lift-off and layer transfer of structures to another substrate or other complex processes that increase production costs.

The 2-inch high-resistivity (100) silicon substrate was prepared with a 300nm plasma-enhanced chemical

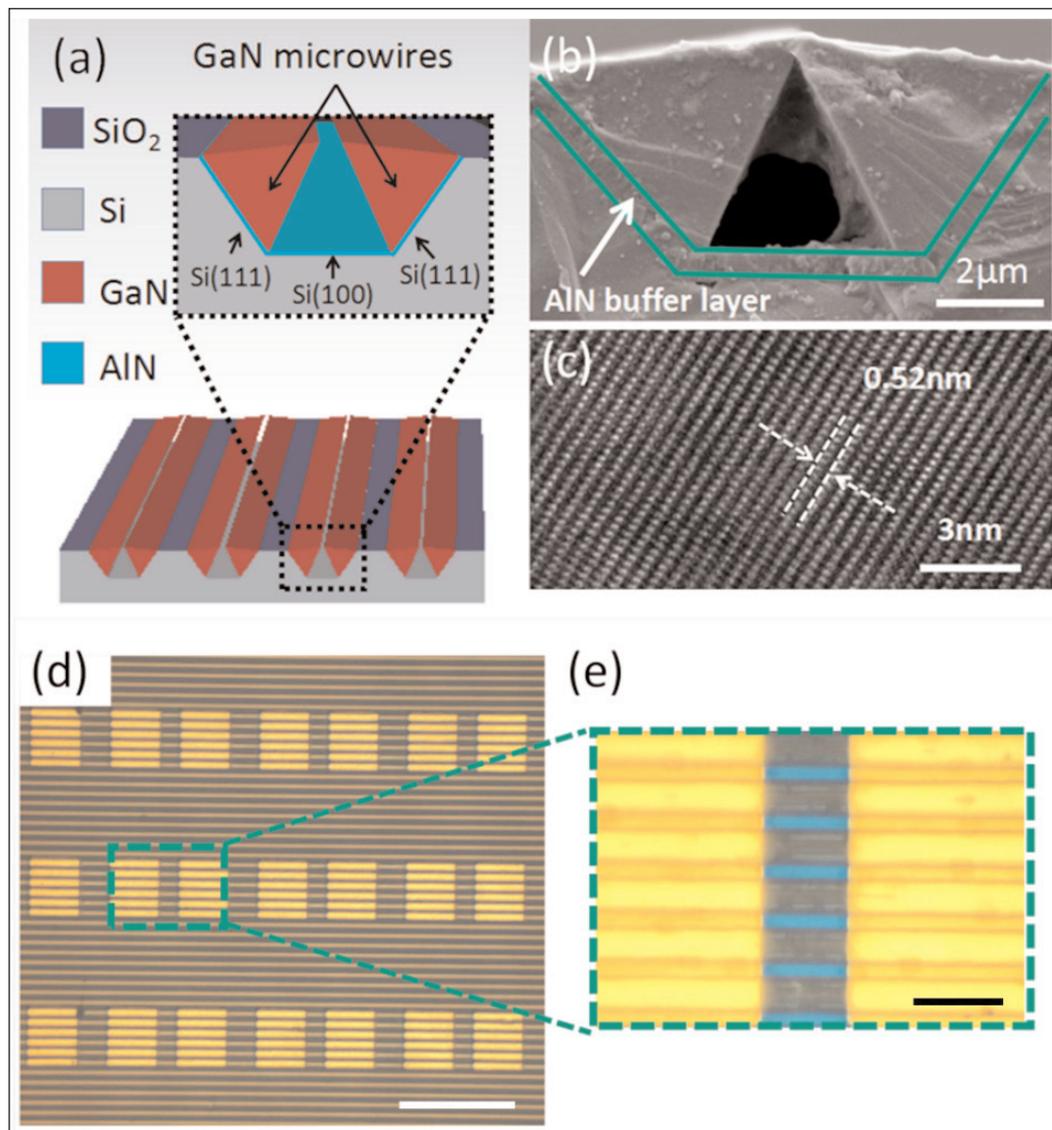


Figure 5. (a) Schematic of GaN-based microwire arrays on patterned silicon substrate. (b) Typical scanning electron microscope image. (c) High-resolution transmission electron microscope image of GaN microwire. (d) Optical microscope image of fabricated orderly arranged detectors; scale bar 100µm. (e) Enlarged image of one detector; scale bar 20µm.

vapor deposition (PECVD) silicon dioxide layer that was patterned into 3µm stripes separated by 7µm silicon gaps. Potassium hydroxide wet etching of the silicon created trapezoidal channels with (111) facets that present a hexagonal atomic arrangement most conducive to III-nitride growth. Native oxide was then removed with hydrofluoric acid solution.

The microwire arrays were produced with low-pressure (100mbar) metal-organic chemical vapor deposition (MOCVD) of 300nm AlN insulating buffer and then unintentionally doped GaN (Figure 5). The wires were contacted with two patterned nickel/gold Schottky electrodes 20µm apart. Photoluminescence experiments (Figure 6) showed a sharp and high-intensity near-band-edge emission peak centered at 364.5nm (~3.4 eV). Yellow luminescence, which indicates impurities and defects, was not observed.

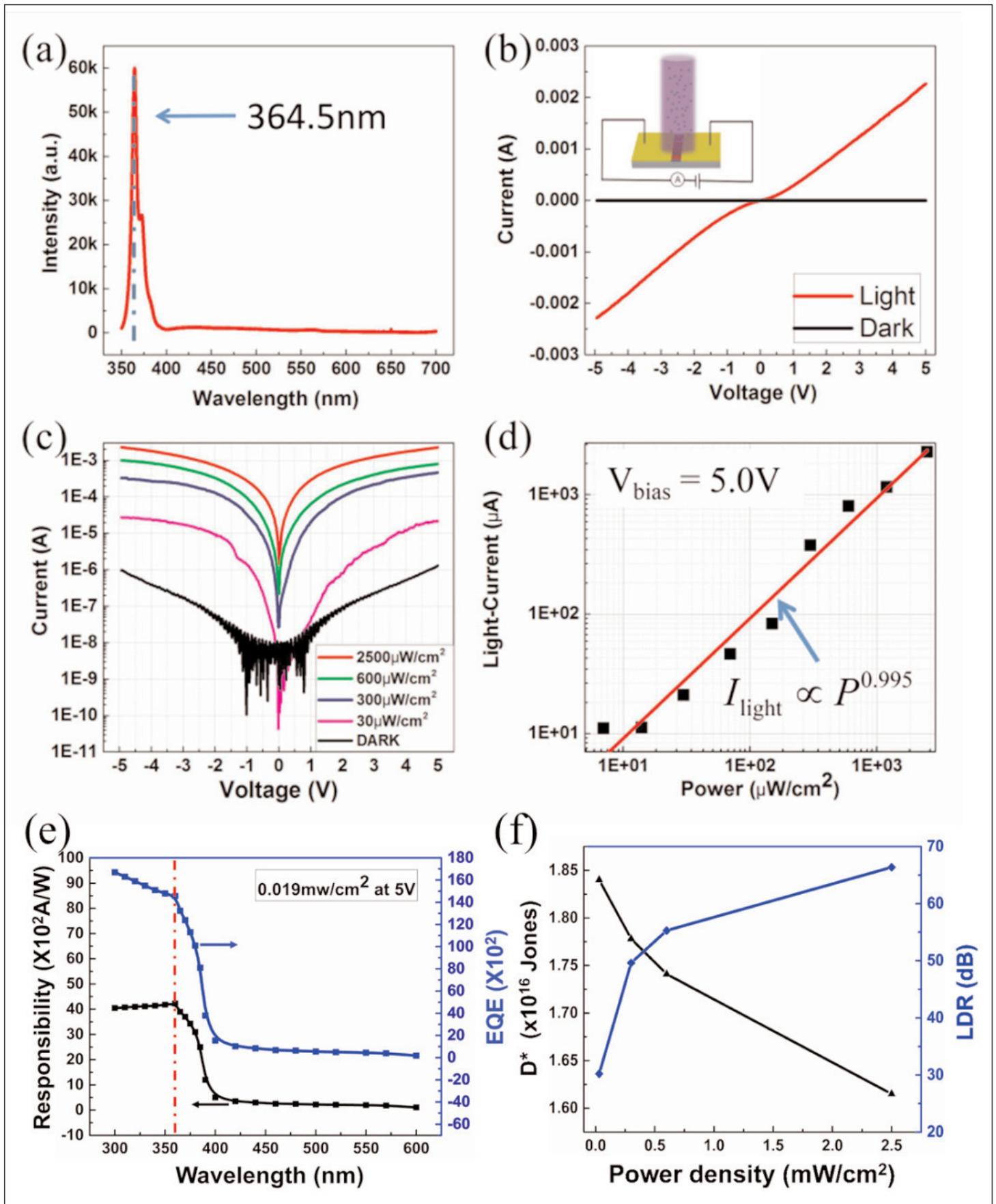


Figure 6. (a) Room-temperature micro-photoluminescence spectrum of GaN microwire. (b) Current-voltage characteristics both in dark (black curve) and under 325nm UV illumination (red curve); inset, testing schematic diagram of photodetector. (c) Light-density-dependent current-voltage curves. (d) Current variation as function of light intensity. (e) Responsivity and EQE-dependent wavelength curves. (f) Specific-detectivity-dependent power density curves.

With 5.0V bias under $2500\mu\text{W}/\text{cm}^2$ 325nm helium-cadmium laser power, the current was 2.71mA. Dark current was $1.3\mu\text{A}$, giving a sensitivity of $2.08\times 10^5\%$. The current-light output power dependence followed a power law with exponent 0.995. The exponent being close to 1 indicates a low density of trap states and high crystal quality of the GaN microwires. The responsivity was calculated at $1.17\times 10^5\text{A}/\text{W}$, while the external quantum efficiency (EQE) came in at 4.47×10^5 . The maximum specific detectivity was 10^{16} Jones.

The researchers claim that their UV photodetector performs in terms of high sensitivity, high responsivity and high EQE, much better than most reported single GaN nano/microwire- and nanowire-array-based photodetectors.

The team's device also improves on most reported GaN-based alternatives in terms of a turn-on time of 36.3ms under $2500\mu\text{W}/\text{cm}^2$ illumination. During reset, there were two exponential processes — a fast one of 75.2ms, followed by a much more extended decay of 9.66s. The researchers suggest traps or other defect states could be involved in the persistent photoconductivity after turn-off of the light source. The researchers suspect that oxygen is desorbed from the surface during UV illumination. When reabsorbed, the oxygen traps electrons, delaying the full return to the dark current state.

The team also created a comparison device on sapphire with $3\mu\text{m}$ GaN layer. The devices featured nickel/gold contacts. The electrode lithography used the same

photomask as for the microwire device on silicon. The sensitivity, responsivity and EQE were $2.77\times 10^4\%$, $0.21\text{A}/\text{W}$ and 0.80, respectively.

Lateral epitaxial overgrowth

Researchers based in Japan, USA and Turkey have developed technology for high-brightness UV AlGaN LEDs using material grown on 200mm silicon substrates [Yoann Robin et al, Materials Science in Semiconductor Processing, vol90, p87, 2019]. The team from Japan's Nagoya University, Virginia Commonwealth University in the USA, Turkey's Cumhuriyet University and Northwestern University in the USA used lateral epitaxial overgrowth methods to improve material quality. The researchers report: "Improvement of the AlN quality and the structure design allowed the optical output power to reach the milliwatt range under pulsed current, exceeding the previously reported maximum efficiency."

The UV-emitting material was grown on (111) silicon using metal-organic chemical vapor deposition. First, a 120nm seed layer of AlN was grown and then patterned for lateral epitaxial overgrowth. The patterning consisted of $2\mu\text{m}$ -deep trenches along the $[10\bar{1}0]$ direction of the AlN structure ($[11\bar{2}]$ relative to silicon substrate). The trenching resulted in stripes that were $2\mu\text{m}$ wide with $4\mu\text{m}$ period.

Further AlN buffer growth was performed at high temperature with precursors delivered in hydrogen carrier gas in pulses. The growth of AlN on the seed stripes coalesced after about $6\mu\text{m}$ of growth. The AlN

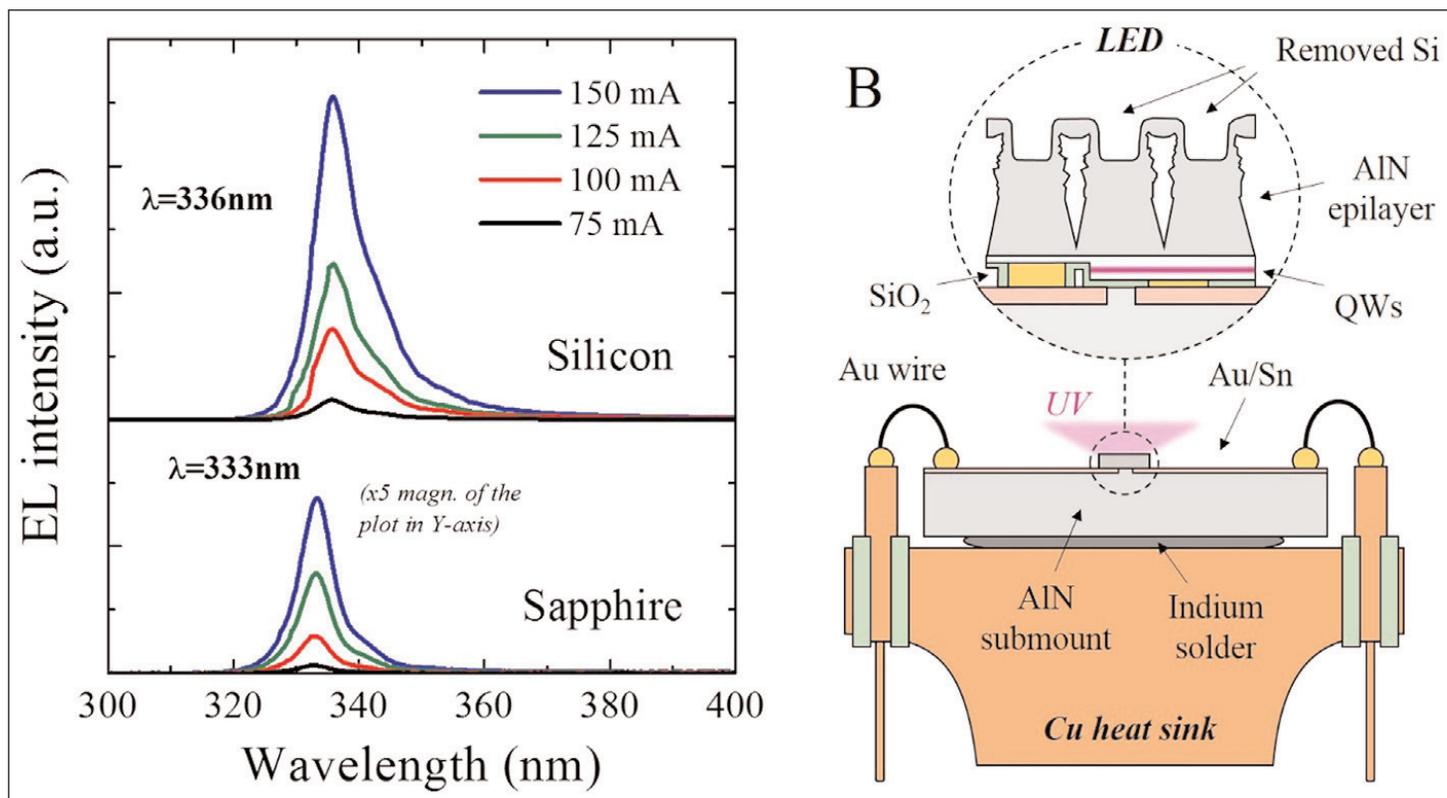


Figure 7. (A) Electroluminescence spectra of UV-LEDs grown on silicon and sapphire (Al_2O_3) recorded at different current densities. (B) Schematic of device structure grown on silicon.

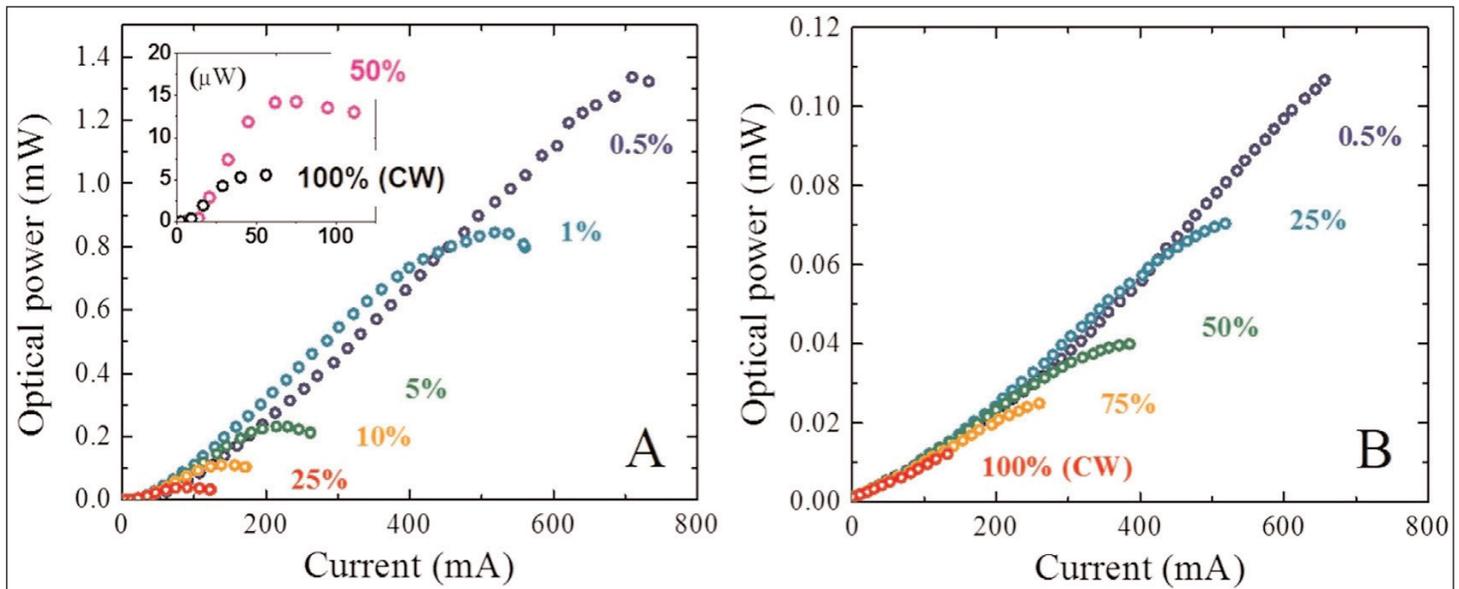


Figure 8. Optical output power measurements of UV-LEDs grown on silicon (A) and sapphire (B) as a function of injection current for different duty cycles.

template was used as the base for growth of 600nm of silicon-doped $n\text{-Al}_{0.2}\text{Ga}_{0.8}\text{N}$, five 3nm $\text{Al}_{0.05}\text{Ga}_{0.95}\text{N}$ wells separated by 7nm $\text{Al}_{0.15}\text{Ga}_{0.85}\text{N}$ barrier layers, a 10nm magnesium-doped $p\text{-Al}_{0.3}\text{Ga}_{0.7}\text{N}$ electron-blocking layer, 100nm of magnesium-doped $p\text{-Al}_{0.15}\text{Ga}_{0.85}\text{N}$ and 50nm of magnesium-doped $p\text{-GaN}$. A comparison epitaxy of the same AlGaIn structure was carried out on a 350nm AlN buffer on polished c-plane sapphire.

LED fabrication began with rapid thermal annealing (RTA) to activate the magnesium doping of the p-type layers. The $300\mu\text{m}\times 300\mu\text{m}$ device mesas were defined by electron cyclotron resonance (ECR) reactive ion etch. Nickel/gold and titanium/gold were deposited by electron-beam evaporation as the p- and n-type electrodes, respectively. Silicon dioxide was used for passivation. Further metalization added a thick titanium/gold layer that made contact with both electrode types.

The LED chips were flipped and mounted on pre-patterned AlN submounts with gold-tin eutectic bonding. The silicon substrate was removed using a hydrofluoric/nitric/acetic acid mix. The sides of the devices were protected with wax during the wet etching. Substrate removal is vital since silicon strongly absorbs UV radiation, unlike sapphire. The devices were then bonded to copper heat-sinks with indium, and finally wire bonds were made for electrical connection. The comparison sapphire-based LED was fabricated similarly, but without substrate removal.

The devices emitted a narrow peak around 336nm wavelength in 1%-duty-cycle pulsed operation ($10\mu\text{s}$ period); the comparison LEDs grown on sapphire emitted nearby at 333nm (Figure 7). The full-width at half maximum (FWHM) of peaks were 8.9nm for material grown on silicon, compared with 6.6nm for sapphire-based structures. The performance of the devices was somewhat similar.

The UV-LED from silicon-grown material achieved a maximum output power of 1.3mW at 700mA injection with 0.5% duty cycle and $10\mu\text{s}$ period (Figure 8). Although this represents only a 0.13% wall-plug efficiency, the result represents one of the highest values reported so far for silicon substrate growth at this wavelength. At higher duty cycles the peak power reduced, mostly likely due to thermal effects related to Shockley–Read–Hall recombination. Moving to continuous wave (CW) operation reduces the peak power by a factor of 300. For the LED grown on sapphire, the corresponding reduction factor was just 10.

Near-field analysis under the microscope showed defective current spreading in the LED grown on silicon, unlike the sapphire-based device. The researchers found cracks on the AlN surface where the silicon substrate was removed. The team comments: "Further investigations indicated that few AlN cracks were visible right after the growth (non-coalesced area or thermal cracking, for instance) and several ones were created during the device processing. Additionally, upon the substrate removal step, the acid mixture penetrated through the cracks and slightly etched the metal contacts and passivation layer of the LED/Si structure."

Further damage was caused by localized regions of high current density leading to hot spots and thermal instability at higher currents and duty cycles. The researchers believe that these factors explain the greater reduction in peak power in moving to CW operation from UV-LEDs grown on silicon. ■

Author:

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

High-performance light emission from III–nitride stress/dislocation control

Diodes have achieved high 592mW 456nm-wavelength output power at a low forward voltage of 2.77V with 350mA injection current.

Researchers in China have used stress and dislocation control measures to improve the performance of III–nitride on silicon light-emitting diode (LED) performance in terms of high output power and low forward voltage [Yuan Li et al, *Journal of Alloys and Compounds*, vol771, p1000, 2019]. Of course, such material can also serve as the basis for III–N electronics taking advantage of high voltage and high frequency handling capabilities.

Growth on silicon reduces costs in terms of the material itself and from mass manufacturing on large-diameter substrates, compared with sapphire, silicon carbide and free-standing or bulk gallium nitride.

South China University of Technology and Guangdong Choicore Optoelectronics Co Ltd in China prepared the (111) 4-inch silicon substrates by 1100°C thermal cleaning and native oxide removal in the metal-organic chemical vapor deposition (MOCVD) reaction chamber. The first layer was a 250nm aluminium nitride (AlN) nucleation buffer grown at 1150°C. The transition to gallium nitride (GaN) was enabled by a range of aluminium gallium nitride (AlGaN) transition buffers (Figure 1).

The materials from samples 'B' and 'C' were used to create LED structures with the following layer sequence: 500nm of undoped GaN, 3µm of n-GaN, 9x(3nm/12nm) of InGaN/GaN quantum wells, a 20nm AlInGaN electron-blocking layer, and 200nm of p-GaN. Samples B and C were chosen since they were crack-free, unlike samples A and D. X-ray analysis suggested higher crystal quality of the cracked wafers as a result of stress release, but such substrates are unsuitable

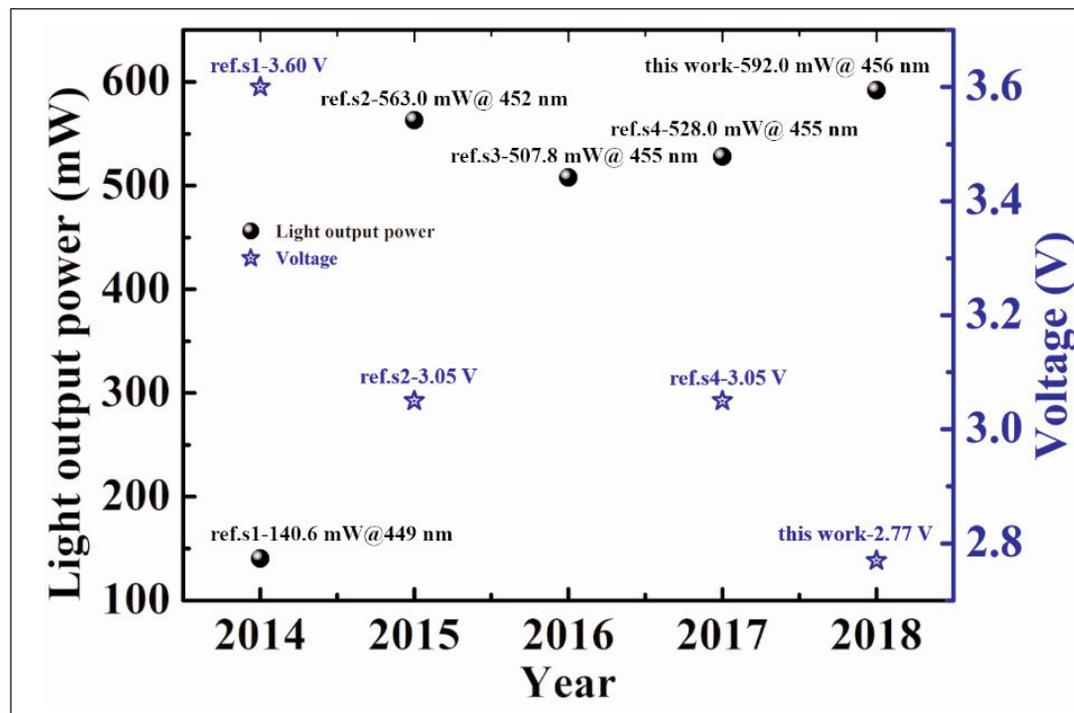


Figure 1. Structures of GaN epitaxial films for samples A, B, C and D.

for device epitaxy and fabrication.

The LEDs were fabricated in a vertical format with the growth substrate removed below the 3µm n-GaN layer, and top and bottom metal contacts applied to the p-GaN and exposed n-GaN layers, respectively.

The cracks in samples A and D were attributed to the 56% mismatch in the coefficient of thermal expansion and consequent stress build up from cooling from the growth temperature to ambient room conditions. The researchers note that, while the improved GaN buffer layer structure results from step-graded AlGaIn transition layers, "the cracks on the surface of sample D show that the compensation effect may become weaker with the further increase in the number of AlGaIn layers and the further decrease in the Al composition of top buffer layer."

Raman spectroscopy gave estimates for the residual stress in samples A–D, in alphabetical order, of 0.37GPa, –0.05GPa, 0.39GPa, and 0.41GPa.

The average light output power at 350mA for the

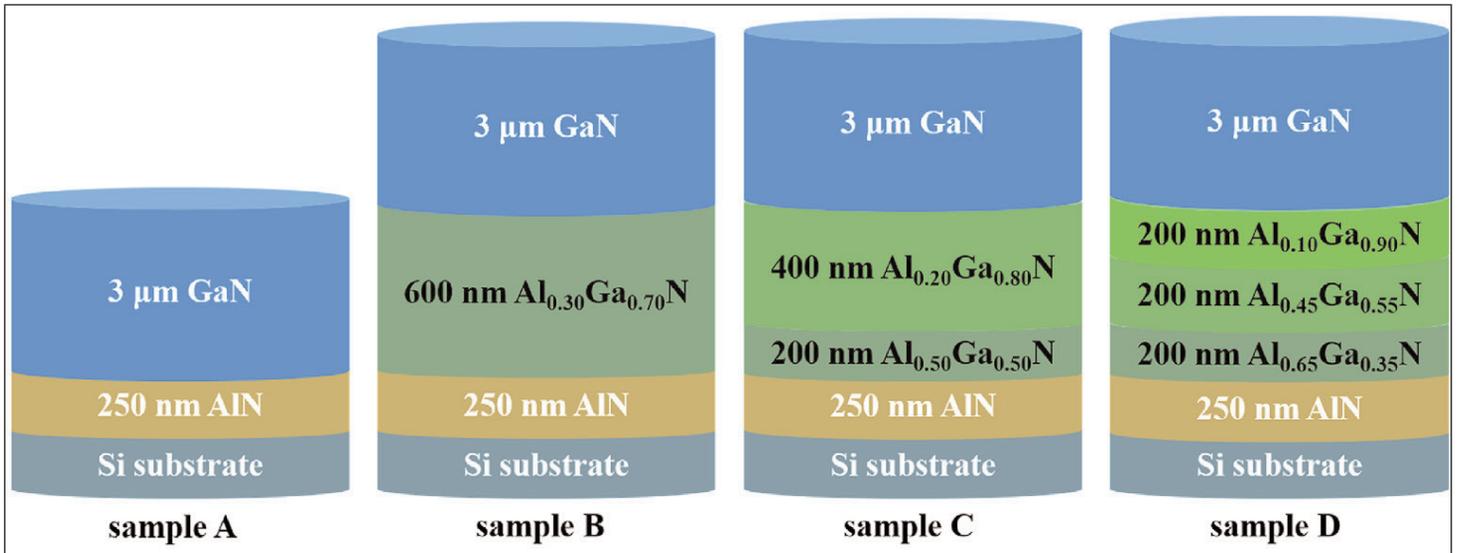


Figure 2. (a) Light output power versus current, and (b) voltage versus current curves from vertical structure LED chips of samples LED-I and LED-II, and photograph of lit-up LED chips working at 350mA inserted in (a).

LEDs on samples B and C were 522mW (LED-I) and 592mW (LED-II), respectively (Figure 2). The corresponding operating voltages were 2.96V and 2.77V. The electroluminescence wavelength peak was at 456nm.

The higher output power and lower operating voltage of LED-II indicates higher efficiency as a result of higher crystal quality and smoother surface morphology.

The vertical diode structure enables higher performance compared with state-of-the-art GaN grown on silicon LEDs through improved current spreading in the thick n-GaN layer (Figure 3). ■

<https://doi.org/10.1016/j.jallcom.2018.09.031>

Author:

Mike Cooke

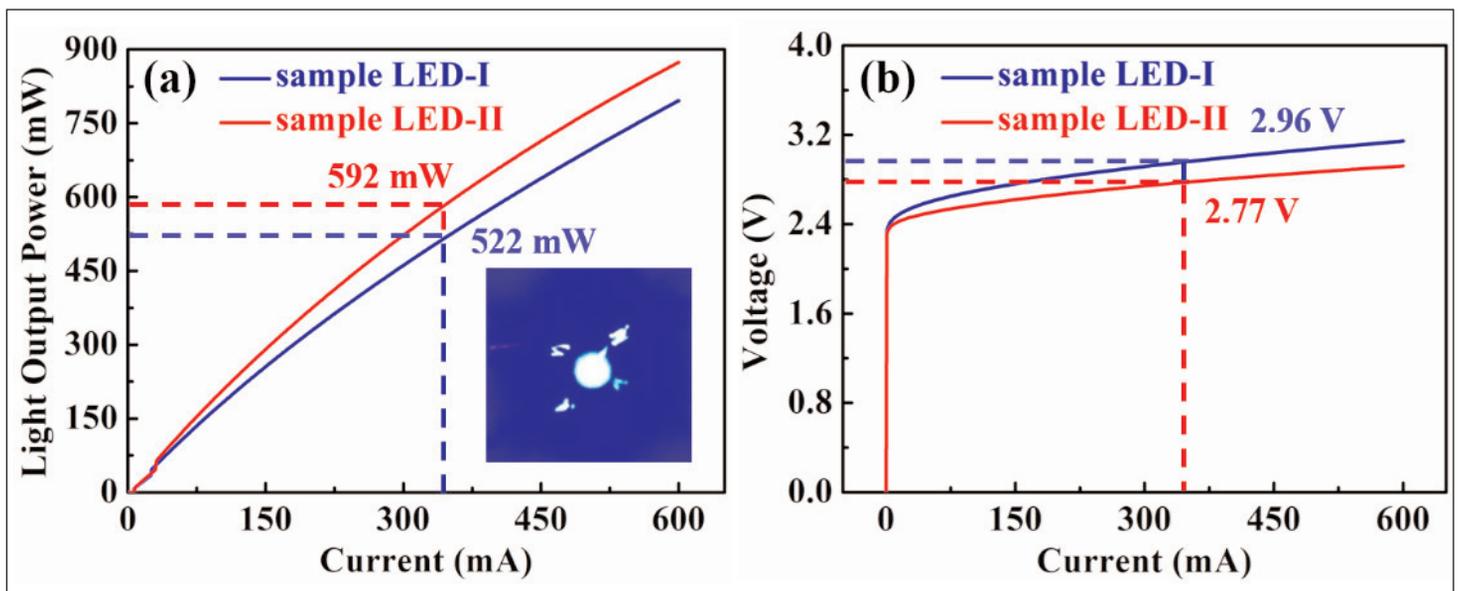


Figure 3. Properties of state-of-the-art high-power LEDs on silicon substrates working at a current of 350mA.

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Low threading-dislocation-density heteroepitaxial AlN film on sapphire

Simple yet effective technique demonstrates potential for mass fabrication of low-cost and high-performance deep ultraviolet devices

In a collaboration that includes Guangzhou University and Peking University, China's Guangdong Institute of Semiconductor Industrial Technology (GISIT) has demonstrated high-quality aluminium nitride (AlN) film grown on sputtered AlN/sapphire. The threading dislocation density (TDD) of the AlN film is reduced to $4.7 \times 10^7 \text{cm}^{-2}$, which is reckoned to be an extremely low value for heteroepitaxial AlN film ('High-quality AlN film grown on sputtered AlN/sapphire via growth-mode modification' by Chenguang He, Wei Zhao, Zhitao Chen et al, *Crystal Growth & Design*, 2018, 18(11) p6816).

Heteroepitaxy of high-quality AlN films is the key to advancing deep-ultraviolet (DUV) devices when a large-size, low-cost AlN substrate is unavailable. To date, however, the prevailing AlN/sapphire template still suffers from a high threading dislocation density. Few reliable methods can obtain high-quality AlN with a TDD of $(3-5) \times 10^8 \text{cm}^{-2}$. The main causes are the large mismatches in both the lattice constants and the coefficients of thermal expansion between AlN and sapphire, as well as the low surface migration of Al species. The research team proposes a strategy for obtaining high-quality AlN film by combining growth-mode modification with sputtered AlN buffer using metal-organic chemical vapor deposition (MOCVD).

Comparison reveals that the sputtered AlN buffer consists of smaller and more uniform grains with better c-axis orientation, leading to better growth-mode modification in the subsequent growth process. On one hand, the better c-axis orientation is inherited by the upper AlN epilayer, resulting in a lower screw dislocation density across the whole growth process. On the other hand, the better growth-mode modification significantly suppresses edge dislocations in the upper AlN epilayer by producing high-density nanoscale voids and many 90° bent dislocations.

The formation of nanoscale voids originates from the high-speed lateral growth and large depth/width ratio between three-dimensional islands. Similar to the case of epitaxial lateral overgrowth (ELOG), the pre-existing

dislocations can bend and terminate at the local free surfaces provided by these voids, following the principle of dislocation line energy minimization. Because of a higher island density, the AlN film with sputtered AlN buffer has a higher void density of $1.7 \times 10^{10} \text{cm}^{-2}$ in the (0001) plane, providing a higher probability for dislocation termination. During the coalescence processes of the voids, the misorientations between the adjacent domains in the AlN film with sputtered AlN buffer are much smaller, so dislocations at the coalescence boundaries are also effectively suppressed.

The 90° dislocation bending in the areas away from the voids is associated with macro-step movement.

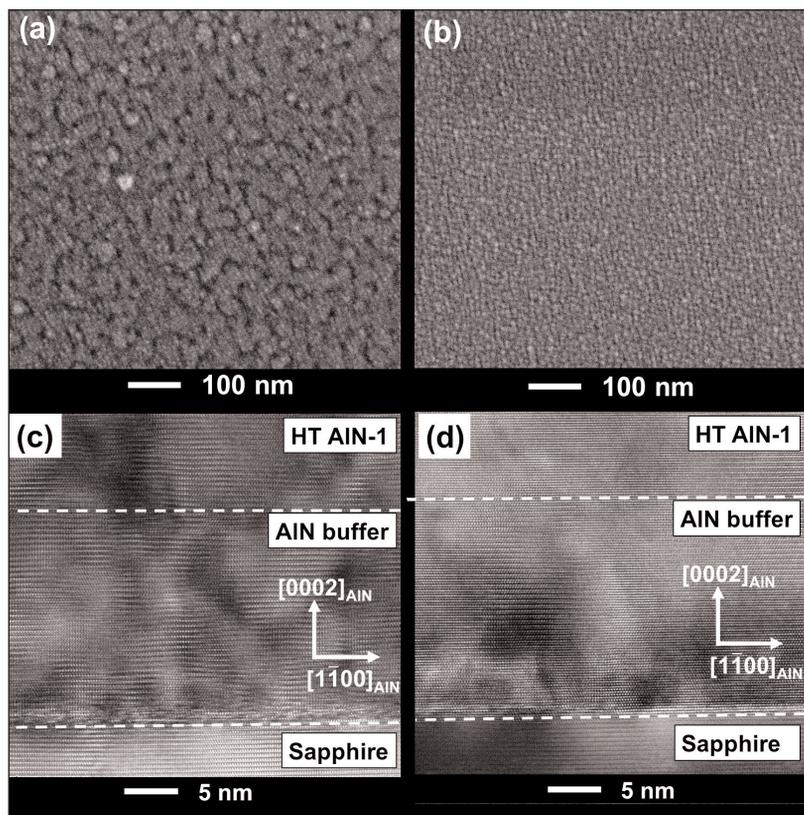


Figure 1. Surface morphologies of (a) MOCVD AlN buffer and (b) sputtered AlN buffer taken with scanning electron microscope (SEM) using magnification of 300,000. Cross-sectional high-resolution transmission electron microscope (HRTEM) images of (c) AlN film with MOCVD AlN buffer and (d) AlN film with sputtered AlN buffer.

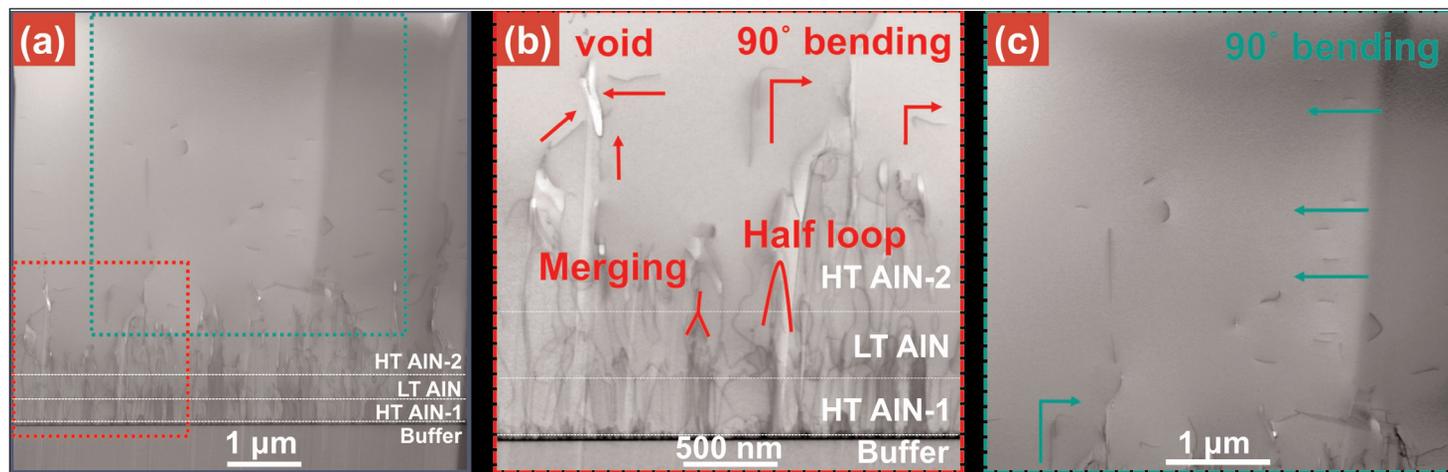


Figure 2. Cross-sectional dislocation distributions of AlN film with sputtered AlN buffer.

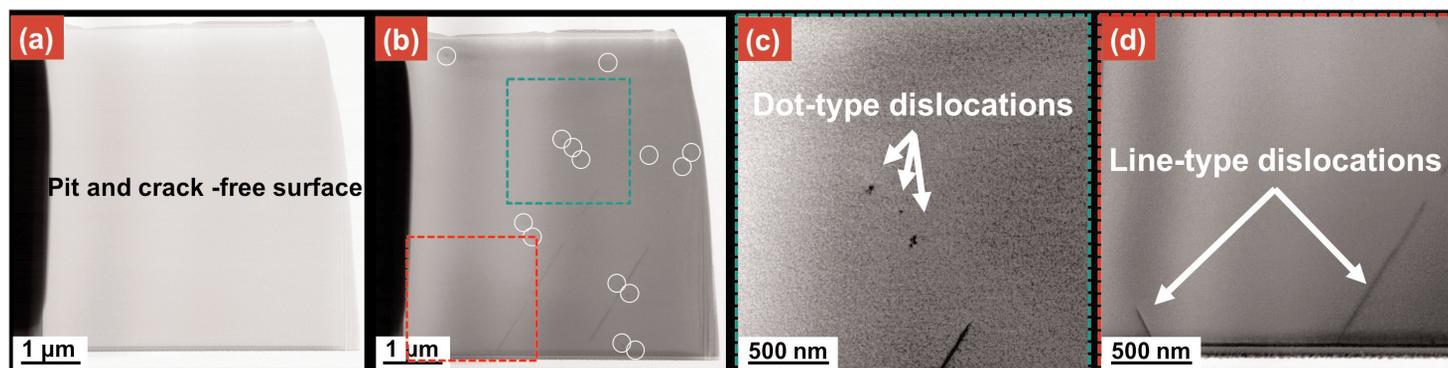


Figure 3. Plan-view TEM images of AlN film with sputtered AlN buffer.

When the macro-step advances laterally and meets with the dislocation in the normal surface, the dislocation will bend as the macro-step and surface advance. The large ratio of lateral growth rate to vertical growth rate results in the 90° dislocation bending. The 90° bent dislocations propagate laterally. Therefore, it is easy for them to come into contact with other dislocations and block them by merging or forming half-loops.

Benefiting from this, only a few threading dislocations can reach the top surface of the AlN film with a sputtered AlN buffer. Plan-view transmission electron microscope (TEM) measurement shows that the TDD of the AlN film with the sputtered AlN buffer is dramatically

reduced to an extremely low value of $4.7 \times 10^7 \text{cm}^{-2}$, which is 81.2% less than the TDD of the AlN film with an MOCVD AlN buffer.

Additionally, the 5.6- μm -thick AlN film is crack-free and pit-free. The root mean square (RMS) roughness of the AlN film with sputtered AlN buffer is as small as 0.14 nm over $3 \mu\text{m} \times 3 \mu\text{m}$. The concentrations of carbon, hydrogen, and oxygen are as low as $1.6 \times 10^{17} \text{cm}^{-3}$, $3.0 \times 10^{17} \text{cm}^{-3}$ and $1.3 \times 10^{17} \text{cm}^{-3}$, respectively.

The researchers say that the very simple yet effective technique demonstrates potential for the mass fabrication of low-cost and high-performance DUV devices. ■

<https://pubs.acs.org/doi/10.1021/acs.cgd.8b01045>

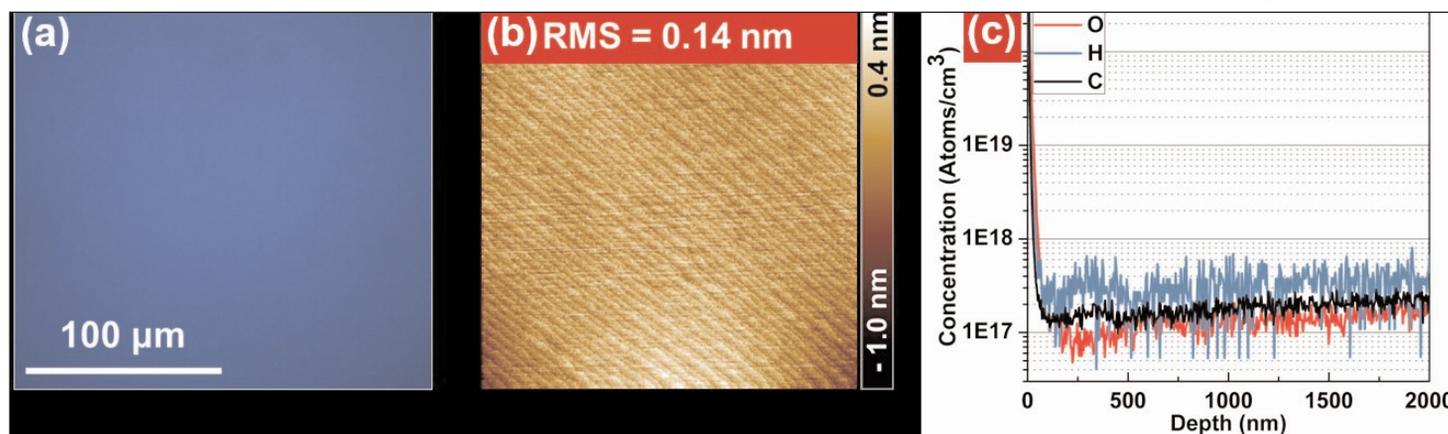


Figure 4. AlN film with sputtered AlN buffer demonstrates (a) crack-free and (b) atomically flat surface. (c) SIMS profiles of carbon, hydrogen and oxygen impurities.

Large-area silicon carbide ultraviolet visible-blind avalanche photodiode

Variable-temperature resist reflow enables low leakage current and avoids premature breakdown under reverse bias.

Hebei Semiconductor Research Institute in China has reported large-area 800 μm -diameter 4H-polytype silicon carbide (SiC) ultraviolet (UV) avalanche photodiodes (APDs) with improved gain, quantum efficiency and dark current [Xingye Zhou et al, IEEE Electron Device Letters, vol39, issue 11 (November 2018, p1724)]. A variable-temperature photoresist reflow technique was used "for the first time" to create smooth beveled sidewalls that suppress leakage currents and avoid premature edge breakdown.

The researchers claim that, to the best of their knowledge, they have achieved the best overall performance for visible-blind UV detectors based on large-area 4H-SiC APDs in terms of high gain of more than 10^6 , high quantum efficiency of 81.5%, low dark current and high UV/visible rejection ratio of 10^3 .

UV detection covers a wide range of applications in astronomy, communications and biochemical analysis. UV is emitted in fluorescence experiments and by flames. Military warning and guidance systems can use visible-blind UV sensing to home in on or track missile plumes.

Up to now, SiC UV APDs have suffered from large dark current and premature breakdown under the larger reverse bias applied. This limits typical diameters

to less than 250 μm , reducing sensitivity. The researchers see their large-area devices as potential replacements for bulky, fragile and costly photomultiplier tubes.

The epitaxial structure consisted of 3 μm heavily doped p-type (p^+), 0.5 μm lightly doped n-type multiplication (n^-), 0.2 μm n charge, 0.5 μm n^- adsorption, and 0.3 μm n^+ contact layers (Figure 1).

The fabrication began with inductively coupled plasma (ICP) mesa etching. The mesa was beveled to avoid edge breakdown effects. The thick photoresist for the mesa etch was subjected to a reflow process where the wafer was subjected to increasing temperature from 90 $^\circ\text{C}$ to 145 $^\circ\text{C}$ at a rate of 5 $^\circ\text{C}/\text{minute}$.

The variable temperature gives a smooth bevel surface, unlike fixed-temperature reflow at 145 $^\circ\text{C}$ for 30 seconds, which results in saw-tooth patterns. A saw-tooth surface increases dark current and causes premature breakdown. The researchers suggest that fixed-temperature reflow creates a non-uniform thermal field with spatial variations in surface tension and reflow velocity for the photoresist, giving the observed surface roughness.

While the variable-temperature reflow gave consistent high breakdown values around 156V, measurements for APDs created using fixed-temperature reflow varied

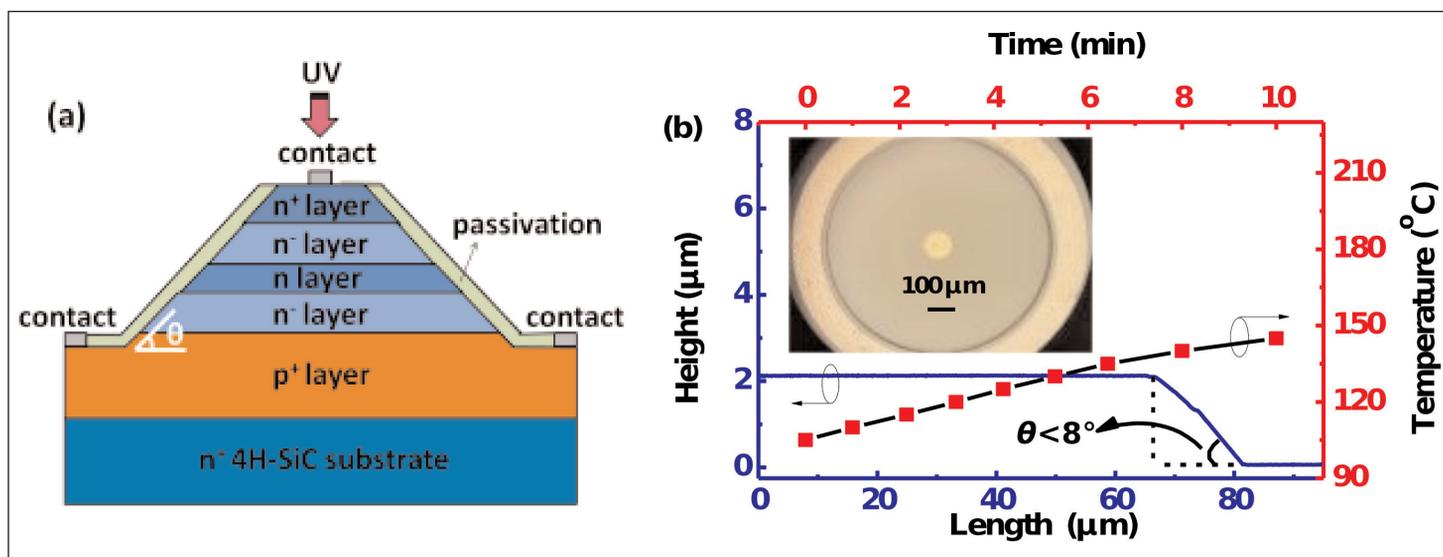


Figure 1. (a) Schematic cross section structure of 4H-SiC APDs; (b) temperature variation for photoresist reflow technique and profile of beveled mesa and (inset) top-view photo of 800 μm -diameter 4H-SiC APD.

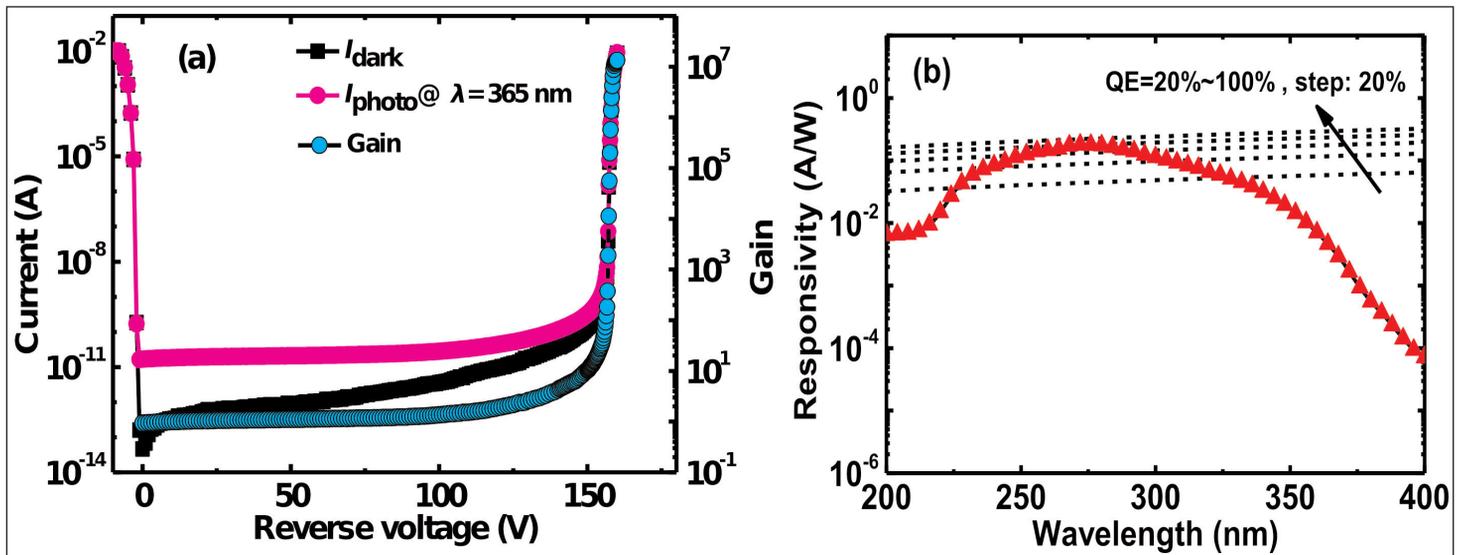


Figure 2. Ultraviolet detection performance of 800µm-diameter 4H-SiC APD: (a) current–voltage measurements and calculated multiplication gain; (b) spectral response corresponding to unity gain at reverse voltage of 140V.

widely in the 100–150V range.

The further fabrication consisted of applying 200nm thermal oxide and 100nm plasma-enhanced chemical vapor deposition (PECVD) silicon nitride passivation, ICP and wet-chemical contact etching, electron-beam evaporation of nickel/titanium/aluminium/gold metal contacts, and 850°C metal contact annealing in nitrogen for three minutes. The completed device was 800µm diameter with the mesa bevel angle less than 8°.

Dark-current measurements with 140V and 150V reverse bias were carried out: the current was found to be quadratically dependent on the diameter, suggesting bulk leakage rather than surface leakage through the edge states. For the 800µm-diameter device the dark current was of the order 1pA (0.2nA/cm²) for low reverse bias.

Multiplication gain factors of more than 10⁶ for 365nm ultraviolet were achieved over the ‘unity gain’ value at 10V reverse bias (Figure 2). Under a xenon lamp, the response with 140V reverse bias (4.2 gain) peaked at 0.18A/W for 274nm wavelengths. The corresponding external quantum efficiency was calculated to be 81.5%. The UV/visible rejection ratio was more than 10³, given by the ratio of responses at 274nm and 400nm.

The 800µm-diameter devices gave gain, quantum efficiency and dark-current performances comparable to that seen with much smaller APDs of less than 300µm diameter. ■

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Author:

Mike Cooke

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Protecting 'Made in America' ingenuity

GTAT's CEO **Greg Knight** argues for the US government to prevent critical SiC production equipment and process technology from being lost abroad.

On the sidelines of the on-again, off-again trade tangle between the United States and China lurks a cross-border issue that must not undermine American ingenuity and efforts to hold American-made technology manufacturing fast, states Greg Knight, president & CEO of GT Advanced Technologies of Hudson, NH, USA (which provides silicon carbide and sapphire materials as well as polysilicon products and crystal growth systems). While the US government does restrict the sale of critically important US technology companies, it does not properly restrict the sale of the underlying related production equipment and processes. America (and Europe) lost its early lead in solar, LED and polysilicon manufacturing industries to China, in part due to unrestricted sales of processing equipment. But US manufacturers and government alike must now come together to not make this mistake again and protect an emerging yet vital new US industry — silicon carbide.

The US is the undisputed global leader in the production of advanced silicon carbide (SiC), a material that will radically accelerate the transformation of the US economy. This little-known strategic asset is one of America's most important technology innovations. My company and a few other American businesses have developed the core underlying material technology to produce SiC crystal on a large scale, prior to it being sliced into wafers and fabricated into semiconductor devices. Semiconductor device manufacturers are replacing traditional silicon with SiC to boost functionality and cut cost in high-power applications. SiC enables longer-range, lower-cost electric vehicles, lesser-cost renewable energy, and more powerful, robust 5G networks. SiC is to advanced electronics what hydraulic fracturing (fracking) is to the natural gas industry, making it less costly and more productive.

SiC technology, and the related intellectual property for production, are closely guarded and protected by a combination of patents and valuable trade secrets. Silicon carbide's ingredients are simple — but the process and equipment that transform them are highly complex. If US companies that have this technology export it, they will enable other countries to do what they have before — expand on the back of easy capital and, in short order, dominate the SiC market. I should know. For the last 15 years, my company sold advanced equipment and process technology to the solar, LED and polysilicon industries, which Asia (China in particular) now dominates. And after just a few years, fueled by massive capital infusions and by copying our equipment designs, Chinese manufacturers took over these industries once dominated by the United States and Europe.

In the past, selling production equipment was GT Advanced Technologies' business model. This strategy made us a lot of money and we could make a lot more by selling SiC production equipment and process technology. However, as the chief executive, I have changed my business model and decided that, as a forward-looking company in the SiC supply chain, we must protect American-developed technology, while still supporting the best interests of our shareholders, employees and community. Let me be clear: I am for free trade and hard-fought technical and commercial competition; however, my company will no longer enable losing a US industry. Other countries must compete using their own sweat, their own technology innovation, their own dime, and see if they can keep up.

Much of the power to protect America's strategic technology assets rests with the US government — specifically CFIUS (the Committee on Foreign Investment in the United States). Last year, CFIUS blocked the sale of US-based Wolfspeed — a Cree Company that makes SiC power products and gallium nitride on silicon carbide (GaN-on-SiC) high-electron-mobility transistors (HEMTs) and monolithic microwave integrated circuits (MMICs) — to Germany's Infineon Technology, because of potential risks to national security. This followed the Obama administration's decisions to block two similar sales to Chinese buyers: LED maker LumiLEDs (a division of Holland-based electronics giant Philips) and Germany-based metal-organic chemical vapor deposition system maker Aixtron (which had a US subsidiary).

Our existing system of protecting America's critical technology falls short. The number of merger & acquisition (M&A) deals or foreign investments that are blocked is irrelevant, when all a company needs to do is to buy the underlying manufacturing equipment and process; it needn't buy the business if we allow the sale of the capital equipment, as this grants the implied rights to the technology's use. It is thus imperative that, from the jump, we prevent the sale of our intellectual know-how via manufacturing equipment sales — because the day we enable any country (China or any other) in this high-growth, strategically critical industry, is the day we will have allowed them once again to buy their way to technical parity and drive another American-birthered industry into the ground.

I cite the electric vehicle (EV) sector as just one of many industries being readied to gallop when more SiC products come to market. Here, and elsewhere, US policy makers would do well to support the fundamental 'Made in America' technology already in our hands. ■

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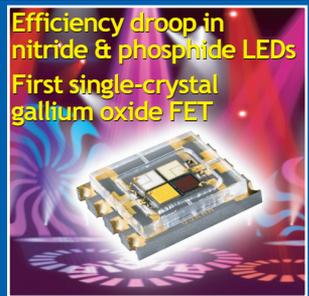


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Peking provides evidence of substitutional C atoms occupying N site with -1 charge state in semi-insulating GaN

Work could provide method for identifying carbon dopant lattice sites in other compound semiconductors.

A team led by Peking University has provided what is said to be unambiguous evidence of substitutional carbon (C) atoms occupying the nitrogen (N) site with a -1 charge state in semi-insulating gallium nitride (GaN).

From the viewpoint of symmetry, it is demonstrated that the observed two local vibrational modes (LVMs) in the Fourier-transform infrared (FTIR) and Raman spectra originate from the substitutional C atoms occupying the N site with a -1 charge state. They are assigned to the non-degenerate A_1 mode and the doubly degenerate E mode of C_{3v} point group, respectively. This experimental data is said to be in excellent agreement with the calculated results [Shan Wu, et al, 'Unambiguous Identification of Carbon Location on the N Site in Semi-insulating GaN', Phys. Rev. Lett. 121, 145505 (2018)].

Carbon doping is essential for producing semi-insulating GaN for fabricating high-electron-mobility transistors (HEMTs) and hence power electronics. However, despite C-related defects in GaN having been investigated for more than 20 years, it has remained mysterious where carbon impurities reside in the GaN crystal lattice.

Now, the researchers at Peking University and their colleagues claim to have solved this long-standing problem through a combination of experimental and theoretical calculations, clarifying the lattice site of C in

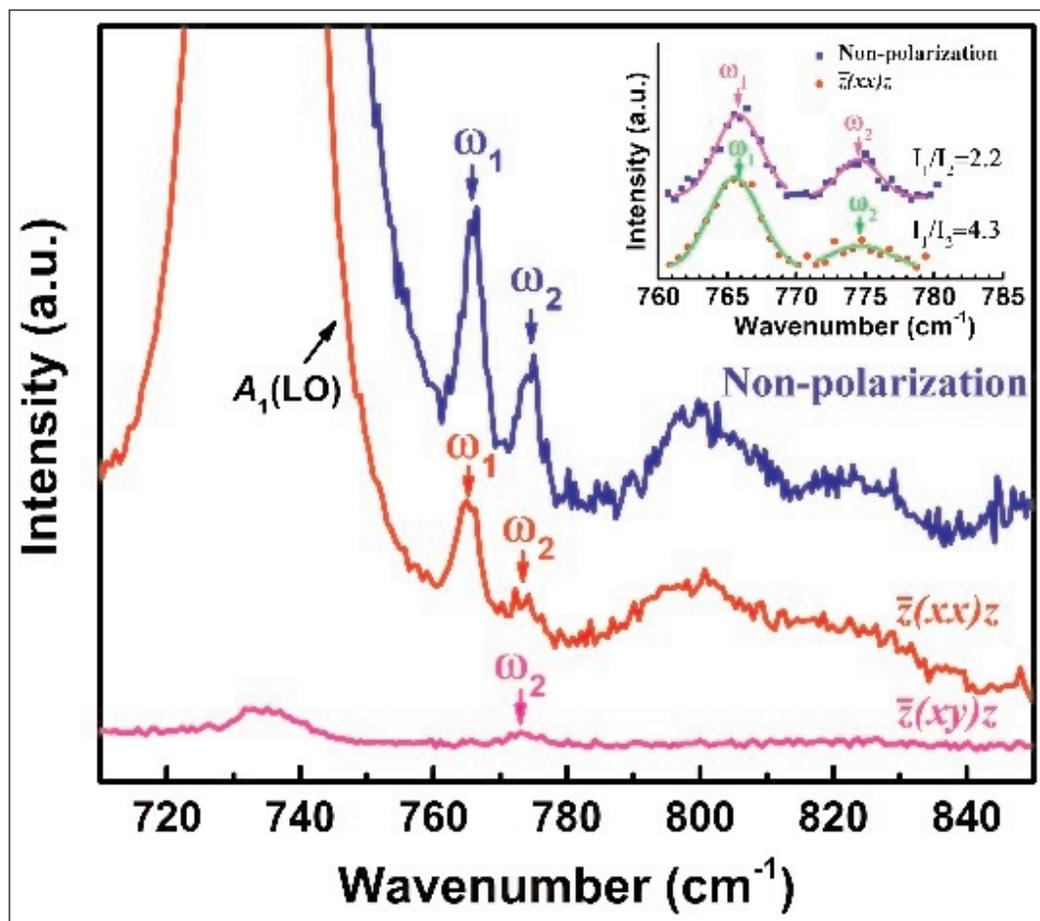


Figure 1 Room-temperature Raman spectra of heaviest C-doped GaN film in non-polarized, polarized configurations. Inset: enlarged fitting curves of LVMs.

GaN using polarized FTIR and Raman spectroscopies in combination with first-principles calculations.

Two LVMs at 766cm^{-1} and 774cm^{-1} in C-doped GaN are observed. The 766cm^{-1} mode is assigned to the non-degenerate A_1 mode vibrating along the c axis, whereas the 774cm^{-1} mode is ascribed to the doubly degenerate E mode confined in the plane perpendicular to the c -axis. The two LVMs are identified to originate from isolated with local C_{3v} symmetry.

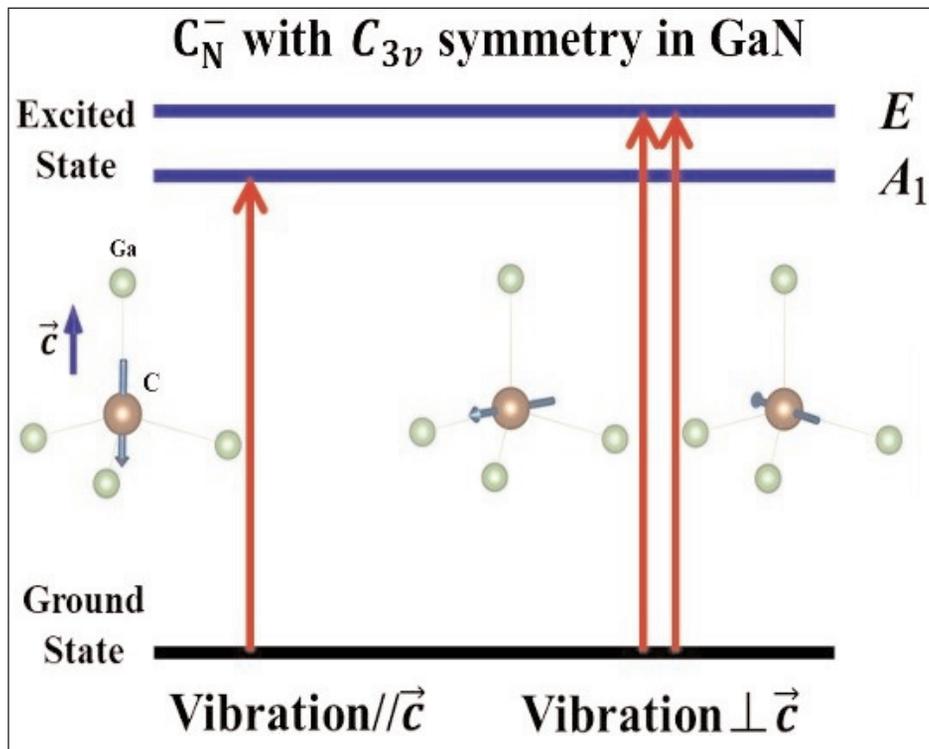
Experimental data and calculations are in outstanding agreement both for the positions and the intensity

Figure 2 Schematic energy-level diagrams and fundamental dipole transitions in a center with C_{3v} symmetry. Calculated vibrational directions of C atom are also depicted.

ratios of the LVMs. They are said to provide the first unambiguous evidence of the substitutional C atoms occupying the N site with a -1 charge state in semi-insulating GaN.

The researchers believe that the work will provide a universal approach for identifying the lattice sites of carbon in other compound semiconductors such as aluminium nitride (AlN), boron nitride (BN), zinc oxide (ZnO) and gallium oxide (Ga_2O_3). ■

<https://journals.aps.org/prl/abstract/10.1103/PhysRevLett.121.145505>
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III-V heterojunction bipolar transistor MOCVD on 200mm (001) silicon

Researchers hope for future application in power amplifiers for mobile phone handsets.

Researchers based in Singapore have used metal-organic chemical vapor deposition (MOCVD) to grow III-V heterojunction bipolar transistors (HBT) directly on 200mm-diameter silicon wafers [Wan Khai Loke et al, *Semicond. Sci. Technol.*, vol33, p115011, 2018].

The team from Nanyang Technological University and Singapore MIT Alliance for Research and Technology (SMART) hopes that the technology could lead to integration with mainstream silicon complementary metal oxide semiconductor (CMOS) electronics using the most effective (001) crystal orientation.

The researchers foresee application in power amplifiers for mobile phone handsets. III-V HBTs have increased high-frequency performance compared with silicon-only devices. Further advantages can arise from bandgap tuning in terms of higher voltage breakdown and low-noise operation.

The researchers first grew a germanium buffer layer on a 200mm (001) p-type silicon substrate. The substrate was offcut 6° in the [110] direction. The epitaxial process was MOCVD of a thin silicon conditioning layer, followed by 60nm of 350°C germanium seeding and 740nm of a 650°C germanium buffer layer. The buffer was subjected to cyclic thermal annealing to control surface roughness to the order of 1nm and to reduce threading dislocation density to the 107/cm² scale.

The HBT structure was also grown by MOCVD, resulting in indium gallium arsenide phosphide (InGaAsP) alloys. Device fabrication used 2.54cmx2.54cm pieces diced from the 200mm epitaxial wafer (Figure 1). The emitter area was 40µmx50µm.

With 5V collector-emitter voltage, the DC gain of one device was 95. The ideality factors for the collector and

base currents were 1.07 and 1.23, respectively. The base sheet resistance came in at 430Ω/square. The breakdown for collector-emitter, collector-base and emitter-base stresses were 9.35V, 13.2V and 9.69V, respectively.

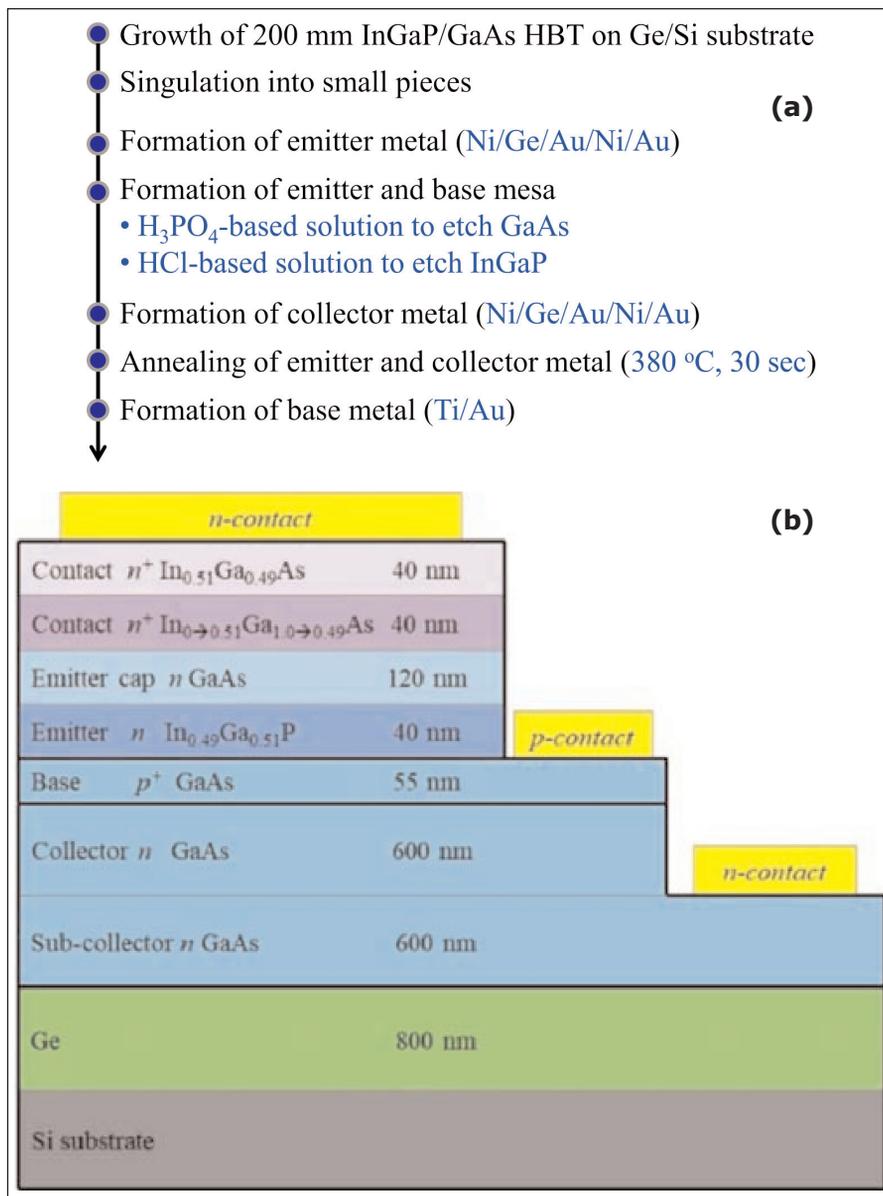


Figure 1. InGaP/GaAs HBT fabrication process flow (a), and schematic cross section of device (b).

Figure 2. Gummel plot (25°C) of InGaP/GaAs HBT.

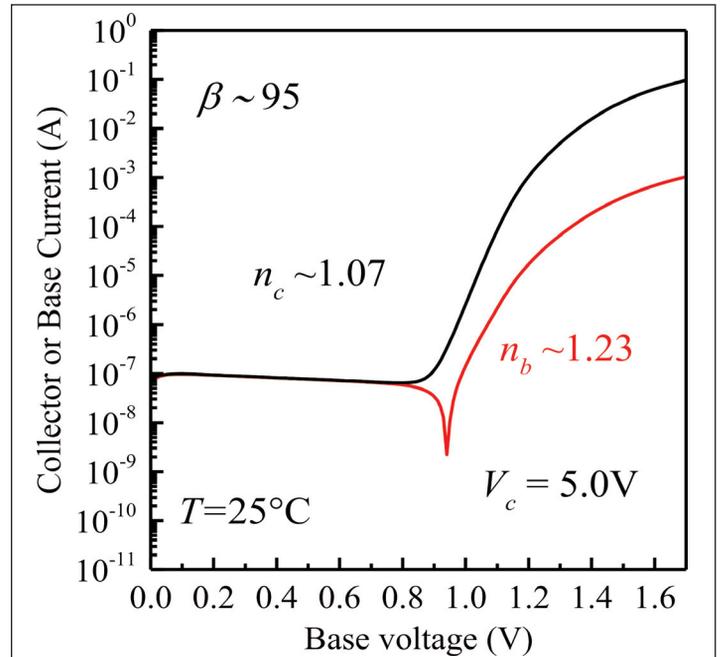
In statistical studies over a number of devices, there was some variation of idealities (<6%) and breakdown (~9%, collector-base average 14.2V). The average gain of 73 varied around 28% — mainly due to variation of the base current. The researchers comment: "The variation of the base current could be due to the defect density, the thickness non-uniformity of the HBT device layers and the fabrication variation from sample to sample."

The researcher believe that, with optimization, the gain could be increased to 239. ■

<https://doi.org/10.1088/1361-6641/aae247>

Author:

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



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E-mail: info@ieee-pvsc.orgwww.ieee-pvsc.org**8–10 July 2019****2019 Summer Topicals Meeting Series**

Fort Lauderdale, FL, USA

E-mail: i.donnelly@ieee.orgwww.sum-ieee.org**9–11 July 2019****SEMICON West 2019**

Moscone Center, San Francisco, California, USA

E-mail: semiconwest@xpressreg.netwww.semiconwest.org**10–11 July 2019****UK Semiconductors 2019 (UKS'19)**

University of Sheffield, UK

E-mail: edmund.clarke@sheffield.ac.ukwww.uksemiconductors.com**21–24 July 2019****AVS 19th International Conference on Atomic Layer Deposition (ALD 2019), featuring the 6th International Atomic Layer Etching Workshop (ALE 2019)**

Bellevue, Washington, USA

E-mail: della@avs.orgwww.ald2019.avs.org**11–15 August 2019****SPIE Optics + Photonics 2019**

San Diego Convention Center, San Diego, California, USA

Abstract deadline: 30 January 2019

E-mail: customerservice@spie.orghttp://spie.org/Optics_Photonics**2–5 September 2019****21st Conference on Power Electronics and Applications (and Exhibition), EPE'19 ECCE (Energy Conversion Congress & Expo) Europe**

Genova, Italy

E-mail: info@epe2019.comwww.epe2019.com**18–20 September 2019****SEMICON Taiwan 2019**

Taipei Nangang Exhibition Centre, Taiwan

E-mail: semicontaiwan@semi.orgwww.semicontaiwan.org**24–26 September 2019****19th International Metrology Congress (CIM 2019)**

Paris, France

E-mail: info@cfmetrologie.comwww.cim2019.com**6–11 October 2019****22nd European Microwave Week (EuMW 2019)**

Paris Expo Porte de Versailles, Paris, France

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