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COMPOUNDS & ADVANCED SILICON

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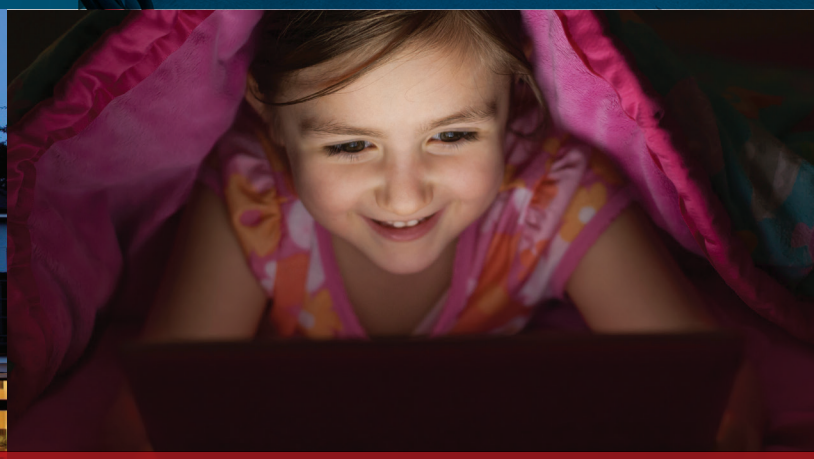
Cree investing $1bn in SiC materials and GaN-on-SiC fab capacity

Soitec buying EpiGaN • MACOM forms GaN-on-Si JV for China 5G
First mass-production order for IQE's Newport Mega Foundry

Lower Cost LEDs



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Veeco's New TurboDisc EPIK700 GaN MOCVD System

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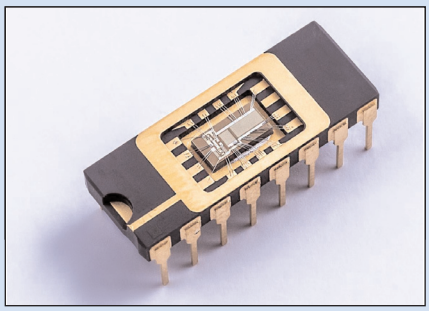
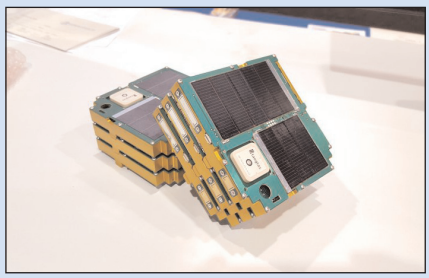
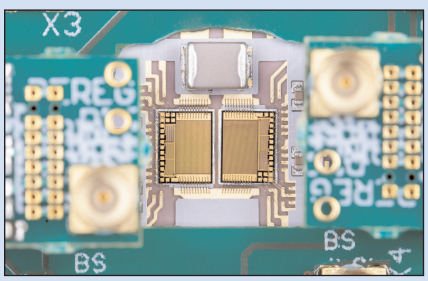


p27 imec has demonstrated a functional GaN half-bridge monolithically integrated with drivers.



p73 Alta Devices' flexible GaAs solar cells are powering 60 ThinSat small satellites launched by NASA.



p88 Fraunhofer IAF's GaN power ICs with integrated transistors, gate drivers, diodes and current and temperature sensors for condition monitoring.

Cover: As part of a $1bn, five-year investment in SiC materials and GaN-on-SiC device production capacity, Cree's new fully automotive qualified North Fab will provide 18 times more manufacturing area than currently exists, initially using 150mm wafers then transitioning to 200mm wafers. **p20**

editorial

Huawei fallout highlights diversity

Following the US Department of Commerce's Bureau of Industry and Security (BIS) in mid-April adding 37 Chinese companies and research institutions (focused on optics, electronics and machine tools etc, including LED maker San'an Optoelectronics) to its list of 'unverified' entities requiring US suppliers to apply for new licences to sell them products or service installed equipment (see last issue's Editorial), in mid-May this 'Entity list' was extended to smartphone and telecom network infrastructure maker Huawei.

Among compound semiconductor-based suppliers, most vulnerable is San Jose-based opto chip and module maker NeoPhotonics, 57% of whose $79.4m Q1/2019 revenue came from China (including 49% from Huawei and subsidiaries) — see page 64. Following the USA's export restrictions on Huawei, NeoPhotonics has since reduced its Q2 revenue guidance by $13m from $88–93m to $75–80m. With future quarters possibly hit more fully, the firm is "evaluating restructuring options to be cash neutral at a lower revenue level" (page 65).

Similarly, Milpitas-based opto firm Lumentum (18% of whose March-quarter revenue came from Huawei) has cut its June-quarter revenue guidance by $30–35m from $405–425m to $375–390m (see page 67). II–VI Inc (which is acquiring California-based fellow opto firm Finisar) will likewise be exposed to restriction on sales to Chinese telecom OEMs.

Among RF component makers, Qorvo (15% of whose full-year revenue came from Huawei) has cut its June-quarter guidance by $50m from $780–800m to $730–750m (page 11). Rival Skyworks is similarly exposed to exports to Chinese OEMs (20% of its Mobile revenue in the December quarter, albeit already weaker in the March quarter and compensated by more diversified Broad Market business — see page 12).

Epiwafer foundry IQE says its "maximum risk exposure is less than 5% of total full-year 2019 revenue", mainly due to its Wireless business unit. Given its diversity of customers by both geography and end-application (via its Photonics and Infrared business units) as well as second-half 2019 market opportunities, IQE is maintaining its full-year guidance (page 35).

Such diversification has already (over the last few years) been enforced on MOCVD system makers Veeco of the USA and Aixtron of Germany, in response to the commoditization of blue LEDs by San'an etc as well as the encroachment by rival domestic Chinese MOCVD makers like AMEC. China has settled at just 10% of Veeco's Q1 revenue (see page 38). Both Veeco and Aixtron have focused on higher-value applications such as vertical-cavity surface-emitting lasers (for 3D sensing) and wide-bandgap gallium nitride (GaN) and silicon carbide (SiC) for RF and power electronics.

Similarly, while finalizing the sale of its Lighting business to Ideal Industries (page 51), LED maker Cree is focusing further on its Wolfspeed Power & RF business (which now comprises over 50% of Cree's revenue — see page 50) by unveiling a $1bn, five-year investment to expand its capacity for SiC materials and GaN-on-SiC device production capacity in Durham, NC, USA (page 20). As well as 5G infrastructure, a burgeoning application for SiC-based devices is electric vehicles (EVs), with Germany's VW choosing Cree as its exclusive SiC partner (page 21).

Although the US–China trade dispute in the near term may impact 5G more, applications such as EVs show the value of diversification for compound semiconductor firms spanning materials technologies.

Mark Telford, Editor

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

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- 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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Mini-LED backlit displays to appear in 2019 and challenge OLEDs

After three years of mini-LED backlight technology development, mini-LEDs will finally make an official appearance on displays in 2019 and compete directly with organic light-emitting diodes (OLEDs), according to the '2019 Mini LED and HDR High-End Display Market Report' by LEDinside (a division of TrendForce). With its eyes having been set on the advantages of mini-LED technology for a while, Apple is also eager to strike collaborations with suppliers in Taiwan and Japan to introduce this technology into desktop displays, notebooks and tablets.

Mini-LEDs possess a local dimming function with a contrast effect similar to that of OLED displays. But, on some product lines, costs for mini-LED backlit displays may even be lower than their OLED counterparts, reckons LEDinside. For traditional liquid crystal display (LCD) panel makers, this translates into an opportunity to re-upgrade product specs and a chance to compete with OLED technology.

Costs to become key to backlit mini-LED mass-production feasibility

Since mini-LED backlight technology only differs from traditional ones in its greater usage of mini-LED chips, panel manufacturers only have to redesign driver ICs, select substrates and reinvest in a few items of equipment, such as those used in surface-mounting and equipment inspection. The availability of existing panel production lines for use allows panel manufacturers to undergo a painless, hassle-free upgrade, notes the report.

In contrast, the increased usage of LEDs will certainly raise costs for traditional LCD panels. Finding a way to lower costs and narrow the gap between mini-LED backlit display and traditional LCD costs will be the key to mini-LED backlight prevalence.

From a supply-chain standpoint, Taiwan panel makers are lagging behind in OLED panel production capacity, and are thus the most motivated to develop mini-LED backlight technology solutions. AUO and Innolux worked with their respective LED subsidiaries in development: AUO with Lextar, and Innolux with AOT, Epileds and other companies as main collaborators. Through these partnerships, they hope to maintain the competitive edge that their LCD products previously possessed. Furthermore, Taiwanese LED giant Epistar, which focuses on advanced displays and backlight applications, is providing products custom made for customers and also has the ability to modify its own facilities.

China's vendors have also been actively developing micro-LED and mini-LED technologies. For example, Sanan has established the first epitaxial wafer and chip production lines for micro-LEDs in first-quarter 2019, and has already finished developing a micro-LED product that uses 20μm chips. Sanan has joined forces with Samsung, becoming Samsung's go-to supplier for mini-LEDs. Chinese panel supplier BOE has also announced that it is forming a joint venture with US-based company Rohinni to produce micro-LED and mini-LED solutions for display backlight sources. Their main aim is to ramp up transfer speed, precision and yield of LEDs to substrates and create cost-competitive products.

www.ledinside.com

Optoelectronics market growing at 7.41% CAGR from $36.88bn in 2018 to $56.63bn in 2024

The optoelectronics market is rising at a compound annual growth rate (CAGR) of 7.41% from $36.88bn in 2018 to $56.632bn in 2024, forecasts a report from market research firm Knowledege Sourcing Intelligence LLP.

Demand for photoelectric components is rising due to increasing demand for cameras worldwide. Further, increasing penetration of smartphones globally, and continuous development of the cameras in them, will further drive market growth in the coming years. The Asia Pacific region will hold the largest market share and will also grow at a good CAGR due to rapid industrialization and the increase in manufacturing activity in the region.

Companies covered in the report include: Texas Instruments Inc, Analog Devices Inc, Maxim Integrated, Renesas Electronics, NXP Semiconductors, Infineon Technologies AG, STMicroelectronics, Microchip Technologies, ON Semiconductor, Vishay Intertechnology Inc, Rohm Semiconductor, Samsung Group, TE Connectivity, TDK Corp and Broadcom Inc.

www.researchandmarkets.com/reports/4767004/global-optoelectronics-market-forecasts-from

Anti-bacterial UV-C LED applications driving stable growth in UV-LED market

UV-LED revenue growing at 29% CAGR to $991m in 2023

UV LED makers did not see explosive growth in revenue as expected for 2018 due to the global recession yet they did see a steady increase, according to the report '2019 Deep UV LED Application Market- Sterilization, Purification and Water Treatment Markets' by LEDinside (a division of TrendForce). UV-LED revenues are expected to ride UV-C LED market demand and are rising at a compound annual growth rate (CAGR) of 29% from $223m in 2017 to US$991m in 2023.

According to analyses by research manager Joanne Wu, as Japanese and Korean manufacturers move eagerly into the UV LED market the global supplier rankings by revenue have been reshuffled in 2018, to Nitride Semiconductors, Seoul Viosys, LG Innotek, Nichia and Epitop (i.e. with Nitride Semiconductors rising from third in 2017, overtaking Seoul Viosys and LG Innotek).

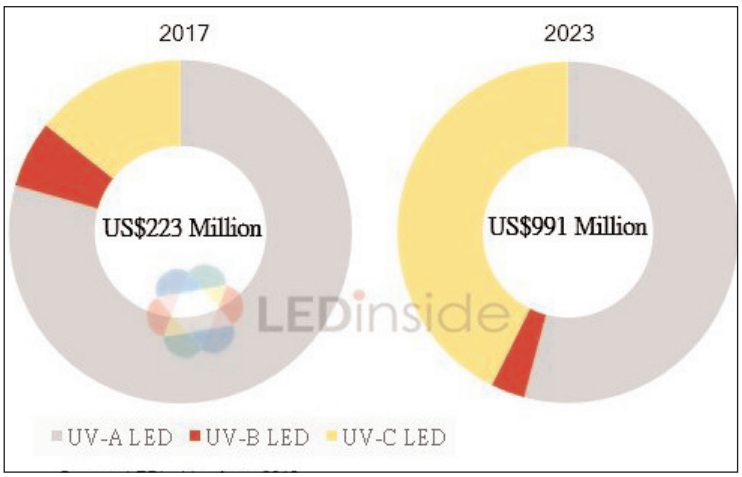
A glance at demand shows that UV-C LED applications continue to be the powerhouse for market growth. LEDinside forecasts that 2019 will see vigorous UV-C LED product development by many LED makers, including Nichia, OSRAM Opto Semiconductors, UVphototonics, Violumas and others, injecting new momentum into the market.

Existing UV-C external quantum efficiencies (EQEs) average 1–3%, while industry leader LG Innotek's EQE may reach up to 4.33%. Other suppliers such as Stanley, DOWA, Nitride Semiconductors and Seoul Viosys also continue to raise product efficiencies.

Nichia released its 280nm-wavelength UV-C LED products in April, while OSRAM is poised to release UV-C LED products in second-half 2019. Taiwanese suppliers such as Epistar and Lextar have launched 275–285nm UV-C LED products, whereas Bioraytron has launched a 265nm UV-C LED. Other companies such as Everlight, Lite-On and UVT are also making their way into UV-C LED markets.

Rank	2017	2018
1	Seoul Viosys	Nitride Semiconductors
2	LG Innotek	Seoul Viosys
3	Nitride Semiconductors	LG Innotek
4	Nichia	Nichia
5	Epitop	Epitop

UV-LED supplier rankings for 2017 and 2018.



UV LED revenue in 2017 and 2023 (forecast).

Suppliers active in UV-C LED product development; market to split into two

There are three main motivators for UV-C LED application market growth: surface/air sterilization, static water sterilization, and flowing water sterilization.

Static water and surface disinfection (for air purification and appliances etc) have more relaxed exposure time requirements and are used in a wide range of applications. They also gave rise to many emerging markets, including baby products, everyday cell phones, escalators, household products (such as toothbrushes), toiletries, cabinets, sport bottles and thermos flasks.

Flowing water sterilization is more demanding due to its fast-acting nature, and naturally requires a higher power level. The market for household water treatment includes applications such as water dispensers, hot and cold kitchen water, whole house water filters and baby products (baby formula makers) etc.

Commercially and industrially speaking, the global water treatment market is about US$20bn, becoming the UV-C LED target market with the most potential for development. The three main methods used in water sterilization are gravity-based purification, RO (reverse osmosis) purification and UV purification. RO purification is a widely used technology, yet it should still be used in conjunction with UV purification to rid water of bacteria and viruses and lower overall TOC (total organic carbon) concentration.

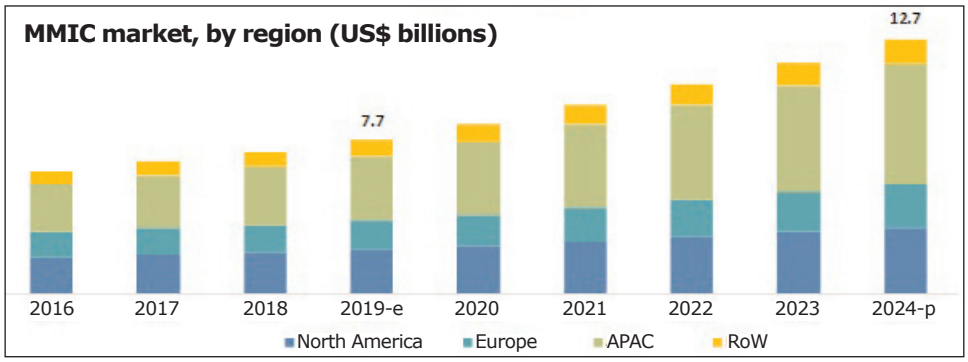
To meet the demands of the water treatment market, Japanese and Korean manufacturers are actively developing high-power UV-C LEDs and moving into the market for flowing water modules. LEDinside predicts that the UV-C LED market will diverge into two: a general consumer market and an advanced commercial/industrial market.

www.ledinside.com

MMIC market growing at 10.6% CAGR from $7.7bn to $12.7bn by 2024

Asia-Pacific to remain largest region

The monolithic microwave integrated circuit (MMIC) market will grow at a compound annual growth rate (CAGR) of 10.6% from $7.7bn in 2019 to $12.7bn by 2024, according to a report 'Monolithic Microwave IC (MMIC) Market by Component (Power Amplifiers, LNA, Attenuators), Material Type (GaAs, InP), Frequency Band (L, S, C), Technology (MESFET, HEMT), Application (Automotive, A&D), and Geography - Global Forecast to 2024' from Global Information Inc. Factors driving growth include: increased demand from the smartphone industry; increasing adoption of E-band frequencies to meet the growing bandwidth requirements of the space, defense and wireless communication infrastructure sectors; and rising defense spending of countries globally.



Power amplifier segment to hold largest market share

Most power amplifiers are designed for a specific application producing a specific type of signal, signal modulation scheme, and a set of specifications such as frequency range, gain (dB), gain flatness (dB), supply voltage (V_{DC}), power decibels (dB-milliwatt), and package type.

MMICs developed using GaN offer high input power survivability of 40dBm, potentially eliminating the requirement for a power limiter in broadband communication, EW (electronic warfare) instrumentation or radar applications.

Growth of this segment can be attributed to the increased use of power amplifiers in defense, automotive, smartphone and wireless communication applications, driven by the continuously growing demand for high data transfer rates in communication systems.

GaN material segment to grow at highest CAGR

As well as its high-brightness emission in optoelectronics, gallium nitride (GaN) is an emerging alternative to silicon due to its high power efficiency, superior high-frequency handling capacity and its flexibility to be used with various substrates such as silicon, sapphire and silicon carbide (SiC). Since it is a hard and mechanically stable material with a wide bandgap and high heat capacity and thermal conductivity, MMICs developed using GaN offer large bandwidth, improved power density and high efficiency to support the future cellular infrastructure such as 5G for the mobile base-station transmitters.

E-pHEMT device segment to grow fastest

Enhancement-mode pseudomorphic high-electron-mobility transistors (E-pHEMTs) offer superior output power and high efficiency with bias voltages of less than $+3V_{DC}$. For commercial communication systems, E-pHEMTs offer a combination of high gain, low noise and wide dynamic range in high-linearity MMIC applications. These transistors can economically provide superior electrical performance in very high frequency (VHF) and ultra high frequency (UHF) wireless communication bands commonly associated with technologies such as gallium arsenide (GaAs) MESFETs and depletion-mode pHEMTs.

Asia-Pacific to be largest market by region

Asia-Pacific was the largest MMIC market by geographic region in 2018. The main growth drivers are the expanding cellular infrastructure in the region and the increasing number of telecom equipment shipments in countries such as China and India. Japan has been a dominant player in the global semiconductor industry since the 1960s, while the strategy of China is to develop the highest-performance products at the lowest cost, which has helped it gain a large share of the Asia-Pacific MMIC market. The increased production of electronic devices in the region due to the low manufacturing cost and availability of cheap labor is another growth driver. Rising demand for smartphones, digital televisions, automobile electronics, and electromedical devices in the Asia-Pacific region is expected to contribute to growth of the MMIC market in the region.

Key players in the MMIC market are cited as Analog Devices (USA), NXP Semiconductor (Netherlands), MACOM (USA), Qorvo (USA), Skyworks Solutions (USA), Broadcom (USA), Infineon Technologies (Germany), Maxim Integrated (USA), Mini-Circuits (USA), OMMIC (France), WIN Semiconductors (Taiwan), United Monolithic Semiconductors (UMS) (France), Custom MMIC Design Services (USA), Microarray Technologies (China), VectraWave (France), BeRex (South Korea), and Arralis (Ireland).

www.giiresearch.com/report/mama833816-monolithic-microwave-ic-mmic-market-by-component.html

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Qorvo reports greater-then-expected quarterly revenue, driven by content gains

Continued growth in Infrastructure & Defense Products mitigating lower Mobile Product end-product volumes

Qorvo Inc of Greensboro, NC, USA (which provides core technologies and RF solutions for mobile, infrastructure and defense applications) has reported full-year revenue growth of 4% from $2.974bn for fiscal 2018 to $3.090bn for fiscal 2019 (ended 30 March).

Fiscal fourth-quarter 2019 revenue was $680.9m, down 18.2% on $832.3m last quarter but up 2.5% on $664.4m a year ago (and above the $660–680m guidance range).

In particular, Mobile Product (MP) revenue was $443m, down 26% on $602m last quarter but only 2% on $452m a year ago. "We executed well on a challenging macro environment, capitalizing on added content and integration trends at multiple customers," says president & CEO Bob Bruggeworth. "We did enjoy a significant content expansion with both Huawei [in China] and our largest Korean-based customer," says Eric Creviston, corporate VP & Mobile Products Group president. "Qorvo's gains are being driven by leadership across product categories, including bulk acoustic wave (BAW)-based solutions, envelope trackers and tuners," states Bruggeworth. The firm achieved record revenue for its BAW-based band 1/3 quadplexers and secured the first design wins for its highly integrated BAW-based hexaplexers, enabling higher orders of carrier aggregation in next-generation 5G handsets.

Qorvo reached a milestone by supplying production volumes of its highly integrated BAW-based mid/high-band power amplifier duplexers (PADs) to the world's top six smartphone OEMs, and it received its first orders for 5G variants (for production this calendar year). Qorvo also introduced the industry's first stand-alone envelope tracking (ET) power management integrated circuit (PMIC) capable of modulating the power supply at 100MHz for 5G New Radio (NR) operation. "Our envelope trackers and antenna tuners are supporting some of the world's most popular wearable devices, enhancing connectivity and increasing battery life for this rapidly growing category," says Bruggeworth. Finally, Qorvo sampled BAW-based 5G antennaplexers, enabling the use of existing antenna architectures for future 5G devices.

Infrastructure & Defense Products (IDP) revenue grew further, up 12.3% on $212m a year ago and 3.5% on the record $230m last quarter to $238m (the 12th consecutive quarter and third year of double-digit year-on-year growth, and a record 35% of total revenue).

In defense applications, Qorvo secured a multi-year design win to supply gallium arsenide (GaAs) and gallium nitride (GaN) components to Lockheed Martin for a US Department of Defense ground-based radar program.

In connectivity, IDP won the entire RF front-end section for meshed WiFi access points by a leading manufacturer of WiFi home networking systems. "We won on the breadth of our technology portfolio and our ability to supply superior BAW filtering and WiFi front ends," says Bruggeworth. In automotive, Qorvo expanded its support of 5G and cellular vehicle-to-everything for multiple automotive OEMs (with commercial rollout of front-end modules now expected to begin in late 2019).

Infrastructure was especially strong, with shipments generally matching the ramp up of reported 5G base-station deployments. "We've almost doubled our business in three of the top four OEMs year-over-year this quarter," says James Klein, corporate VP & IDP president. "We increased our support of 5G massive MIMO infrastructure deployments and secured new design wins across all anticipated sub-6GHz 5G frequency bands," notes Bruggeworth.

"We're able to leverage the breadth of our defense and base-station capabilities to address the demands of next-generation 5G networks, from 6GHz frequencies through millimeter wave," he adds. "In millimetre-wave applications, our experience enabling phased-array radars with leading-edge compound semiconductor technologies is helping us to support the higher frequencies and beam-steering requirements of next-generation cellular base stations."

On a non-GAAP basis, gross margin was 48.2%, down from 49.5% last quarter but up from 48% a year ago and above the expected 47%. This was due to lower costs related to inventory builds in support of the firm's near-term outlook and improving manufacturing efficiency, despite lower utilization, including the impact of the phased closure of its surface acoustic wave (SAW) fab in Apopka, Florida, and idling its fab in Farmers Branch, Texas, involving period costs of $13m.

Operating expenses are up, from $150.5m last quarter to $160.8m, due to higher personnel costs (including seasonal payroll effects).

Net income was $150.9m ($1.22 per diluted share, above the expected $1.05), down from $234.1m ($1.85 per diluted share) last quarter but up from $138.6m ($1.07 per diluted share) a year ago. For the full fiscal year, EPS grew by 12% to $5.76. "Despite a softer-than-expected second half, we delivered another year of double-digit earnings growth," notes chief financial officer Mark Murphy.

Operating cash flow was $187m and reflected inventory builds to aid near-term customer demand. Capital expenditure (CapEx) was a year-low of $35.3m, and the lowest

as a proportion of revenue for several years (making full-year CapEx $221m, or 7% of revenue). Free cash flow was hence $152m.

During the quarter Qorvo repurchased nearly $300m in stock (making $638m for the full fiscal year, or 108% of free cash flow). Qorvo also repurchased $68m of its remaining 7% coupon 2025 notes and added $270m to its 2026 notes at a rate under 5.2%.

Cash and cash equivalents overall hence fell from $926m to $711m.

"Qorvo delivered a solid March quarter with revenue and EPS above the midpoint of our guidance, driven by content gains, operational excellence and a broad market exposure to long-term growth trends, including 5G," Bruggeworth summarizes.

"We ended our fiscal year 2019 strongly with March quarter revenue, gross margin and earnings per share well above our initial expectations," notes Murphy.

"We are poised to benefit from multiple long-term growth trends, including 5G, IoT and the proliferation of GaN," reckons Bruggeworth.

On 6 May, Qorvo completed the acquisition of Active-Semi International Inc of Dallas, TX, USA, a fabless supplier of PMICs and power application controllers (PACs). "We are eager to leverage our scale, sales channel and customer relationships to accelerate the adoption of their programmable power management solutions. We are also excited to bring their power management technologies to our existing customers, and extend our reach into new high-growth power management markets [worth $3bn]," he adds. "Our efficiency is a critical requirement, and power management solutions intersect multiple growth drivers for Qorvo, including 5G base stations, defense, automotive and IoT."

"We forecast an even stronger start to fiscal year 2020," says Murphy. For fiscal first-quarter 2020 (to end-June 2019), Qorvo expects revenue to grow to $780–800m. "We expect IDP to post another quarter of double-digit year-over-year organic growth and to be up sequentially with the addition of Active-Semi [albeit flattish organically]," says Murphy. "For Mobile, we are forecasting robust sequential and year-over-year growth, including year-over-year growth in the quarter at our three largest customers."

Gross margin should fall to 45–45.5% due to product mix and manufacturing costs. OpEx should rise to $173m due to higher personnel and development program costs as well as the addition of Active-Semi. "We expect OpEx to remain around these levels through the year," says Murphy. Diluted EPS should still rise to $1.30.

For full-year fiscal 2020, Qorvo forecasts revenue growth of 4%, including continued organic growth plus $50m from Active-Semi. Specifically, while Mobile should stay roughly flat for the year, IDP should show double-digit growth. "We expect the Active-Semi programmable power management business will be accretive to gross margins and contribute a small amount to earnings in fiscal 2020," says Murphy.

Base-station business will effectively double, driven largely by 5G deployments (mostly massive MIMO and including GaN-based devices), forecasts Klein. "We'll also see our GaN revenue double as well as we go through the year, and we expect most of that is going to come from base station, although we've had some really key wins on the defense side as well," he notes.

Higher quarterly gross margins through the balance of the year should amount to full-year margin of 48% (with the long-term target remaining 50%). CapEx should be less than $250m, weighted towards expanding and improving BAW, GaN and GaAs capabilities.

"For fiscal year 2020, we currently project growth in revenue, earnings and free cash flow. This outlook reflects the strength we are seeing in a number of our end markets and the health of our distribution channels," concludes Murphy.

Qorvo cuts June-quarter revenue guidance from $780–800m to $730–750m due to US export ban on sales to China's Huawei

In response to the US Department of Commerce's Bureau of Industry and Security (BIS) adding Huawei Technologies Co Ltd and 68 of its affiliates to its 'Entity List' prohibiting the sale to Huawei of products covered by Export Administration Regulations (EAR) without obtaining an appropriate export license, Qorvo has updated the financial guidance it provided on 7 May for its fiscal first-quarter 2020 (to end-June 2019) and full-year 2020.

Sales from Mobile Products (MP) and Infrastructure & Defense Products (IDP) operating segments to Huawei and affiliates accounted for about $469m (15%) of Qorvo's total revenue in its fiscal full-year 2019 (ended 30 March). Qorvo is continuing to review the impact of the BIS action on its business, including its ability to apply for and obtain licenses to allow it to ship products to Huawei in the future. Pending further developments, Qorvo has ceased shipments to Huawei and its affiliates and cannot predict when it will be able to resume such shipments.

Meanwhile, Qorvo is revising its fiscal Q1/2020 guidance for non-GAAP revenue from $780–800m to $730–750m, for gross margin from 45–45.5% to 45.5%, and for diluted EPS from $1.30 to $1.15.

Currently, for fiscal second-quarter 2020, Qorvo's assumes no sales to Huawei and is projecting revenue to be roughly flat sequentially. However, due to the ongoing uncertainty of this situation, the firm is not providing any additional update to its fiscal 2020 guidance.

www.qorvo.com

Skyworks' quarterly revenue falls 11% year-on-year to $810m

Continued growth in Broad Markets mitigates decline in Mobile business, particularly across China end-markets

For fiscal second-quarter 2019 (ended 29 March), Skyworks Solutions Inc of Woburn, MA, USA (which manufactures analog and mixed-signal semiconductors) has reported revenue of $810.4m, down 16.6% on $972m last quarter and 11.3% on $913.4m a year ago.

By market sector, Mobile (Integrated Mobile Systems and Power Amplifiers) fell from 73% of total revenue last quarter to 67%, while Broad Markets rose from 27% to 33%.

"Continued strengthen in our high-growth Broad Market business [with both sequential and year-over-year growth] allowed us to partially offset unit declines in Mobile, particularly across China end-markets," says senior VP & chief financial officer Kris Sennesael.

"Skyworks delivered another quarter of solid financial performance leveraging the strength of our business model and momentum across our high-growth Broad Markets and IoT [Internet of Things] portfolio," says president & CEO Liam K. Griffin.

On a non-GAAP basis, gross margin was 50.7%, down from 51% last quarter but level with a year ago.

Operating expenses (OpEx) have been cut by 3% from $139m last quarter to $135m.

Net income was $256.6m ($1.47 per diluted share), down from $324.6m ($1.83 per diluted share) last quarter and $302.4m ($1.64 per diluted share) a year ago.

Cash flow from operations was $192.1m. Capital expenditure (CapEx) was $96.7m. During the quarter, Skyworks distributed $66m in dividends and repurchased 1.7 million shares of common stock for $141.5m. Overall, cash, cash equivalents and marketable securities hence fell from $1102m to $991m. The firm has no debt.

Since the end of the quarter, Skyworks' board of directors has declared a cash dividend of $0.38 per share of the firm's common stock, payable on 11 June to stockholders of record at the close of business on 21 May.

"During the quarter, our design-win execution accelerated, building a growing pipeline of new opportunities while positioning us for continued traction across a diverse set of end markets, applications and customers," says Griffin.

"For example, in the quarter we led the transition to the latest WiFi-6 standard with platform wins at Aruba, Asus, Cisco and Netgear. We gained content with our SkyOne platform and DRx engines in Samsung's flagship Galaxy S10 smartphones. We leveraged our portfolio of audio SOCs supporting new high-fidelity stereo headsets, Samsung's premium sound bars, and gaming applications. We enabled long-range machine-to-machine (M2M) communication in smart meters and street lighting, and we captured sockets in the first commercially available 5G indoor access point. We also secured massive MIMO infrastructure wins with Ericsson and Nokia as they roll out 5G. We expanded our automotive footprint with LTE devices supporting eCall, remote entry, in-cabin entertainment and additional features. We extended our reach across new categories in both aerospace and defense, leveraging our new C-band filtering solutions," Griffin adds.

Driven by such strategic wins and content gains in mobile, as well as traction across diverse customers, markets and applications, Skyworks expects revenue to rebound to $815–835m in fiscal third-quarter 2019 (to end- June). Gross margin should be 50.5–51%. Diluted earnings per share should grow to $1.50

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"Looking ahead, we are well positioned to outperform with seasonal product ramps and 5G gaining further traction," says Sennesael. "Broad Markets business continues to outperform and is on path for double-digit growth again in fiscal 2019," adds Griffin.

"Our advanced connectivity solutions are enabling the critical wireless protocols that form the backbone of today's mobile economy," says Griffin. "From data center to cloud, media and entertainment, to e-commerce and ride-hailing services, our innovative technology is underpinning the newest generation of connected applications. As we transition to 5G, these connections become increasingly more important," he adds. "Through our unique systems expertise, strategic partnerships and global scale, Skyworks is well positioned to address the technical challenges and complexity of 5G, capitalizing on a new era of unprecedented opportunity."

www.skyworksinc.com

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IN BRIEF

pSemi hires VP of IP & licensing

Murata company pSemi Corp of San Diego, CA, USA — a fabless provider of RFICs based on SOI — has appointed Rajappan 'BG' Balagopal as VP of intellectual property and licensing, driving strategic development and management of its patent portfolio.

In over 20 years in IP management (including strategy, valuation, supply chain management, general legal counseling, business development and transactions), Balagopal has supervised interdisciplinary teams of attorneys, technologists and business professionals to solve complex IP problems, generate IP revenues and reduce IP costs and risks for large and small companies. He has also been VP of technology IP management at The Walt Disney Company and director of patent & technology transactions at Intel. Prior to joining pSemi, he ran an IP law and business consulting practice, serving diverse clients in industrial equipment, consumer products, semiconductors, communications, media and software.

www.psemi.com

Anokiwave adds chief strategy officer

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 added to its executive leadership team by appointing Alastair Upton to the new position of chief strategy officer, based at the firm's office in Billerica, MA, and reporting directly to CEO Robert Donahue.

Upton will be responsible for developing and executing Anokiwave's business strategy in all key markets, including responsibility for the strategic marketing organization, driving the company product roadmaps, and managing partnership programs.

Prior to assuming the CSO role, Upton was senior VP of business development, responsible for capturing new 5G mmWave business opportunities, developing working relationships with partners, including network operators, and for providing overall telecoms expertise.

Upton joined Anokiwave in June 2018, bringing more than 35 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, Upton served in a variety of leadership roles including general manager, VP of engineering, business unit director, and senior director of RF product marketing. His global experience across several generations of technology and networks provides him with a comprehensive perspective on all Anokiwave's mmWave markets, says the firm.

"Alastair is uniquely qualified to drive business strategy and growth," reckons CEO Robert Donahue. "Alastair is an experienced executive with a history of visionary ideas and successful implementation, and is a valuable asset as we continue to ramp our business in 5G, SATCOM and radar markets," he adds. "Anokiwave and its customers will benefit greatly from Alastair's drive to develop new, innovative products, and to identify and create industry collaborations that foster market and company growth."

Alastair earned his MS Executive Engineering Degree at the University of Pennsylvania and his B.Sc. Electronic & Electrical Engineering at University of Leeds in the UK.

www.anokiwave.com

Analog Devices promotes VP of Communications business unit to chief technology officer

Analog Devices Inc of Norwood, MA, USA (which supplies mixed-signal ICs for cable access) says that Daniel Leibholz, VP of ADI's Communications business unit, has been named chief technology officer, developing and leading the firm's technology strategy for applications across end-markets.

"Over the years we have built ADI's brand as a premier analog technology and solutions provider for B2B applications," says president & CEO Vincent Roche. "In our rapidly evolving industry, staying on the cutting edge is essential as we seek to solve the very hardest problems faced by our customers. Dan's combination of technology vision, experience developing ADI's digital and analog offerings, and strong business background will help us to continue to deliver innovations of maximum impact for our customers and their markets."

As VP of ADI's Communications business unit, Leibholz oversaw growth while the firm delivered what are said to be best-in-class offerings for the 5G wireless and wired markets. Previously, he led a various teams across ADI, including Digital Signal Processing and Consumer/Portable technologies. Leibholz joined the firm in 2008 from Advanced Micro Devices Inc, where he was an AMD Fellow. Prior to that, he was a Distinguished Engineer at Sun Microsystems Inc.

www.analog.com

Altum RF opens office in Eindhoven

Altum RF (a start-up that designs high-performance millimeter-wave to digital solutions for next-generation markets and applications) has announced the opening of its office located on the campus of Eindhoven University of Technology, The Netherlands .

Founded in 20018, Altum RF's engineers are employing decades of modeling expertise and system applications knowledge to develop products based on proven technologies like gallium arsenide (GaAs), gallium nitride (GaN), silicon germanium (SiGe) or RF CMOS for commercial and industrial applications. Working with both customers and global partners on technical support and customer service, the firm says it can significantly shorten product development cycles by managing the entire supply chain from design to packaging, testing and qualification. Applications span telecom, 5G, Satcom, radar sensors, test & measurement, aerospace & defense and industrial, scientific & medical

(ISM) applications. Altum RF adds that it has strategic roadmaps to rapidly expand its product portfolio.

"Opening an office on this university campus gives us the strategic advantages of access to top engineering talent and to leading-edge electrical engineering research and development," says CEO Greg Baker. "We work closely with electrical engineering research groups and collaborate with other start-ups to develop ground-breaking technology, so this location is ideal," he reckons. "There is also an excellent source of high-tech talent in this region, which is important for our expansion plans in the future."

IN BRIEF

R&D office opened in Sydney, Australia

Altum RF has announced the opening of its Sydney, Australia R&D office. The laboratory and office space is situated in the area of Ultimo, adjacent to the Sydney Innovation and Technology Precinct and a short walk from Sydney University, University of Technology Sydney and Central Station.

"Altum RF celebrates the opening of its Australian research and development office, which is located in an academically charged area and adjacent to the epicenter of the Asia-Pacific innovation landscape," says CEO Greg Baker. "Our vice president of engineering Tony Fattorini will be based here and lead a growing team of highly experienced engineers that have been developing RF and microwave components for decades."

www.altumrf.com

Founder Baker made CEO; co-founder Fattorini VP engineering

Altum RF has announced its founder Greg Baker as its CEO.

With more than 25 years of experience in the RF and microwave semiconductor industry (including component design, business development, marketing and sales), Baker has a clear understanding of product development, operations and supply chain management, customer partnerships, sales channels and strategic marketing.

Most recently with MACOM as senior VP & general manager of its RF & Microwave business unit, Baker also previously served as CEO of Nitronex LLC. Prior to that, he was general manager of RF Small Signal Products at NXP Semiconductors and senior VP of sales & marketing at Mimix Broadband Inc. Earlier in his career, he held numerous technical and managerial positions at

Sirenza Microdevices over 10 years, including VP of international sales, VP & general manager of the Standard Products unit, VP of engineering, and senior director of marketing.

"It is an exciting time in the RF and microwave industry, and I am eager to start this new international company and build a strong technical team to support customers and meet the market's requirements for innovative products," says Baker. "I look forward to working with our customers to provide world-class technical support and solutions, with a focus on quick time-to-market utilizing our top-tier operations supply chain for fabrication, packaging and testing of products."

Also, co-founder Tony Fattorini has been made VP of engineering.

With more than 20 years of new product development, technology innovation and design-for-manufacture experience, his background includes microwave and millimeter-wave circuit design, packaging techniques, thermal analysis and team management.

Most recently with MACOM as engineering manager and senior principal engineer, Fattorini had the responsibilities of developing new MMIC products from concept to production release and managing a team of design engineers. Prior to that, he was advanced technology leader and senior MMIC designer at Mimix Broadband (acquired by MACOM). Also, at Siemens he was a design engineer in the Microwave Circuits Group at Roke Manor Research.

Marktech develops InP HBT epi technology for 5G large-capacity signal processing applications

Marktech Optoelectronics Inc of Latham, NY, USA, a privately held designer and manufacturer of standard and custom optoelectronics components and assemblies — including UV, visible, near-infrared (NIR) and short-wave infrared (SWIR) emitters, detectors, indium phosphide (InP) epiwafers and other materials — has developed in-house InP epitaxial crystal mass-production technologies for ultra-high-speed (5G) large-capacity signal processing applications.

The R&D was carried out under the direction of Dr Gako Araki, a 25-year expert in ultra-high-speed InP heterojunction bipolar transistor (HBT) and high-electron-mobility transistor (HEMT) epitaxial crystal growth technologies. A member of the Marktech team since 2010, Araki's experience includes a series of related R&D tenures at the New Energy and Industrial Technology Development Organization (NEDO) and NTT Advance Technology Corp, both in Tokyo, Japan.

Research was carried out in two distinct phases. Phase 1 consisted of ultra-high-speed InP epitaxial crystal growth technology development using small prototype metal-organic chemical vapor deposition (MOCVD) equipment (4x4-inch). Phase 2 consisted of actual ultra-high-speed InP epi manufacturing using large mass-production MOCVD equipment, known as GAKOUS (10x4-inch). Given that true InP-HBT epi performance testing requires electrical characteristic evaluation on larger HBT devices, Marktech instead focused R&D on developing new manufacturing equipment that could produce InP-HBT epi with the necessary uniform quality, size and quality for large-capacity ultra-high-speed signal processing applications. These goals were achieved via a new crystal manufacturing method: carbon-doped indium gallium arsenide (InGaAs) growth without hydrogen.

Marktech says that its evaluation of the small MOCVD prototype derived from this equipment demonstrated favorable performance characteristics. It then performed high-frequency HBT electrical characterization on the prototype with equally favorable results. Marktech was hence able to conclude its development of the new GAKOUS InP HBT MOCVD epi growth production equipment, whose capabilities offer the necessary prototype growth technology reproducibility and uniformity for manufacturing quality control in ultra-high-speed InP epi growth applications.

As a final accompaniment to this R&D, Marktech developed a series of non-destructive electron mobility measurement systems. This included time-resolve photoluminescence testing with infrared wavelength area measurements, a technique which proved useful in the performance of InGaAs channel layer quality checks, as well as HBT gain estimates by p-InGaAs base layers during crystal growth and production. Using these techniques, it was determined that the small prototype 4x4-inch MOCVD system exhibited satisfactory performance with new organic materials, independent source injection and a narrow gap between the injector and surface to avoid complex surface reactions. Marktech has hence developed its new GAKOUS MOCVD system to produce InP epi that could offer the same performance and reliability as that of the prototype, yet with sufficient quality and uniformity for larger-scale commercial InP HBT and HEMT epi production volumes.

"Our team's commitment to proactive R&D efforts that address diverse or emerging market sector needs has been well-demonstrated over the years, whether that's a 5G application, LiDAR, wearables, or others," says CEO Mark Campito. "We look forward to working in partnership with key 5G industry players to help them achieve their device performance goals."

www.marktechopto.com

MACOM board member Daly made president & CEO

MACOM Technology Solutions Holdings Inc of Lowell, MA, USA (which makes semiconductors, components and subassemblies for RF, microwave, millimeter-wave and lightwave applications) has appointed Stephen G. Daly (who has over 25 years of experience in the semiconductor industry) as president & CEO, succeeding John Croteau, who resigned on 15 May.

Croteau had served as president & CEO since December 2012, and will act in an advisory capacity for the next two months to ensure a smooth transition. "We thank John for his leadership for the past six and a half years and his commitment to MACOM's customers, employees and investors," comments John Ocampo, chairman of the board.

Prior to joining MACOM's board in 2015, for almost ten years Daly was chairman, president & CEO of Hittite Microwave Corp of Chelmsford, MA (a provider of analog and mixed-signal integrated circuits, modules and subsystems for commercial and military radio frequency, microwave and millimeterwave applications, acquired in 2014 by Analog Devices Inc). Daly's 17-year career at Hittite included leading its initial public offering in 2005 and establishing it as an innovative designer of high-performance semiconductor products that generated industry-leading profitability.

www.macom.com

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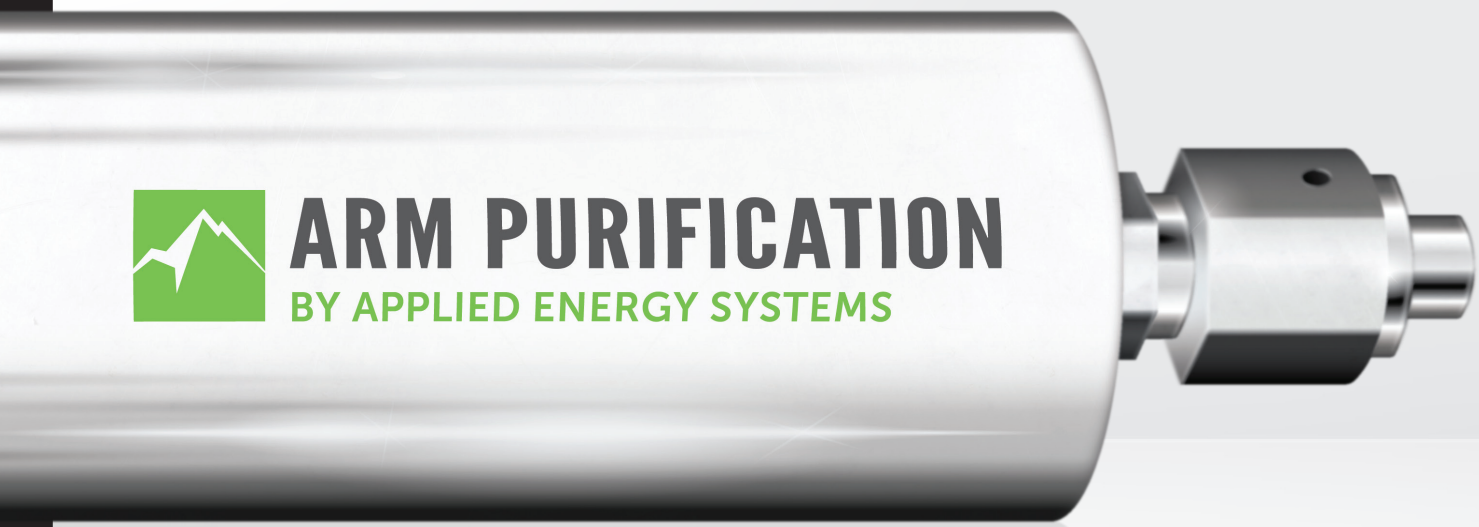

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ROHM buying Panasonic's diode & transistor unit

ROHM of Kyoto, Japan is acquiring part of the diode and transistor business of Kyoto-based Panasonic Semiconductor Solutions Co Ltd, a group company of Panasonic Corp of Osaka, Japan that was founded in 2014. The transfer is scheduled for October.

Established in 1958, ROHM's Semiconductor business has been developing, producing and selling semiconductor devices since the 1960s as a core business of the ROHM Group and claims to have the largest shares of the global markets for small-signal transistors and diodes. Looking ahead, given the strong prospects of continuous growth in the automotive electronics, industrial equipment and other markets, ROHM will be expanding its business in bipolar transistors, circuit-protective Zener diodes, TVS diodes and other products. As a part of that, ROHM is investing in a wide range of business resources in order to strengthen product lineups, further enhance product quality and ensure stable supplies. By acquiring the Panasonic business, ROHM aims to further expand its market share.

To ensure a smooth transition and stable supply to customers, ROHM will outsource production to Panasonic and maintain the same supply structure as before until the transfer is complete.

Going forward, both companies will be jointly preparing for the transfer of business, including obtaining all necessary approvals and permits.

www.rohm.com
http://panasonic.net

ROHM expands range of power devices to complete power solutions

At PCIM Europe 2019 (Power Conversion and Intelligent Motion) in Nuremberg, Germany (7–9 May), ROHM Semiconductor showcased power semiconductor solutions focused on E-mobility and power supply applications.

The firm says that, with its new developments resulting from its research and design initiatives, it can offer not only a full line-up of efficient, compact products for their applications but also a complete solution for the power tree.

Highlights include:

Automotive-grade SiC MOSFETs

In March, ROHM announced the addition of the SCT3xxxxxHR series to its range of automotive-grade silicon carbide MOSFETs, yielding what is claimed to be the largest lineup of AEC-Q101-qualified SiC MOSFETs providing the high reliability necessary for automotive onboard chargers and DC/DC converters.

Gate driver for SiC MOSFETs

The new series of isolated gate driver ICs for power MOSFETs will expand ROHM's existing product portfolio, offering new solutions to increase the flexibility and improve the design of industrial and automotive power systems. The lineup has a 3.75KV-isolation, AEC-Q100 gate driver device designed specifically to drive SiC power MOSFETs. It has a built-in active Miller clamping to prevent parasitic turn-on effects and integrates an under-voltage lock-out (UVLO) optimized to drive ROHM's SiC MOSFET, improving the reliability of the system, says the firm.

1700V/250A full-SiC power module

ROHM claims its 1700V/250A full-SiC power module has the highest level of reliability in high-temperature and high-humidity standards. With better switching characteristics than silicon solutions it allows the miniaturization of heat-sink and surrounded components in applications.

Power management ICs

Based on long experience with discrete power devices, ROHM also offers a range of system-on-chip (SoC) and application power management ICs for automotive, industrial and consumer market. The portfolio also includes isolated DC–DC regulators plus optimized AC–DC converters that allow the assembly of high-efficiency power supplies based on SiC technology.

ROHM Semiconductor Europe appoints Christian André as chairman and Toshimitsu Suzuki as president

ROHM Semiconductor Europe of Willich-Münchheide, near Dusseldorf, Germany (the European branch of Japan's ROHM Semiconductor) has strengthened its management board by appointing Toshimitsu Suzuki as president. Former acting president Christian André remains chairman.

André has been working for ROHM for 29 years, including 14 years as acting president. He will focus on the firm's next phase of growth and strategic vision to generate long-term value to customers and shareholders.

After being senior sales director for ROHM in Europe for over four years, Suzuki assumes full responsibility for the European business, setting new aims for further strategic development and implementation of products in the European market.

"He will contribute to scale up to a greater level the operational excellence," says André. "The strengthening of our management board is a necessary and consistent step in order to be well prepared for the future," he adds.

"Together, we will work to maximize the potential of our technology to drive the next growth of the company," says Suzuki.

www.rohm.com

AC/DC converter IC with built-in 1700V SiC MOSFET

Power semiconductor maker ROHM of Kyoto, Japan has announced the availability of the BM2SCQ12xT-LBZ series of AC/DC converter ICs with a built-in 1700V silicon carbide (SiC) MOSFET, optimized for 400V_{AC} industrial applications including ; lighting (e.g. street lamps), commercial AC systems and general-purpose AC servos and inverters used in high-power equipment.

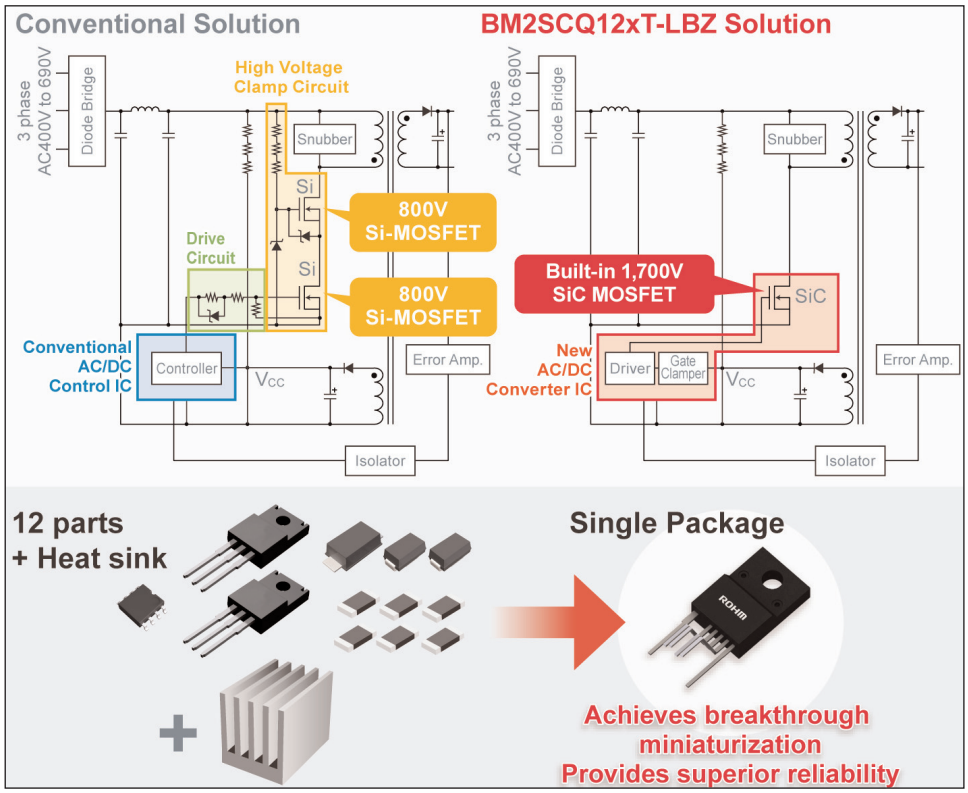
In recent years, the growing demand for energy saving has resulted in the adoption of power semiconductors such as SiC in 400V_{AC} industrial applications, since SiC power semiconductors deliver greater power efficiency, miniaturization and higher voltage capability than existing silicon power devices. Also, industrial equipment consists of a main power supply circuit and a built-in auxiliary power supply that supplies power to various control systems. The use of low-voltage silicon MOSFETs and insulated-gate bipolar transistors (IGBTs) limits the amount of power savings in auxiliary power supply.

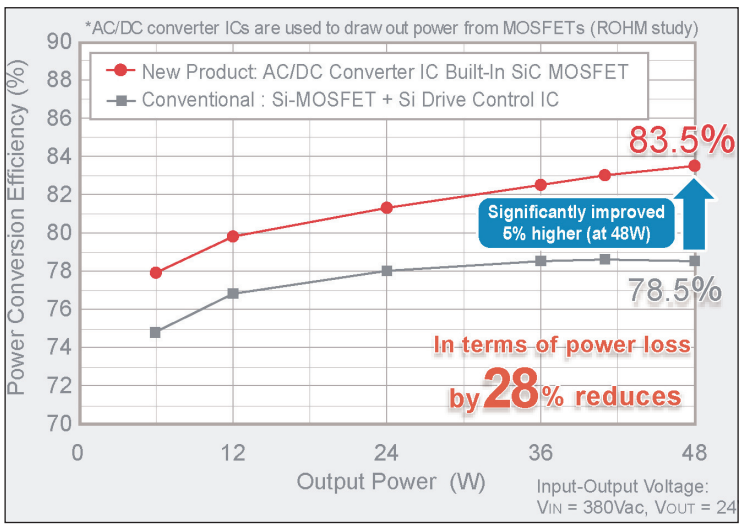
In response, ROHM has aimed to develop ICs that maximize the performance of SiC power semiconductors. In 2015, it was first to offer AC/DC converter ICs for driving high-voltage, low-loss SiC MOSFETs. Now, what's claimed to be the first AC/DC converter ICs with a built-in SiC MOSFET should further accelerate the adoption of AC/DC converters that use SiC MOSFETs in industrial equipment.

Furthermore, the BM2SCQ12xT-LBZ series integrates 1700V SiC MOSFETs, which is also reckoned to be an industry first. The series enables what are claimed to be breakthrough energy savings and facilitates efficient AC/DC converter design by resolving many of the issues encountered by designers using discrete solutions.

For example, incorporating a SiC MOSFET and control circuitry optimized for auxiliary power supplies for industrial equipment in a single package can significantly reduce the number of external parts required compared with conventional designs — from 12 parts 12 components (AC/DC converter IC, 800V silicon MOSFET x2, Zener diode x3, resistor x6) plus heat-sink to a single IC. The high withstand voltage and voltage noise resistance of the internal SiC MOSFET also make it possible to reduce the size of components used for noise suppression.

The new product also helps in minimizing both the component failure risk and the amount of resources required to develop systems using SiC MOSFETs.





Also, the internal SiC MOSFET and the built-in gate driver circuit optimized for it enable a 5% boost in power efficiency over conventional silicon MOSFETs (and a 28% reduction in power loss), it is reckoned. This can translate to a dramatic reduction in size, improved reliability and superior power savings in industrial applications, the firm adds.

ROHM says it is committed to developing not only power semiconductors such as SiC devices but also the ICs for controlling them, and to providing optimized solutions that contribute to greater energy savings and performance in industrial equipment.

The new product is available as samples now and in OEM quantities in May. Evaluation boards will be released later this year.

www.rohm.com/products/power-management/ac-dc-converters-ics

Cree investing $1bn to expand SiC materials production and power & RF fab capacity by up to 30-fold

Automotive-qualified North Fab to provide nearly 18 times more manufacturing area for power & RF devices; existing Durham fab to be converted into materials mega factory

As part of its long-term growth strategy, Cree Inc of Durham, NC, USA is to invest up to $1bn over five years in expanding its silicon carbide capacity with the development of an automated 200mm SiC fabrication facility ($450m) and a materials mega factory ($450m) at its US campus headquarters in Durham (together with $100m in other investments associated with growing the business), marking the firm's largest investment to date in fueling its Wolfspeed silicon carbide (SiC) and gallium nitride on silicon carbide (GaN-on-SiC) business.

Upon completion in 2024, the facilities will substantially increase the firm's silicon carbide materials capability and wafer fabrication capacity, targeting wide-bandgap semiconductor solutions that are enabling the technology shifts underway within the automotive, communications infrastructure and industrial markets.

"We continue to see great interest from the automotive and communications infrastructure sectors to leverage the benefits of silicon carbide to drive innovation. However, the demand for silicon carbide has long surpassed the available supply," says CEO Gregg Lowe. "We are announcing our largest-ever investment in production to dramatically increase this supply and help customers deliver transformative products and services to the marketplace," he adds. "This investment in equipment, infrastructure and our workforce is capable of increasing our silicon carbide wafer fabrication capacity up to 30-fold and our materials production by up to 30-fold compared to Q1 of fiscal year 2017, which is when we began the first phase of capacity expansion. We believe this will allow us to meet the expected growth in Wolfspeed silicon carbide material and device demand over the next five years and beyond."

A five-year investment will leverage Cree's North Fab building and refurbished 200mm equipment to yield an automotive-qualified production facility.

The plan will deliver extra capacity for its Wolfspeed silicon carbide business through the build out of an existing empty structure as a 253,000ft^2, 200mm power & RF wafer fabrication facility as an initial step to serve the projected market demand. The new North Fab is designed to be fully automotive qualified and will provide nearly 18 times more surface area for manufacturing than exists currently, opening initially with the production of 150mm wafers. The firm will convert its smaller existing Durham fabrication and materials facility into a materials mega factory.

"These silicon carbide manufacturing mega-hubs will accelerate the innovation of today's fastest-growing markets by producing solutions that help extend the range and reduce the charge times for electric vehicles, as well as support the rollout of 5G networks around the world," says Lowe. "This represents the largest capital investment in the history of silicon carbide and GaN technologies and production with a fiscally responsible approach," he believes. "By using existing facilities and installing a majority of refurbished tools, we believe we will be able to deliver a state-of-the-art 200mm-capable fab at approximately one-third of the cost of a new fab."

The expanded campus will also create high-tech job opportunities and serve as an advanced manufacturing workforce development initiative. Cree plans to partner with state and local community and four-year colleges to develop training programs to prepare its workforce for the long-term employment and growth opportunities that the new facilities will present.

www.cree.com

Cree chosen as silicon carbide partner for Volkswagen's 'Future Automotive Supply Tracks' program

Volkswagen and Cree to work with tier-1 and power module suppliers on silicon carbide-based electric vehicle projects

Cree Inc of Durham, NC, USA has been selected as the exclusive silicon carbide partner for Volkswagen Group's 'Future Automotive Supply Tracks' initiative (FAST). The aim of FAST is to work together to implement technical innovations more quickly than before and to realize global vehicle projects more efficiently and effectively.

"The Volkswagen Group has committed to launch almost 70 new electric models in the next ten years, which is up from our pledge of 50 and increases the projected number of vehicles to be built on the group's electric platforms from 15 million to 22 million in that timeframe," says Michael Baecker, head of Volkswagen Purchasing Connectivity. "An effective network is our key to success," he adds. "Our FAST partners are our strategic partners, each of them outstanding in their respective field."

The agreement connects two simultaneous revolutions: the automotive industry's move from internal combustion engines to electric vehicles (EVs) and the growing adoption of silicon carbide in the semiconductor market. It should also drive innovation for both parties.

Cree's CEO Gregg Lowe with Michael Baecker, head of Volkswagen Purchasing Connectivity during Volkswagen Group's FAST partner selection ceremony in Wolfsburg, Germany.

The use of silicon carbide accelerates the automotive industry's transformation to electric vehicles, enabling greater system efficiencies that result in electric cars with longer range and faster charging, while reducing cost, lowering weight and conserving space.

"Cree's technology is at the heart of the dramatic change underway in EVs, and we are committed to supporting the automotive industry as it transitions to more efficient, higher-performing SiC-based solutions," says Cree's CEO Gregg Lowe. "VW Group is a global power in the automotive field with a strong commitment to electric vehicles, and this partnership will leverage the advantages of silicon carbide to enable longer driving distances, shorter charge times and improved efficiency," he adds.

Volkswagen Group and Cree will be working with tier-one and power module suppliers to engineer SiC-based solutions for future Volkswagen Group vehicles. The partnership was unveiled on 10 May, after Cree announced on 7 May that it is expanding its manufacturing capacity for silicon carbide MOSFETs and wafers.

www.cree.com

GTAT settles with SEC on 2014 bankruptcy investigation

Privately held GT Advanced Technologies Inc, the parent company of GTAT Corp of Hudson, NH, USA (which produces crystal growth equipment for the solar, power electronics and optoelectronics industries as well as sapphire material for precision optics and other specialty industries) has entered into a settlement agreement with the US Securities and Exchange Commission (SEC) relating to an investigation into events leading up to the firm's bankruptcy filing in 2014.

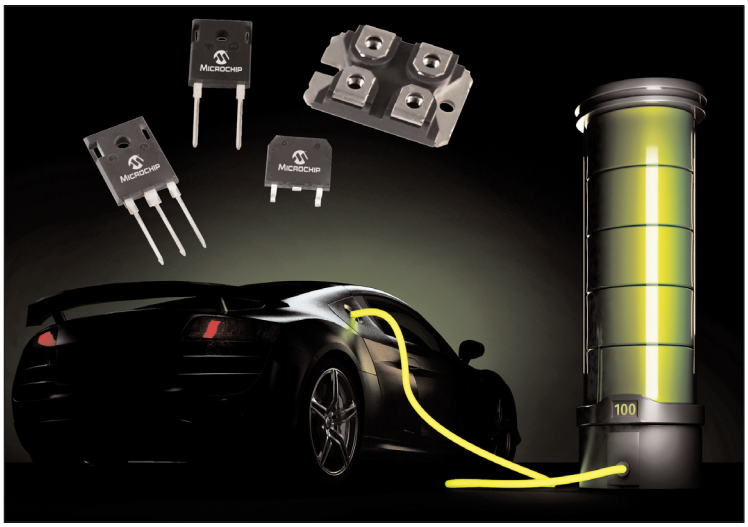
The firm says it welcomes the conclusion of the matter, which allows it to focus its efforts on its ongoing business. "The company is committed to operating its business with the upmost integrity and in compliance with all applicable laws and regulations, including those relating to record keeping and financial reporting," says Michèle Rayos, who became VP & chief financial officer in November 2017. "We have implemented and continue to review our internal controls to ensure best practices in this area," he adds.

"We are pleased to have the investigation behind us, allowing us to focus all our efforts into expanding the availability and use of silicon carbide and sapphire into current and future markets," states Greg Knight, who became president & CEO in September 2016 after its emergence from bankruptcy earlier that year. "Our technical expertise in crystal growth technologies enables us to be a game changer in advanced materials and we are dedicated to continually improving our products while exploring new opportunities," he adds.

GT Advanced Technologies Inc's shareholders are private equity firms and financial institutions, most of which were former creditors in the bankruptcy.

www.gtat.com

Microchip announces production release of 700V MOSFETs and 700V & 1200V Schottky barrier diodes



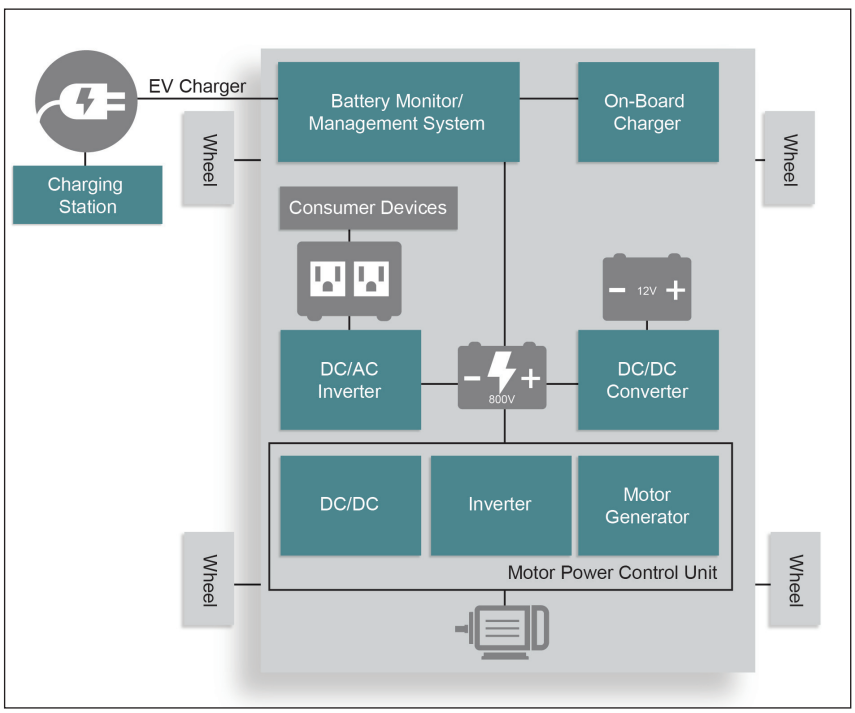
Microcontroller, mixed-signal, analog and Flash-IP solution provider Microchip Technology Inc of Chandler, AZ, USA has (via its Microsemi subsidiary) has announced the production release of a family of silicon carbide (SiC) power devices offering proven ruggedness and the performance benefits of wide-bandgap technology. Complemented by Microchip's broad range of microcontrollers (MCUs) and analog solutions, the SiC devices join a growing family of reliable SiC products that meet the needs of electric vehicles (EVs) and other high-power applications in fast-growing markets.

The new 700V SiC MOSFETs and 700V and 1200V SiC Schottky barrier diodes (SBDs) join Microchip's existing portfolio of SiC power modules. The more than 35 discrete products that Microchip has added to its portfolio are available in volume, supported by comprehensive development services, tools and reference designs, and offer ruggedness proven through rigorous testing. Microchip now offers a broad family of SiC die, discretes and power modules across a range of voltage, current ratings and package types.

"SiC technology's accelerated evolution and adoption has begun, and Microchip offers both a long heritage in this market and the ongoing commitment to playing a leadership role in ensuring that global supply continues to meet growing demand for these products," says Rich Simoncic, senior VP of Microchip's Discrete and Power Management business unit. "We are building out our portfolio with reliable products that are backed by the strong support infrastructure and supply chain that our customers need to execute and scale their development programs."

Microchip says that its SiC MOSFETs and SBDs offer more efficient switching at higher frequencies and pass ruggedness tests at levels considered critical for guaranteeing long-term reliability. The SiC SBDs are said to perform about 20% better than other SiC diodes in such unclamped inductive switching (UIS) ruggedness tests that measure how well devices withstand degradation or premature failure under avalanche conditions, which occur when a voltage spike exceeds the device's breakdown voltage. The SiC MOSFETs are also said to outperform alternatives in these ruggedness tests, demonstrating what is claimed to be excellent gate oxide shielding and channel integrity with little lifetime degradation in parameters even after 100,000 cycles of repetitive UIS (RUIS) testing.

Microchip is one of the few suppliers to provide a range of both silicon and SiC discrete and module solutions. Its products are suitable for the growing number of EV systems including external charging stations, onboard chargers, DC–DC converters and powertrain/traction control solutions. The new SiC devices are backed by Microchip's customer-driven obsolescence practice, which ensures devices will continue to be produced for as long as customers need them.



The expanded SiC portfolio is supported by a range of SiC SPICE models, SiC driver board reference designs and a power factor correction (PFC) Vienna reference design. All the firm's SiC products are available in production volumes along with their associated support offerings. A variety of die and package options are available for the SiC MOSFETs and SiC diodes.

www.microchip.com

UnitedSiC adds seven TO220-3L- and D2PAK-3L-packaged SiC FETs to 650V product portfolio

Silicon carbide power semiconductor maker United Silicon Carbide Inc (USCi) of Monmouth Junction, NJ, USA has added seven new TO220-3L and D2PAK-3L device/package combinations to its UJ3C (general purpose) and UF3C (hard switched) series of 650V SiC field-effect transistors (FETs).

The new devices provide high-voltage power performance in the fast-growing data-center server, 5G base-station and electric vehicle (EV) markets, where they can be used in power supplies, telecom rectifiers and on-board chargers, respectively. They are targeted at designers who prefer a 3-lead, TO220 or D2PAK package option, yet are still looking to enhance power performance in power-factor correction (PFC) circuits, LLC resonant converters, and phase-shifted full-bridge converters.

Unique to UnitedSiC's UJ3C and UF3C FET portfolio is its true 'drop-in replacement' functionality. Designers can significantly enhance system performance, without the need to change gate drive voltage, by replacing their existing silicon IGBTs, silicon FETs, SiC MOSFETs or silicon superjunction devices with UnitedSiC FETs.

Both series of SiC FETs are based on UnitedSiC's unique cascode circuit configuration, in which a normally-on SiC JFET is co-packaged with a silicon MOSFET to produce a normally-off SiC FET device that has standard gate-drive characteristics. Existing systems upgraded with the UnitedSiC 'drop-in replacement' FETs can hence expect a performance increase with lower conduction and switching losses, enhanced thermal properties and integrated gate ESD protection. In the case of new designs, the UnitedSiC FETs are said to deliver increased switching frequencies to gain substantial system benefits in both efficiency and reduction in size as well as cost of passive components such as magnetics and capacitors.

The three-leaded, industry-standard TO220-3L package offers enhanced thermal characteristics made possible by UnitedSiC's sintered-silver packaging technology. New products available in this package include the UJ3C device with $R_{DS(on)}$ values of 30mΩ and 80mΩ and the UF3C device with an $R_{DS(on)}$ spec of 40mΩ.

The three-leaded, industry-standard D2PAK-3L targets surface-mount designs and is certified to IPC and JEDEC's Moisture Sensitivity Level 1. New products available in this package include the UJ3C device with $R_{DS(on)}$ specs of 30 and 80mΩ and UF3C devices with $R_{DS(on)}$ specs of 30mΩ and 40mΩ.

Select devices are also available in automotive versions that meet the AEC-Q101 standard.

Dependent on $R_{DS(on)}$ values, prices range from $5.18 to $14.35 each for the D2PAK-3L options and from $5.18 to $13.79 each for the TO220-3L options in 1000-unit quantities. Devices are in stock at UnitedSiC franchised distributors, including Mouser and Richardson Electronics.

www.mouser.com/usci
https://unitedsic.com/cascodes

Pre-Switch launches 200kW SiC inverter evaluation system

Pre-Switch Inc of Campbell, CA, USA, a start-up that is delivering soft switching for DC/AC and AC/DC power conversion, has announced its CleanWave 200kW silicon carbide automotive inverter evaluation system that enables power design engineers to investigate the accuracy of its soft-switching architecture and platform over varying load, temperature, device tolerance and degradation conditions.

Pre-Switch's platform — including the Pre-Drive3 controller board, powered by the Pre-Flex field-programmable gate array (FPGA), and the RPG (resonant power gate) gate driver board — virtually eliminates switching losses, it is claimed, enabling fast switching at 100kHz (significantly improving low torque motor efficiency). High switching frequency also reduces motor copper and iron losses. For electric vehicles (EVs) this results in a massive increase in range of 5–12%. The soft-switching solution also benefits industrial motors, solar, wind and traction applications or any other power converter requirement greater than 100kW that seeks to reduce costs and improve efficiency.

"Critical design challenges hindering EV adoption have been solved," claims CEO Bruce T. Renouard. "Previously, the limited switching frequency of inverters resulted in a distortion of the output power sine wave causing excessive motor inefficiencies. Our CleanWave inverter evaluation system — which is available to pre-order now — uses artificial intelligence (AI) to constantly adjust the relative timing of elements within the switching system required to force a resonance to offset the current and voltage waveforms, thereby minimizing switching losses and increasing EV range."

Pre-Switch's forced-resonant soft-switching topology replaces the traditional IGBT driver or silicon carbide driver with a common intelligent controller board, Pre-Drive3, and a specific plug-in RPG module optimized for the customer's chosen SiC or IGBT package. The Pre-Switch architecture is claimed to increase efficiency and range, while reducing size and weight.

www.pre-switch.com

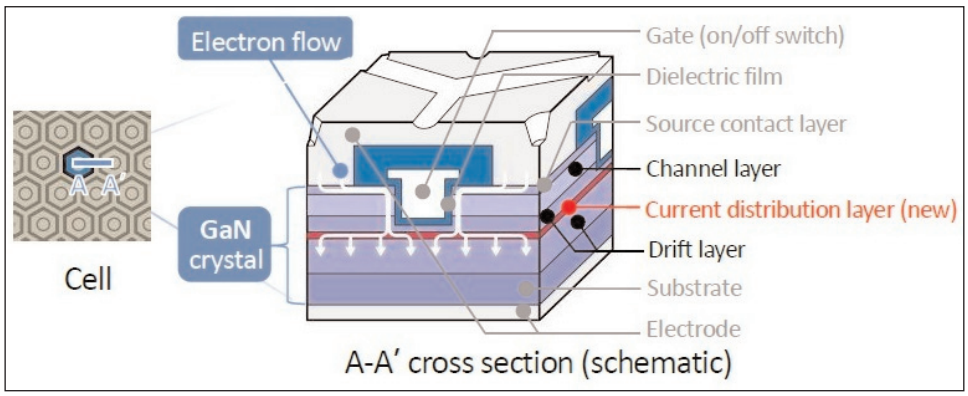
Toyoda Gosei doubles operating current in vertical GaN power device from 50A to 100A

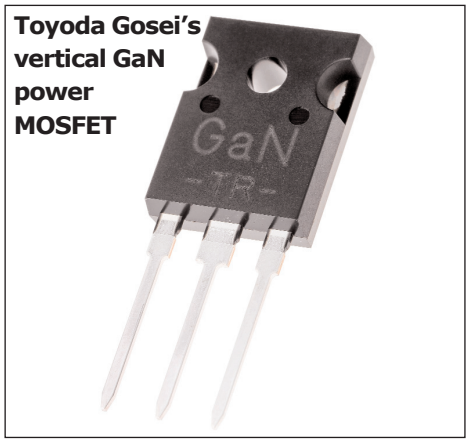
High 1.2kV breakdown voltage and low 1.8mΩcm² resistance achieved with high-frequency ≥10MHz operation

Toyoda Gosei Co Ltd of Kiyosu, Aichi Prefecture, Japan has developed a vertical gallium nitride (GaN) power semiconductor device with high current operation of 100A on a single chip, one of the highest levels yet achieved, it is claimed.

In addition to applications as electronic components for power conversion in home appliances, mobility, industry etc, the proliferation of electric vehicles (EVs) and renewable energy has been boosting demand for power devices with higher performance. With the silicon used in conventional devices however, it is difficult to significantly improve efficiency in converting high power. Specifically, after half a century of improvements, the balance between high breakdown voltage and low electrical resistance is approaching its limits due to the physical properties of silicon, making it difficult to achieve further significant reductions in conduction loss during high-power operation and in switching loss during high-frequency operation.

Toyoda Gosei has sought to overcome this by using GaN, which has the physical property of high breakdown voltage (more than 10 times that of silicon), and a chip structure in which electricity flows vertically to the GaN substrate. This material and structure combination allows thinner and smaller device designs and other improvements that lead to higher performance. In particular, with thinner, lower-resistance GaN, conduction loss can be reduced. Also, with a vertical structure, the entire chip is used in current flow, making it possible to make semiconductors smaller and to reduce switching loss. With this combination, Toyoda Gosei has achieved high breakdown voltage (1.2kV level) and low resistance (1.8mΩcm²), and high-frequency operation (≥10MHz).



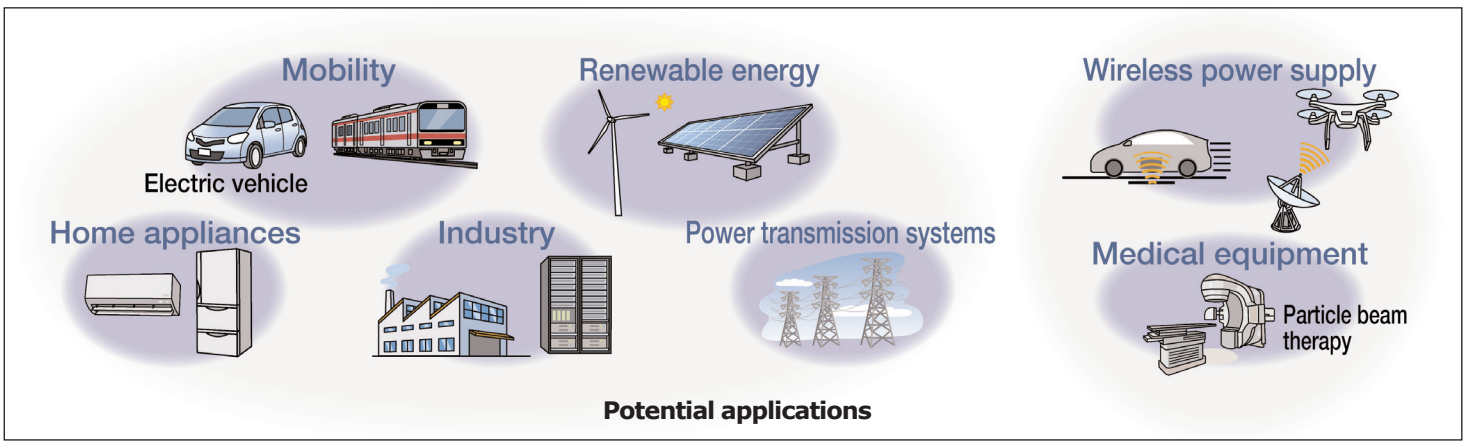


Toyoda Gosei's vertical GaN power MOSFET

The firm's latest development, which has doubled the electric current capacity from the previous 50A to 100A on a single chip, results from the introduction of a new current distribution layer that lowers electric resistance by expanding the flow of electricity on the drift layer. This new technology was presented at the 31st IEEE International Symposium on Power Semiconductor Devices and ICs (ISPSD 2019) in Shanghai, China (19–23 May).

Toyoda Gosei says that it aims to continue improving the reliability and other qualities of the devices for their early commercialization, in collaboration with manufacturers in power electronics.

www.toyoda-gosei.com



Potential applications

MACOM and Goertek forming JV to supply GaN-on-Si products for China's 5G build out

Goertek providing $134.6m to MACOM, which retains sales rights outside China, Hong Kong and Macau

MACOM Technology Solutions Holdings Inc of Lowell, MA, USA (which makes semiconductors, components and subassemblies for analog RF, microwave, millimeter-wave and photonic applications) has agreed to establish a joint venture with Goertek Inc, a multi-billion-dollar electronic components company based in Shandong, China. The JV will be based in Hong Kong and will supply, market and distribute gallium nitride on silicon (GaN-on-Si)-based RF power components into China's base-station market.

Goertek focuses mainly on R&D, manufacturing and sales of components (acoustics, sensor, optoelectronic etc) and finished products (for VR/AR/MR, wearable, hearable, home applications etc). Viewing semiconductors as a strategic focus, Goertek has developed capabilities covering chip design, packaging, testing, algorithm and system integration, and has developed large-scale production capacity for MEMS products.

Goertek will provide up to $134.6m to MACOM, including $30m up front. MACOM will further be entitled to royalties and dividend preferences in the JV. Goertek and MACOM will each contribute $25m in working capital. MACOM retains rights to sell GaN-on-Si products outside China, Hong Kong and Macau.

"This joint venture is a capstone to MACOM's strategy to become a scale player within the multi-billion-dollar 5G base-station market in China, which in turn enables us to further invest in US-based innovation," says MACOM's president & CEO John Croteau. "We are pleased to be able to leverage our existing design capabilities and resources in China by aligning with a JV partner of the caliber of Goertek. They perfectly complement our GaN-on-Si based RF power component products with high-volume manufacturing expertise, well-connected sales and proven supply-chain management into China's top OEMs and service providers," he adds.

"Leveraging MACOM's superior GaN-on-Si technology, we will provide world-leading RF components to the 5G market in China, as well as enriching our RF capabilities," comments Goertek's CEO Long Jiang.

Subject to closing conditions (including receipt of approval from China's State Administration for Market Regulation), the deal is expected to close in second-half 2019.

www.goertek.com/en
www.macom.com

Navitas' GaNFast power ICs enable 2x shrink and 75% more emergency lighting

Navitas Semiconductor Inc of El Segundo, CA, USA says that its GaNFast power integrated circuits are enabling HotSpot Plus FHSAC1-UNV-70S, a high-reliability 70W normal + 7W emergency back-up lighting power system made by Fulham Co Inc of Hawthorne, CA, USA (which makes commercial lighting components and electronics for commercial general lighting, parking structure, signage, horticultural, UV and other applications). Gallium nitride (GaN) power IC technology powers both the main LED luminaire and charges the on-board $LiFePO_4$ battery to provide everyday lighting and up to 90 minutes of emergency runtime.

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

New, high-speed GaN power ICs are said to have up to 20x the performance of silicon chips. By operating at high frequency and simultaneously increasing efficiency, GaNFast power ICs reduce the size, weight and cost of components such as transformers, heatsinks and printed-circuit boards. GaNFast's 3–4x increase in power density enables a 2-to-1 reduction in LED hardware and leaves room to expand battery size to 14.4Whr and increase emergency lighting by 75% for increased safety compared with similar-sized 4W emergency-only systems, it is reckoned.

The Hotspot Plus 70S was developed for original equipment manufacturers (OEMs) looking for a highly reliable, universal LED driver that would meet state and city safety requirements in a single, compact, all-in-one emergency/LED driver. Suitable for luminaires where LED driver space is limited, the HotSpot Plus 70S has the smallest form-factor available (424mm x 30mm x 25mm), it is claimed, and features universal 120–277V_{AC} input with a maximum of 70W (programmable constant current output of 350–2400mA/11–55V_{DC}) normal and up to 7W emergency output, so customers can stock a single LED driver for a broad range of fixtures.

"With the HotSpot Plus 70S, our goal was to provide an LED driver + Emergency LED driver with integrated batteries in the same size as a single-function non-emergency LED driver, and the Navitas GaNFast power ICs enabled us to reach this goal," says Alvaro Garcia, senior director, product management, at Fulham. "This significant achievement is an industry first, which will enable our customers to design smaller more cost-effective LED lighting systems," he reckons.

"Fulham joins a rapidly growing list of mobile and consumer brands in high-volume production with GaN power ICs that are setting a new standard in energy savings and power density," says Navitas' CEO Gene Sheridan.

Navitas presents GaNFast charging technology at PCIM

Navitas presented its latest GaNFast power IC advances and end-customer examples at the PCIM (Power Conversion Intelligent Motion) Europe 2019 conference in Nuremberg, Germany (7–9 May).

"Navitas has enabled customers to deliver the highest-performance, fastest-charging, mass-production smartphone and laptop power solutions in the market," says Stephen Oliver, VP marketing & sales. "GaNFast ICs are now building a new class of kW+ power systems for cloud computing, new energy and a broad range of eMobility solutions, from ebike and drone chargers to full-size EV [electric vehicle] on-board chargers (OBC), which increase power densities and battery-charging rates by 3x, improve energy savings by 50% or more, to extend driving range and lower system costs".

Navitas presented the following conference papers/events at PCIM Europe on 8 May:

- Industry Forum: 'GaN – Devices are Mature' — 'Drive your Destiny, Let's Go GaNFast!' by Tom Ribarich of Navitas Semiconductor;
- Session: GaN System Integration — 'System Integration Benefits in GaN Power ICs' (A05- 5043) by Marco Giandalia and Dan Kinzer of Navitas Semiconductor;
- Section: AC-DC and DC-AC Converters — 'GaN High Density 300W AC-DC Converter' (E03- 4955) by Tom Ribarich and Stephen Oliver of Navitas Semiconductor and Peter Bredmeier of Ongineer, Germany.

www.fulham.com
www.navitassemi.com

Imec demos fully monolithical co-integration of GaN half-bridge with drivers

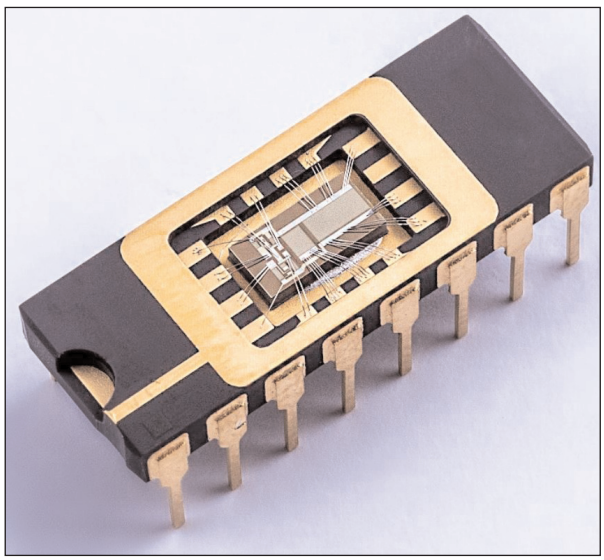
Galvanic isolation using SOI and QST as GaN-IC platform eliminates back-gating effect and reduces switching noise

At PCIM (Power Conversion Intelligent Motion) Europe 2019 in Nuremberg, Germany (7–9 May), nanoelectronics research centre imec of Leuven, Belgium demonstrated a functional GaN half-bridge monolithically integrated with drivers. Mounted on a buck-convertor test board, the chip converts an input voltage of 48V to an output voltage of 1V, with a pulse width modulation signal of 1MHz. The achievement leverages imec's gallium nitride on silicon (GaN-on-Si) and GaN-on-QST technology platforms, reducing parasitic inductance and boosting commutation speed.

GaN power electronics is currently dominated by off-the-shelf discrete components. Half-bridges — common subcircuits in power systems — are fabricated from separate discrete components, either in separate packages or integrated in one package, especially for the higher-voltage ranges. A challenge, especially at high voltages, is that on-chip half-bridges designed on GaN-on-Si technology are limited in performance by a back-gating effect that negatively affects the high-side switch of the half-bridge, as well as by switching noise that disturbs the control circuits.

To unlock the full potential of GaN power technology, imec monolithically co-integrated a half-bridge and drivers in one GaN-IC chip. Complemented by low-voltage logic transistors, a suite of passive components for low-ohmic and high-ohmic resistors, and a MIM-capacitor, high-end integrated power systems can be realized on a single die.

Imec's solution builds on imec's GaN-on-SOI and GaN-on-QST technology platforms that allow for galvanic isolation of the power devices, drivers and control logic, by the buried oxide and oxide-filled



deep trench isolation. This isolation scheme not only eliminates the detrimental back-gating effect that negatively affects the high-side switch of the half-bridge, but also reduces the switching noise that disturbs the control circuits. With the design of a co-integrated level shifter for driving the high-side switch, a dead-time controller to avoid overlapping gate input waveforms, and an on-chip pulse-width modulation circuit, highly integrated buck and boost convertors can be fabricated.

"Someone might think that by using SOI or QST wafers instead of silicon wafers will result in more expensive technology. However, with GaN-on-Si several discrete devices need to be individually packaged (with advanced packages to take advance of the GaN fast switching performance) and connected to their drivers and other elements at the board or packaged level," says business development manager Denis Marcon. "Instead, with imec's GaN-IC technology, the full converter including drivers and analog blocks etc is on-chip, which can then be packaged with simple package technology (as the frequency-sensitive components are already connected on-chip). This dramatically saves on the cost of the final power system."

With imec's GaN-IC technology, the full converter including drivers and analog blocks etc is on-chip, which can then be packaged with simple package technology (as the frequency-sensitive components are already connected on-chip)

To further boost the performance of these monolithic integrated power systems, imec aims to extend its platform with additional co-integrated components, such as Schottky diodes and depletion-mode HEMTs.

"With the aim to further foster innovation in the GaN power electronics, this GaN-IC platform is available for prototyping through our multi-project-wafer (MPW) service," notes Stefaan Decoutere, program director GaN power electronics at imec. "The possibilities for high-end power systems with unprecedented performance, either in switching speed, operating frequency or energy efficiency, with reduced inductive parasitics and unseen reduction of the form-factors, will further boost the use of GaN for power supplies in the consumer and re-useable energy market segments," he believes.

imec exhibited its GaN (e-mode) technology and GaN-IC technology at PCIM (Power Conversion Intelligent Motion) Europe 2019 in Nuremberg, Germany (7–9 May).

www.mesago.de/en/PCIM/main.htm
www.imec.be

NI launches 5G millimeter-wave RFIC transceiver and power amplifier tester

NI of Austin, TX, USA, which provides a software-defined platform for accelerating the development and performance of automated test and automated measurement systems, has launched the mmWave Vector Signal Transceiver (VST) to address the test challenges of 5G millimeter-wave RFIC transceivers and power amplifiers. The product was demonstrated at NIWeek 2019 (20–23 May) in multi-site production test configurations for packaged part and wafer-level test and in validation test configurations using over-the-air measurements.

With chipmakers racing to commercialize 5G mmWave technology, engineers face the challenge of accelerating product schedules combined with new and often unsolved technical requirements, notes NI. The firm's mmWave test solutions address these challenges in both R&D labs and high-volume manufacturing, delivering:

- measurement quality to meet rigorous technical requirements;
- an architecture designed to scale to the specific needs of production test for mmWave chips;
- a unified software experience that simplifies measurement and automation; and
- identical instrumentation in validation and production to simplify correlation efforts and reduce development time.

NI's mmWave VST combines an RF signal generator, an RF signal analyzer and integrated switching with 1GHz of instantaneous bandwidth at frequencies up to 44GHz. In addition to existing PXI-based characterization systems in the lab, the instrument natively integrates into the NI Semiconductor Test System (STS) for deployment in high-volume manufacturing applications. 5G mmWave STS configurations support up to eight mmWave VST instruments, with integrated IF capabilities, and up to 72 mmWave ports in a tester configuration that is optimized for EVM performance. Choosing a tester built on the modular PXI platform helps engineers adopting STS to quickly integrate new measurement capabilities like 5G into their test cells more cost-effectively and with less risk of delaying time to market, says NI.

"In the race to bring 5G technology to market, traditional approaches to RF semiconductor test are struggling to deliver on the flexibility and cost expectations of 5G devices," says NI's president & chief operating officer Eric Starkloff. "The mmWave VST is yet another example of NI's ability to combine our industry-leading platform with deep customer insight to enable customers' disruptive innovations."

The product features several innovations to address the test requirements of 5G mmWave devices. The new calibrated integrated switching for up to 32 channels enables improved accuracy of beamforming and phased-array measurements without additional infrastructure. The modular head design delivers accurate and cost-effective measurements while preserving forward compatibility with future 5G bands. Engineers can hence simultaneously perform measurements at both 5–21GHz and 23–44GHz.

The mmWave VST complements NI's modular instrumentation portfolio of more than 600 PXI products, ranging from DC to mmWave, and its measurement software for 2G, 3G, LTE Advanced Pro, 5G NR, Wi-Fi 802.11ax, Bluetooth 5 etc, with support for many languages including LabVIEW and C# .NET.

www.ni.com/5g

Silvaco opens Chengdu office to support China expansion and growing demand for power semiconductor design

Silvaco Inc of Santa Clara, CA, USA (which provides electronic design automation and IP software tools for process and device development) has opened its latest China office to accommodate its continuing growth and broaden its footprint in China.

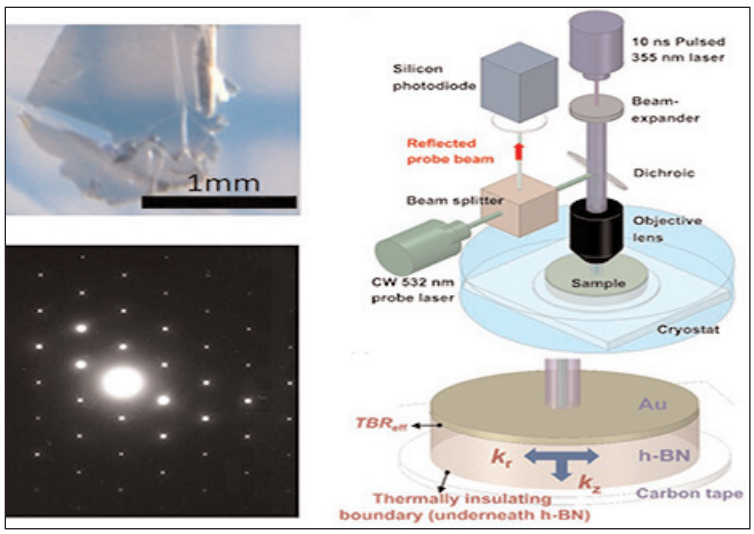
Located in the Gaoxin District of Chengdu, Sichuan Province (Building E6-1, 9th floor, Software Park, No. 1366, Central Tianfu Avenue), the newest Silvaco China office will provide product engineering and support. The Chengdu region has risen to become the fourth pole of China's IT industry (after Beijing, Shanghai and Shenzhen) and is the home of industry giants such as Dell, TI, IBM, Huawei and Alibaba.

"China is a key part of the global semiconductor ecosystem with the expansion of mobile and big-data electronics businesses driving new developments in artificial intelligence (AI), digital display, the Internet of Things (IoT) and power ICs," says Silvaco China's general manager Sharon Fang. "Silvaco China began in 2013, and our new Chengdu office is in the magnificent Tianfu Software Development Park, where more than 400 companies have established their facilities. We can draw on the talents of its huge community for our product engineering and support," she adds. "Along with our Shanghai and Shenzhen offices, Chengdu strengthens our commitment to the expanding semiconductor IC market and especially to power ICs, which we see as a growing business opportunity."

www.silvaco.com

Ultra-pure boron nitride yields high thermal conductivity twice that of copper

Development promises high-performance, high-energy-efficiency electronic devices



A team led by professor Martin Kuball of the University of Bristol's Center for Device Thermography and Reliability (CDTR) in the UK has found that, by making an ultra-pure version of boron nitride, it was possible to demonstrate its high thermal conductivity potential for the first time, which at 550W/mk is twice that of copper, paving the way for safer and more efficient electronic devices including mobile phones, radars and even electric cars ('Modulating the thermal conductivity in hexagonal boron nitride via controlled boron isotope concentration', Communications Physics vol2, Article no: 43 (2019)).

"Most semiconductor electronics heat up when used. The hotter they get, the greater the rate at which they degrade, and their performance diminishes," notes Kuball. "As we rely more and more upon our electronic devices, it becomes increasingly important to find materials with high thermal conductivity which can extract waste heat," he adds.

"Boron nitride is one such material which was predicted to have a thermal conductivity of 550W/mK, twice that of copper. However, all measurements to date seemed to show its thermal conductivity was much lower [220–420WmK]," Kuball continues. "By making this material 'ultra-pure', we have been able to demonstrate for the first time its very high thermal conductivity potential." Specifically, for monoisotopic ^{10}B h-BN, an in-plane thermal conductivity as high as 585WmK is measured at room temperature, about 80% higher than that of h-BN with a disordered isotope concentration (52%:48% mixture of ^{10}B and ^{11}B).

Kuball says that the next step was to start making active electronic devices from boron nitride, as well as integrating it with other semiconductor materials.

"In demonstrating the potential of ultra-pure boron nitride, we now have a material that can be used in the near future to create high-performance, high-energy-efficiency electronics," he adds. "Our reliance on electronics is only going to increase, along with our use of mobile phones and adoption of electric cars. Using more efficient materials, like boron nitride, to satisfy these demands will lead to better-performance mobile phone communication networks, safer transportation and ultimately, fewer power stations."

www.nature.com/articles/s42005-019-0145-5
www.bristol.ac.uk/physics/research/cdtr

Keysight launches dynamic power device analyzer with double-pulse tester for safely characterizing wide-bandgap semiconductors

Keysight Technologies Inc of Santa Rosa, CA, USA has launched a dynamic power device analyzer with double-pulse tester (PD1500A) to deliver reliable, repeatable measurements of wide-bandgap (WBG) semiconductors, while ensuring the safety of measurement hardware and staff performing the tests.

Growth of the electric vehicle (EV) market is driving strong demand for small, high-power, efficient electric power systems. As the industry turns to WBG semiconductor technology for mission-critical applications like renewable energy and EVs, many power converter designers are hesitant to adopt such new technology due to potential reliability and repeatability risks in characterizing a new generation of semiconductors including insulated-gate bipolar transistor (IGBT), silicon carbide (SiC), and gallium nitride (GaN), says Keysight.

Fully characterizing a SiC or GaN device requires static and dynamic measurements. Keysight says its B1505A and B1506A power device analyzers deliver these static measurements and, with the addition of the new PD1500A, now also

provides the flexibility needed to address dynamic measurements. This functionality is key, since the standards for WBG devices, established by the Joint Electron Device Engineering Council (JEDEC), continue to evolve, notes the firm.

The PD1500A is designed to be modular, allowing many device types to be tested and different characterization tests to be performed at a variety of power levels. The initial system provides complete double-pulse test characterization and parameter extraction for silicon and SiC power semiconductors with ratings up to 1.2kV and 200A.

The new PD1500A Dynamic Power Device Analyzer with Double-Pulse Test Capability is said to provide reliable, repeatable measurements of wide-bandgap semiconductors that enable users to:

- lower costs and accelerate time to market by reducing design time and number of prototypes needed;
- ensure a safe test environment;
- document, support and maintain an off-the-shelf test solution, as well as maintain multiple test solutions across one or more sites;
- quickly respond to reliability concerns with measurements that focus on ruggedness (e.g. short-circuit and avalanche);
- simplify and automate the testing processes; and
- improve device models used in design and simulation software (PD1000A).

Additional modules will be added to the PD1500A in the future to perform tests on devices requiring more current, such as GaN and power modules.

www.keysight.com/en/pd-2404038-pn-B1506A/power-device-analyzer-for-circuit-design

StratEdge highlights high-frequency, thermally efficient packages at CS ManTech

At the International Conference on Compound Semiconductor Manufacturing Technology (CS ManTech 2019) in Minneapolis, MN (29 April-1 May), StratEdge of San Diego, CA, USA displayed its thermally efficient packages for compound semiconductor devices such as GaN and GaAs, which enable them to meet the critical requirements of markets such as telecom, mixed-signal, VSAT, broadband wireless, satellite, military, test & measurement, automotive, down-hole, and MEMS.

StratEdge uses hardened, or post-fired, ceramic that does not shrink, resulting in complete dimensional stability and precise mechanical tolerances. The firm then mates these ceramics with its patented electrical transition designs to manufacture packages with exceptionally low electrical losses that operate efficiently, even at frequencies as high as 63+GHz. StratEdge offers complete automated assembly services for these packages, including gold-tin solder die attach.

"StratEdge was one of the first companies to make packages for compound semiconductors and has regularly attended CS ManTech since its inception," notes president Tim Going. "Over the years, our patented technology has delivered superior electrical performance for GaN, GaAs and other compound semiconductor devices while providing mechanical stability for these sensitive devices," he adds.

www.csmantech.org
www.stratedge.com

Exagan opens Power Solutions Center to extend applications support and market reach

Exagan's new Power Solutions Center.

Continuing its progress in accelerating the adoption of gallium-nitride (GaN)-on-silicon semiconductors in power markets, gallium nitride technology start-up Exagan of Grenoble and Toulouse, France (founded in 2014 with support from CEA-Leti and Soitec) has opened a new Power Solutions Center in Toulouse to extend its applications support and market reach in wide-ranging, customer-specific end products. The opening of the facility, which is operating in close collaboration with technology partner CEA Tech, follows the launch of Exagan's first GaN applications center in Taipei, Taiwan last October.

The Toulouse facility provides customers with new application-development and product-validation capabilities using highly specialized electronic equipment. It also enables Exagan to master new architectures for GaN solutions while also boosting power-conversion efficiencies in current topologies.

Exagan says that its technology and products are designed to offer value in device performance, robustness and ease of integration with existing platforms. G-FET power transistors can be fabricated in existing 200mm CMOS wafer fabs, enabling a multi-source supply, easy scalability and optimal cost/performance benefits.

With its fab-lite business model, Exagan offers control of GaN technology integration from starting materials to full implementation in end products, enabling product optimization and volume manufacturing. The firm's product portfolio covers a wide range of power levels and applications, from small fast-charging systems, data centers and onboard automotive chargers up to fast-charging stations for electric vehicles.

"Building on a robust GaN technology and product portfolio, Exagan is now deploying GaN Power Solutions Centers in Europe and Asia to work closely with customers," says president & CEO Frédéric Dupont. "Our goal is to deliver the best functionality and value by optimizing GaN devices' industry-leading balance of power density, power efficiency, reliability and system costs," he adds.

The market for GaN in power electronics is projected to increase at a compound annual growth rate (CAGR) of 93% by 2023, according to market research firm Yole Développement.

Exagan exhibited its GaN-based product portfolio — including G-FET power transistors, G-DRIVE intelligent system-in-a-package (SiP) solutions and evaluation modules — at PCIM Europe 2019 in Germany. Specifically, the firm showcased the performance of its G-FET power transistors in applications such as 65W USB PD 3.0 power chargers and power factor correction (PFC) ranging from 300W up to 1.5kW for next-generation data centers.

www.mesago.de/en/PCIM/main.htm
www.exagan.com
www.cea-tech.fr

Soitec opening direct sales operation in China

Soitec of Bernin, near Grenoble, France, is opening a direct sales channel in China. Customers in China can now benefit from not only direct contact and support relationships with Soitec's local team (which includes sales and technical support engineers) but also access to Soitec's global technical expertise and network across engineered substrates, most notably its silicon-on-insulator (SOI) products, addressing the full range of applications for China's growing electronics markets.

Recently announced as the first materials supplier to join the China Mobile 5G Innovation Center (an international alliance chartered to develop 5G communication solutions for China), Soitec says that it brings its long-standing worldwide partnerships across fabless semiconductor companies, foundries, system-level integrated device manufacturers (IDMs), research/innovation centers, universities and industry consortia. Both silicon and non-silicon engineered substrates are essential in bringing to mass deployment 5G mobile communications for applications including self-driving cars, industrial connectivity and virtual reality.

Soitec says that, in addition to direct access to a local sales and support team, it offers Chinese customers continued SOI wafer manufacturing, responsiveness and high-volume capacity readiness due to its historical partnership with Shanghai Simgui Technology Co Ltd. In February, Soitec and Simgui announced an enhanced partnership and increased annual production capacity of 200mm SOI wafers from 180,000 to 360,000 units at Simgui's manufacturing facility in Shanghai, in order to better serve the growing global market for RF-SOI in mobile and power-SOI products. Simgui will focus on SOI wafer manufacturing and Soitec will now manage worldwide product sale of 200mm SOI wafers. Furthermore, Simgui's fab has been qualified by multiple key customers inside and outside China.

"The value of SOI reaches far beyond the substrate level into device, system and final applications in the global value chain," says Soitec's CEO Paul Boudre. "To promote this value to Chinese customers as well as their downstream customers worldwide, Soitec will now support China with a comprehensive global team of experienced sales, marketing and business development professionals who are well connected to all major players in the global value chain."

Soitec presented at SEMICON China 2019 (20–22 March) in Shanghai at the National Silicon Industry Group.

www.soitec.com

G-ray Nanotech and IKZ collaborate to develop detector-grade GaAs wafers

High-purity crystal to be made in wafer form factor for x-ray detectors

G-ray Nanotech (part of development-stage company G-ray Industries SA of Neuchâtel, Switzerland) and IKZ (Leibniz Institute for Crystal Growth) in Berlin, Germany have entered into a long-term R&D collaboration covering the doping of gallium arsenide (GaAs) structures and the manufacturing of high-purity crystals in wafer form factor for detector applications.

"The competencies of IKZ will allow us to accelerate significantly the expansion of our latenium detector architecture into medium-large energy x-rays applications as well as in the infra-red spectrum," says G-ray Nanotech's CEO Philippe Le Corre.

G-ray Industries SA is developing ultra-high-performance detectors dedicated to industrial non-destructive-testing solutions. Based on G-ray's patented latenium technology, the detectors are being developed in partnership with Switzerland's Center for Electronics and Microtechnology CSEM (Centre Suisse d'Electronique et de Microtechnique).

The latenium evaluation kits are available for evaluation purposes from first-quarter 2019. Also, G-ray's technologies - in particular the covalent bonding of a silicon wafer to a GaAs, germanium or silicon wafer at low temperatures and the very fast epitaxial growth of germanium structures - are being targeted at the fields of high-energy physics research for new particle detectors and at vision systems for the automotive industry.

"IKZ is committed to push high-performance crystalline materials to market applications, and the state-of-the-art x-ray imaging detector development at G-Ray is a nice opportunity for us," comments IKZ's scientific director professor Thomas Schroeder. "We consider 3D heterointegration via bonding approaches as a fruitful strategy for us to innovate technologies by high-quality, precisely tailored crystalline materials," he adds.

"With our expertise in materials science and technology we have supported the G-ray team right from the start," says Gian-Luca Bona, CEO of Empa (the Swiss Federal Laboratories for Material Science and Technology). "This is an outstanding opportunity to bring a ground-breaking x-ray detector technology to the market."

www.g-ray.ch
www.empa.ch
www.ikz-berlin.de

Soitec expanding engineered substrate portfolio into GaN by buying EpiGaN

Acquisition accelerates penetration across high-growth 5G, power and sensor markets

Soitec of Bernin, near Grenoble, France, which makes engineered substrates including silicon-on-insulator (SOI) wafers, has agreed to acquire EpiGaN nv of Hasselt, near Antwerp, Belgium – which supplies gallium nitride on silicon (GaN-on-Si) and gallium nitride on silicon carbide (GaN-on-SiC) epitaxial wafers – for €30m in cash plus an additional earn-out payment based on completion of certain milestones. EpiGaN will be integrated as one of Soitec's business units.

EpiGaN's GaN products are used primarily in RF 5G, power electronics and sensor applications, with the total addressable market of GaN technologies estimated to be 0.5–1 million wafers per year within five years.

Founded in 2010, EpiGaN was founded by chief executive officer Dr Marianne Germain, chief technology officer Dr Joff Derluyn and chief operating officer Dr Stefan Degroote as a spin-off of nanoelectronics research center Imec of Leuven, Belgium. The founders jointly developed GaN-on-Si technology at Imec, part of which has been licensed to EpiGaN. EpiGaN was joined in 2011 by start-up investment firms Robert Bosch Venture Capital, Capricorn Cleantech Fund and LRM (to enable the installation of its wafer production facility), followed later by ACAPITAL and SPFI-FPIM.

"GaN technology is gaining significant traction in RF and power markets," notes Soitec's CEO Paul Boudre. "GaN epiwafers represent a natural strategic fit with Soitec's current portfolio of engineered substrates," he adds. "The acquisition of EpiGaN further extends and complements Soitec's portfolio beyond silicon to create new value-added process solutions for both RF 5G and power systems."

In the mobility space the co-optimization of performance, low power and cost is key, says Soitec. The arrival of 5G sub 6GHz and millimeter wave (mmW) is driving new generations of base stations compared with 4G, which in turn require more energy-efficient, higher-performing, smaller and more affordable power amplifiers (PAs). Soitec will expand its engineered substrates offering for PAs, with GaN leading the way in today's smaller, lighter, more efficient and cost-effective base-station designs, the firm adds.

"EpiGaN has developed a technology which is ready and optimized for 5G broadband network applications," says Germain. "Our technology creates the unique opportunity for Soitec's customers to quickly develop product solutions targeting new high-growth markets, such as RF devices, efficient power switching devices and sensor devices," she adds.

"The GaN technology developed by EpiGaN opens up many future opportunities and we believe Soitec is an excellent partner to further develop the full potential of EpiGaN," comments Katleen Vandersmissen, director of EpiGaN and representative of cornerstone investor LRM (Investment Company of Limburg).

It is reckoned that, given GaN's use in power transistor designs, the EpiGaN acquisition also creates new complementary growth opportunities across Soitec's existing Power-SOI products. Both Power-SOI and GaN address the requirements for integrating high-voltage and analog functions in intelligent, energy-efficient and highly reliable power IC devices, for use in consumer electronics, data-center, automotive and industrial markets.

www.epigan.com
www.soitec.com

IQE gains full product qualification and first mass-production order for Newport Mega Foundry for epi materials

Leading VCSEL customer being followed by ten more customers

Epiwafer foundry and substrate maker IQE plc of Cardiff, Wales, UK says that its recently constructed Newport Mega Foundry has received its first mass-production order from its leading existing vertical-cavity surface-emitting laser (VCSEL) customer.

Gaining full product qualification status is the result of extensive quality and process audits by the customer and their end OEM, plus exhaustive product qualification trials including full reliability testing. Qualification of further tools is in progress and is expected to complete over the coming months.

In addition to qualification with this customer, further VCSEL product qualifications are at advanced stages with more than ten other customers, two of which are expected to reach successful conclusion over the next few weeks. IQE says that customer feedback from the additional qualifications confirms the quality and performance from the new facility.

Under construction for the last 18 months, the Newport Mega Foundry is reckoned to be the world's largest outsource epi facility for compound semiconductors. It currently has ten large-scale production metal-organic chemical vapor deposition (MOCVD) systems installed, with space for up to 90 more. The manufacturing facility also houses an extensive suite of wafer characterization tools to ensure quality.

The first ten systems are dedicated to 6" VCSEL production for end applications that include 3D sensing, high-speed datacoms, advanced driver assistance systems (ADAS), LiDAR, proximity sensing and time-of-flight (ToF) systems.

The market for VCSELs is expected to grow rapidly over the coming years as 3D sensing is installed across multiple user platforms, including facial recognition, world-facing cameras for augmented reality (AR) and 3D photography, security cameras, industrial sensing and heating, ADAS, LiDAR, high-speed datacoms and proximity sensing.

"IQE has invested heavily, along with help from the Cardiff City Region Deal (CCR), to build the worlds largest outsource epi facility, demonstrating our commitment to providing the capacity required for large-scale deployment of VCSELs and other compound semiconductor (CS) products, as the CS industry moves through a real inflection point in volume manufacture," says IQE's CEO & president Dr Drew Nelson.

"IQE is committed to leadership of this mass CS scaling, offering a unique range of wafer products and complementary technologies, enabling our customers to introduce disruptive products to the end marketplace," he adds. "We have a powerful and extensive roadmap for VCSEL technology, which we believe will help the acceleration of the deployment of VCSELs across many end applications."

IQE is also developing integrated solutions using wafer processing technologies such as nanoimprint lithography (NIL) and quasi photonic crystals (QPC) to enhance the functionality and performance of VCSEL arrays.

The order and start of production is in line with the IQE's previously provided revenue guidance for 2019.

www.iqep.com

IQE appoints non-executive director, chairing Audit Committee

Epiwafer foundry and substrate maker IQE plc of Cardiff, Wales, UK has appointed Mrs Carol Chesney as non-executive director to the board. She will chair the Audit Committee, as well as serving as a member of IQE's Nomination and Remuneration Committees.

Chesney is currently serving as a non-executive director and chair of the Audit Committee of Renishaw plc since October 2012, in addition to currently serving as a non-executive director and chair of the Audit Committees of Hunting PLC since April 2018 and Biffa PLC since July 2018.

Previously, Chesney was company secretary of Halma plc (the FTSE 100 health, safety and environmental technology group) until 2018, having also served as group financial controller. Her role there included corporate governance, legal compliance, equity incentives, pensions, internal audit management, taxation, property, health and safety compliance, environmental reporting and anti-bribery and corruption compliance.

Chesney is a Fellow of the Institute of Chartered Accountants in England and Wales (FCA), and qualified with Arthur Andersen in the UK.

"Her appointment brings to the group a unique breadth of board-level experience from across a diverse range of listed businesses that will add an invaluable perspective to IQE as the company continues to build its position as a global technology leader," comments IQE's chairman Phil Smith.

www.iqep.com

IQE maintains 2019 guidance despite Huawei export ban

Maximum risk exposure estimated to be under 5% of 2019 revenue

IQE plc of Cardiff, Wales, UK says that — in response to the US Department of Commerce's Bureau of Industry and Security (BIS) adding Huawei Technologies Co Ltd and 68 of its affiliates to its 'Entity List' prohibiting the sale to Huawei of products covered by the Export Administration Regulations (EAR) without obtaining an appropriate export license — it is clarifying its potential exposure to the situation, as it supplies epiwafers to multiple chip firms in global supply chains, some of whom supply Huawei.

"The situation involving the ban is dynamic and it is not clear at this time how long it will remain in force or what the full implications will be," says IQE. However, the firm believes it is in a strong position to adjust to the possible consequences and scenarios resulting from this in a positive manner. "Across all product lines, IQE has supply relationships with multiple non-US customers, so is well placed to adapt to mid to long-term share shifts at both the component (chip) and the OEM level," the firm reckons. Most of IQE's technologies and supply chains are not affected by the ban and IQE complies fully with the EAR, it adds.

In the short term, IQE believes it may experience some delay to orders and the potential for adjustment of supplier-managed inventory levels, predominantly in its Wireless business unit. The Photonics and Infrared business units are essentially unaffected.

IQE says it has been engaging across its customer base in recent days specifically on this subject, and estimates that its current maximum risk exposure is less than 5% of total full-year 2019 revenue guidance. "Although there remains uncertainty and unpredictability related to this specific matter, given the market opportunity IQE faces in second-quarter 2019, the company leaves full-year guidance unchanged," the firm states.

"The recent ban on sales of products from US companies to Huawei and its affiliates is a factor completely outside of IQE's control," notes CEO Dr Drew Nelson. "However, our long-term strategy of supplying as many of the supply chains into all major OEMs as possible protects IQEs overall supply to a very significant degree. As a result, we believe the ban will have a limited impact on our mid- to long-term revenue trajectory. Indeed, the breadth of IQE's current product range, the new materials technologies being introduced to market over the coming months and years, and IQE's global manufacturing footprint are powerful mitigating factors in dealing effectively with the ongoing changing geopolitical landscape in our industry," he believes.

www.iqep.com

CS Applications Catapult partners with Faraday Grid to conduct market research on power electronics industry

The UK's Compound Semiconductor Applications (CSA) Catapult has been appointed by Faraday Grid Ltd to conduct market research on the power electronics industry.

CSA Catapult is a not-for-profit organization (based in South Wales) focused on accelerating the adoption of compound semiconductors and on bringing applications to life in three technology areas: power electronics, RF & microwave; photonics; and advanced packaging. It works UK-wide across industry sectors from automotive to medical, and from digital communications to aerospace.

Faraday Grid aims to enable a future energy system architecture that can deliver clean, reliable and affordable power from anywhere to anyone across the grid. Specifically, it comprises plug-and-play Faraday Exchanger devices that dynamically balance and smooth power flowing across the energy system, providing an open platform for technologies and solutions to connect and transact and enabling better power quality and lower energy costs than a traditional electricity network.

CSA Catapult has delivered research findings around the key trends and drivers across the power electronics industry and the impact on materials, sourcing and cost. Application areas explored included electric vehicles (EVs) and power converters.

CSA Catapult's research found that the UK's electric grid requirements will grow 10–15% per annum over the next 10–15 years, and that EVs will drive 85% of that. The Catapult hence modeled various scenarios for the industry and provided Faraday Grid with technology, economic and supply-chain roadmaps.

"In the early 20th century, the UK led the world in developing the electricity grid. Today, the centralized nature of our electricity grid means it is not responsive to the nation's future power needs," says CS Catapult CEO Stephen Doran. "The Faraday Grid enables smart grid networks and decentralized energy storage, which are critical if we are to power electric vehicles up and down the country," he adds.

"The electricity grid needs to adapt to keep pace with greater supply from renewables and increasing demand from households and businesses," notes Faraday Grid's chief supply-chain officer Jim Darroch.

www.csa.catapult.org.uk
www.faradaygrid.com

AXT's margins rebound despite revenue falling further

InP sales exceeds GaAs for first time

For first-quarter 2019, AXT Inc of Fremont, CA, USA — which makes gallium arsenide (GaAs), indium phosphide (InP) and germanium (Ge) substrates and raw materials — has reported revenue of $20.2m, down 0.9% on $22.2m last quarter and 17.2% on $24.4m a year ago.

In particular, substrate sales were $16.8m, down 2.3% on $17.2m last quarter and 13.4% on $19.4m a year ago. Revenue from raw material joint ventures was $3.4m, down about 32% on both $5m last quarter and $5.1m a year ago.

"The demand environment in Q1 was largely what we expected as a result of general economic slowdown around the world including the semiconductor industry plus the combination of trade relations, weakness in the LED market, a slowdown in growth in the data-center market as well as inventory rebalancing at several of our large customers," says CEO Dr Morris Young.

"In gallium arsenide, revenue for both wireless and LED applications have seen setbacks in recent quarters and, as expected, were soft in Q1. This was related to both a weak global demand environment and customer-specific challenges," he adds.

In indium phosphide, Q1 was the second-largest revenue quarter in AXT's history. It is also the first time that InP surpassed GaAs as the firm's largest sales contributor. "We received a large order from a customer in Asia that we believe relates to 5G telecommunication infrastructure," notes Young.

The number of 10%-or-more customers hence grew to two, while the top five customers again generated about 35% of total revenue.

Of total revenue, 65% came from Asia-Pacific (down further, from 69% last quarter), 13% from North America (rebounding from 10%), and 22% from Europe (up further, from 21%).

Although it is still below 39.2% a year ago, gross margin has rebounded from 26.3% last quarter to 33.1%, despite the drop in revenue. This is due mainly to the shift in product mix (from GaAs to higher-margin InP) as well as favorable raw material pricing and good manufacturing discipline.

We are taking the opportunity to strengthen our financial structure by controlling inventory, applying discipline to our spending, focusing on gross margin improvement, and making appropriate adjustments in our joint venture portfolio

"We are taking the opportunity to strengthen our financial structure by controlling inventory, applying discipline to our spending, focusing on gross margin improvement, and making appropriate adjustments in our joint venture portfolio," says Young.

Operating expenses have been cut from $6.5m last quarter to $6.1m. Operating profit was $0.629m, an improvement from an operating loss of $0.638m.

Net loss was $1.1m ($0.03 per share), level with last quarter but better than the expected $0.04–0.06. However, AXT would have been profitable without a charge of $1.7m comprising a quarterly loss assigned to AXT of $0.6m plus an impairment charge of $1.1m to completely write down its investment in germanium mining JV Tongmei (of which AXT owns 25%). "This mining company has been underperforming for some time and has been a headwind for the collective financial contribution to our joint venture portfolio," notes chief financial officer Gary Fischer. "In early April, we learned of its continuing difficulties and have a forecast for losses throughout all of 2019, which are large enough to reduce the asset on our books to zero," he adds. "Beginning in Q2, the net result that investors will notice from this change is that the equity accounting on our unconsolidated joint venture companies is likely to be breakeven or a little better as our germanium mining company has been the single largest underperforming investment in that portfolio."

AXT also reduced its majority ownership in one of its consolidated JVs (gallium-based raw material firm Ji-Ya) to 39% by selling part of its stake to the investment partner (the landlord of the JV, and now the largest shareholder). The JV has been struggling for some time, due mainly to the industry-wide drop in raw gallium prices. "As a result, we will no longer be using the accounting method of consolidation to bring the results of this company to our consolidated results, including our revenue line," notes Fischer. "Instead, we will use the equity method of accounting, where our ownership will impact to below the operating numbers in the line called equity in earnings/loss of unconsolidated joint ventures. The net result that investors will notice is that we will consolidate two raw material companies rather than three," he adds. The no-longer-consolidated JV contributed only $0.2m in revenue in Q1/2019, so AXT' revenue from raw material JVs going forward will hence likely remain at $3.5–4.5m per quarter.

Depreciation and amortization during the quarter was $1.5m. Capital expenditure (CapEx) was $4.2m. "We continue to execute the relocation of our [GaAs and Ge manufacturing] facility [from Beijing to Dingxing, China] on schedule and with positive customer qualification results," Young says. Due mainly to the new facility and equipment, cash, cash equivalents

and investments hence fell during the quarter from $39m to $34m.

Net inventory rose from $58.6m to $63m (41% in raw materials, 53% in work in progress and only 6% in finished goods). "Reduction in inventory is a focus for us in 2019. With relatively low revenue, we decrease inventory by almost $1m in the quarter, with the rest of the decrease resulting from not consolidating through our gallium company," says Fischer. "With our programs we have in place, we would expect to be able to drive it below $50m and perhaps a bit more over the coming year," he adds.

"With a strong performance in our indium phosphide business in Q1, we are building a solid foundation for its growth this year," says Young.

"We do expect a moderate improvement in business conditions in the second quarter," says Fischer. For Q2/2019, AXT expects revenue to rebound to $23.5–24.5m, driven by record InP revenue (largely due to Q1's 5G-related order), as well as growth in GaAs for LEDs and a modest improvement for wireless applications. Gross margin should rise further. Earnings per share should be steady at $0.02–0.04.

"The percentage of revenue coming from the new facilities [in Dingxing] is relatively small, probably 15–20%," says Young. "All our major customers have received qualification samples. A few of those largest customers have already qualified… We hope that the vast majority of our customers will take our product from the new facility by the end of the year," he adds.

"Our primary expenditure will be focused on the completion of the facility-related items, for which we expect to spend approximately $21m [per quarter] over the course of the year, or an additional $60m over the balance of the year," says Fischer. "Some of this cost will be offset in our cash balance by reduction in inventory, as well as our expectation of returning to positive operating cash flow," he adds. "The current facility in Beijing has considerable value that we will be able to monetize in the future."

"We are taking opportunity to strengthen our financial structure by reducing inventory, being careful of our spending, focusing on gross margin improvement and making appropriate adjustment in our joint venture portfolio," summarizes Young. "We are encouraged by the significant technology trends that are likely to drive demand for our products over time," he adds. "Our focus on the fundamentals of our model today will provide positive returns as the economic environment improves," he believes.

www.axt.com

Veeco's Q1 revenue levels out at $99m after drop off of commodity LED MOCVD system sales to China

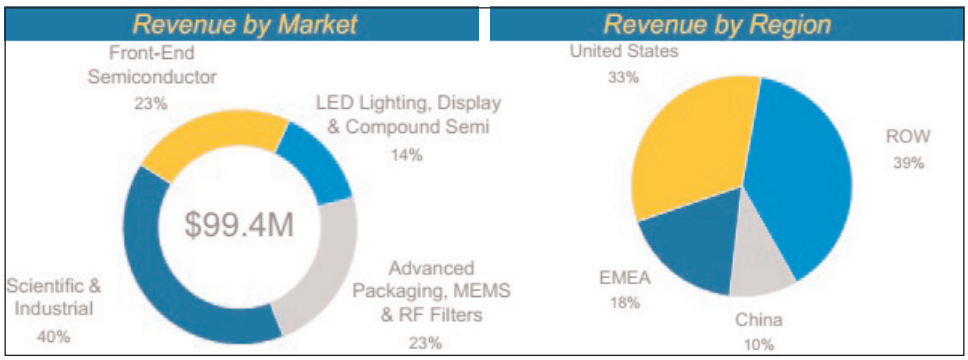
Gross margin expected to recover from 35.5% to 40% by year-end as product mix improves

For first-quarter 2019, Epitaxial deposition and process equipment maker Veeco Instruments Inc of Plainview, NY, USA has reported revenue of $99.4m, down 37% on $158.6m a year ago but roughly level with $99m last quarter (and above the midpoint of the $85–105m guidance range, driven by strength in services business). "With the commodity LED business [which includes the sale of metal-organic chemical vapor deposition (MOCVD) systems to the China LED market] largely behind us, our revenues for the quarter have stabilized," notes CEO Bill Miller.

With almost no contribution from commodity LED equipment sales (as expected), the LED Lighting, Display & Compound Semiconductor segment remained just 14% of total revenue (following the plunge from 46% in Q3/2018 to 14% in Q4/2018). Most of the segment's revenue was therefore in Compound Semiconductors, including MOCVD systems for specialty LEDs, automotive, photonics and power electronics applications.

The Advanced Packaging, MEMS & RF Filter segment — including lithography and Precision Surface Processing (PSP) systems sold to integrated device manufacturers (IDMs) as well as outsourced assembly & test firms (OSATs) for Advanced Packaging in automotive, memory and other areas — has rebounded from a low of just 14% of total revenue last quarter to 23%, driven by multiple Advanced Packaging lithography systems sold for high-bandwidth memory as well as CPUs and other applications.

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 Inc) has risen slightly from 22% of total revenue last quarter to 23%, driven by multiple laser spike anneal (LSA) systems shipped to a leading foundry for process steps at an advanced technology node.



The Scientific & Industrial segment has fallen back from last quarter's high of 50% of total revenue to 40%, driven by shipments to data storage customers as well as several ion beam sputtering systems shipped to optical customers.

Geographically, the quarter saw slight rebounds in China from just 9% to 10% of total revenue and in Europe, Middle East & Africa (EMEA) from just 17% to 18%. Meanwhile, the USA has fallen back from 41% to 33%, while the rest of the world (which includes Japan, Taiwan and South Korea) has risen further from 33% to 39%.

On a non-GAAP basis, gross margin has fallen further, from 36.5% a year ago and 36% last quarter to 35.5% (albeit towards the high end of the 34–36% guidance range, driven by tighter spending controls). Operating expenses were cut further, from $46.5m a year ago and $42.6m last quarter to $40m (better than the targeted $41m). "Our cost-reduction efforts were achieved a quarter earlier than previously communicated," notes chief operating officer & chief financial officer Sam Maheshwari.

Despite still being well below net income of $9.2m ($0.20 per diluted share) a year ago, net loss has been cut from $7.5m ($0.16 per diluted share) last quarter to $6.4m ($0.14 per diluted share), above the midpoint of the expected range of $14–5m ($0.30–0.10 per share).

"We are executing according to our plan, with Q1 revenue and EPS results above the midpoint of our guided range," says Miller.

Due mainly to the $6.4m net loss as well as working capital investments and biannual debt interest payment, cash flow from operations has worsened from $2m last quarter to cash outflow of –$22m. Capital expenditure (CapEx) was $2.2m. During the quarter, cash and short-term investments have hence fallen by about $24m, from $261m to $237m (of which $66m is held offshore).

Order bookings were $107.2m. "We saw strength in Scientific & Industrial orders, driven by our data storage customers," notes Maheshwari. "We also received multiple advanced packaging lithography system orders and another EUV [extreme ultraviolet] mask-blank [ion beam deposition] system order [the firm's fifth production-capacity order — the first was shipped in April]." Despite bookings being down 4.3% on $112m last quarter, order backlog grew from $288m to $295m.

For second-quarter 2019, Veeco expects revenue to be steady, at $90–110m. Gross margin should

recover to 37–39%. With OpEx remaining about $40m, net earnings are expected to range between a loss of $9m ($0.18 per diluted share) and a profit of $1m ($0.02 per diluted share). Although the cash balance declined during Q1, Veeco expects to generate positive cash flow in Q2/2019.

"Based on our backlog and current visibility, we see Q3 sales tracking above Q2," says Maheshwari. "We also see our gross margins further improving due to favorable product mix," he adds. "For the second half of 2019, we see top-line improving over the first half by roughly 10%. We continue to target gross margin of 40% by the end of this year."

Veeco's growth initiatives (which align with multiple megatrends) are:

- ion beam deposition systems for EUV mask blanks and laser annealing for advanced wafer processing (Front-End Semiconductor);
- MOCVD (Compound Semiconductor) for 3D sensing/VCSELs (vertical-cavity surface-emitting lasers); and
- lithography for wafer-level packaging (Advanced Packaging).

"On our MOCVD technology applied to the VCSEL market, we have been enhancing our TurboDisc platform to produce high-performance epitaxial VCSEL stacks," says Miller. "We are currently working with multiple customers to place the beta tool in their facilities [expected in the near term]," he adds. "This market today is absorbing the capacity that was recently added for the smartphone facial recognition application. However, we believe that additional 3D sensing applications such as world-facing sensors and automotive LiDAR will generate demand for some time. This is a potential market opportunity of $100–150m per year."

"We remain confident about growing our top line and returning to profitability," concludes Miller.

www.veeco.com

Riber's Q1 revenue falls 10% year-on-year as weak evaporator sales outweigh MBE system sales growth

Significant revenue growth forecast for full-year 2019

For first-quarter 2019, Riber S.A. of Bezons, France — which manufactures molecular beam epitaxy (MBE) systems as well as evaporation sources and effusion cells — has reported revenue of €6.6m (32.3% from Asia, 30.1% from Europe and 37.6% from the USA). This is down 10% on €7.3m a year ago due to a drop in revenue from evaporators, despite strong growth in revenue for MBE systems and services & accessories.

Revenue from evaporators (cells and sources) was just €0.8m, down 85% on €5.2m a year ago, attributed to the freeze on investments in equipment for organic light-emitting diode (OLED) screen production following the major investments made in previous years.

Revenue for MBE systems was €4.1m (reflecting the invoicing of two production systems), up 413% on only €0.8m (just one research system) a year ago.

Revenue for services & accessories was €1.7m, up 31% on €1.3m a year ago, in line with the firm's strategy to develop this business (which makes a strong contribution to gross margin).

The order book at the end of March was down 11% from €36.1m a year ago but remained high, at €32.2m, despite no orders being recorded for evaporators (€0.1m versus €8.3m a year ago). This was because MBE systems orders were up 25% from €20.2m to €25.3m (comprising 14 MBE systems, including seven production tools). Services & accessories orders were down 11% from €7.6m a year ago, but still at a 'satisfactory' level of €6.8m.

Riber notes that, considering the good level of orders (with a high percentage of systems to be delivered in 2019), it is forecasting significant growth in full-year revenue in 2019 compared with 2018.

www.riber.com

French laser maker 3SPT orders Riber production MBE system

Riber has received an order from France-based 3SP Technologies (3SPT) for a 412 P production MBE system (for delivery in 2020) in order to increase its optoelectronic component production capacity.

3SPT, a subsidiary of O-Net Technologies (Group) Ltd of Shenzhen, China (which provides optical networking products for telecoms and datacoms applications), specializes in fabricating high-performance laser chips and modules, targeting the needs of increasing data rates in optical fiber communication networks and data centers.

Riber has also received an order from a new client in the Middle East for a Compact 21 (said to be the world's most widely sold research MBE system), for delivery in 2020, to strengthen its research capabilities for emerging 2D semiconductor materials and oxides.

Riber reckons the order highlights its capacity for development in new high-growth geographical markets.

The firm says the Compact 21 was chosen for its performance levels and flexibility (enabling it to adapt to complex research needs) as well as the extensive portfolio of Riber components.

Aixtron's Q1 gross margin & earnings exceed expectations

Positive currency exchange rate effects and reduced costs offset increased low-margin sales in product mix

For first-quarter 2019, deposition equipment maker Aixtron SE of Herzogenrath, near Aachen, Germany has reported revenue of €68.7m, down 22% on €87.9m last quarter but up 10% on €62.4m a year ago. "Business development in the first quarter of 2019 was in line with our expectations," says president Dr Bernd Schulte.

Specifically, equipment revenue was €56.1m, up 10% on €50.8m a year ago (rising 81% to 82% of total revenue). Meanwhile, revenue from spare parts & services has grown by 0.9% from €11.6m a year ago to €12.5m.

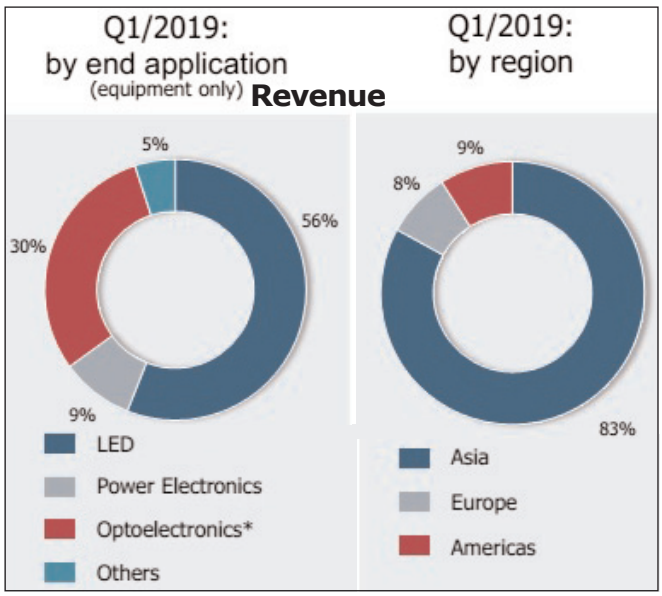
Of equipment revenue, metal-organic chemical vapor deposition (MOCVD) systems for manufacturing Optoelectronic components (consumer optoelectronics, telecom/datacom and solar) declined from 70% a year ago to 30%, as expected, while systems for manufacturing Power Electronics components fell from 11% to 9%. In contrast, lower-margin MOCVD systems for producing LEDs have risen from a low of just 14% a year ago to 56% of total revenue.

Correspondingly, on a regional basis, Asia has risen from 46% of revenue a year ago to 83% (almost doubling from €29m to €56.7m), while Europe has dropped from 38% to 8% (falling by 77% from €23.5m to €5.4m) and the USA from 16% to 9% (falling by 34% from €9.9m to €6.5m).

Reflecting the higher share of lower-margin LED systems in the product mix, cost of sales rose from €35.6m (57% of revenue) in Q1/18 to €42m (61% of revenue) in Q1/19.

Gross margin hence fell to 39%, but only slightly from 43% a year ago aided by the advantageous US$/€ exchange rate and lower product costs.

Operating expenses have been cut further, by 10% from €18.9m a year ago to €17m, due mainly to lower project-related costs.



"Our continued productivity gains and lower costs, combined with a favorable US$/€ exchange rate, are positive factors supporting both our gross margin and our results," says Schulte.

Operating result (EBIT) was €9.7m (14% of revenue), up from €7.9m (13% of revenue) a year ago due to the revenue growth and cost cutting.

However, net profit has fallen, to €8.5m, from €12.3m a year ago (which had been boosted by the positive impact of deferred tax assets of €5m).

Due to inventories rising by €6.7m from €73.5m to €80.2m (mainly reflecting the expected level of sales in subsequent quarters plus the construction of prototypes and the procurement of items that could be affected by Brexit) and trade receivables falling by €5.3m from €40.1m to €34.8m (from 36 days to 28 days sales outstanding), operating cash flow was –€11.9m (an improvement from –€21.1m a year ago).

After capital expenditure of €5.6m, free cash flow was hence –€17.5m (an improvement on –€22.3m a year ago).

During the quarter, cash including other financial assets (bank deposits with maturity of over 3 months) fell by €15.8m from €263.7m to €247.9m.

Order intake (including spare parts and service) was €53.6m, down 26% on €72.2m last quarter and 32% on €78.6m a year ago. "While in terms of revenues Q1/2019 was the strongest first quarter in many years, order intake reflects the current reluctance of our customers to invest in the expansion of [optoelectronics] production capacity," says Schulte. So, despite being up 9% on €114.9m a year ago, equipment order backlog has fallen by 9% from €138.3m last quarter to €125.7m.

However, the prospects for the core optoelectronics and power electronics business are intact, reckons the firm. In particular, Aixtron continues to expect increasing demand for lasers due to increasing applications in 3D sensor technology, security infrastructure or optical data transmission as well as the increasing use of LEDs and specialty LEDs in displays and other applications. Also, the firm expects an increased use of gallium nitride (GaN)- or silicon carbide (SiC)-based devices for energy-efficient communication and energy management in automobiles, consumer electronics and mobile devices.

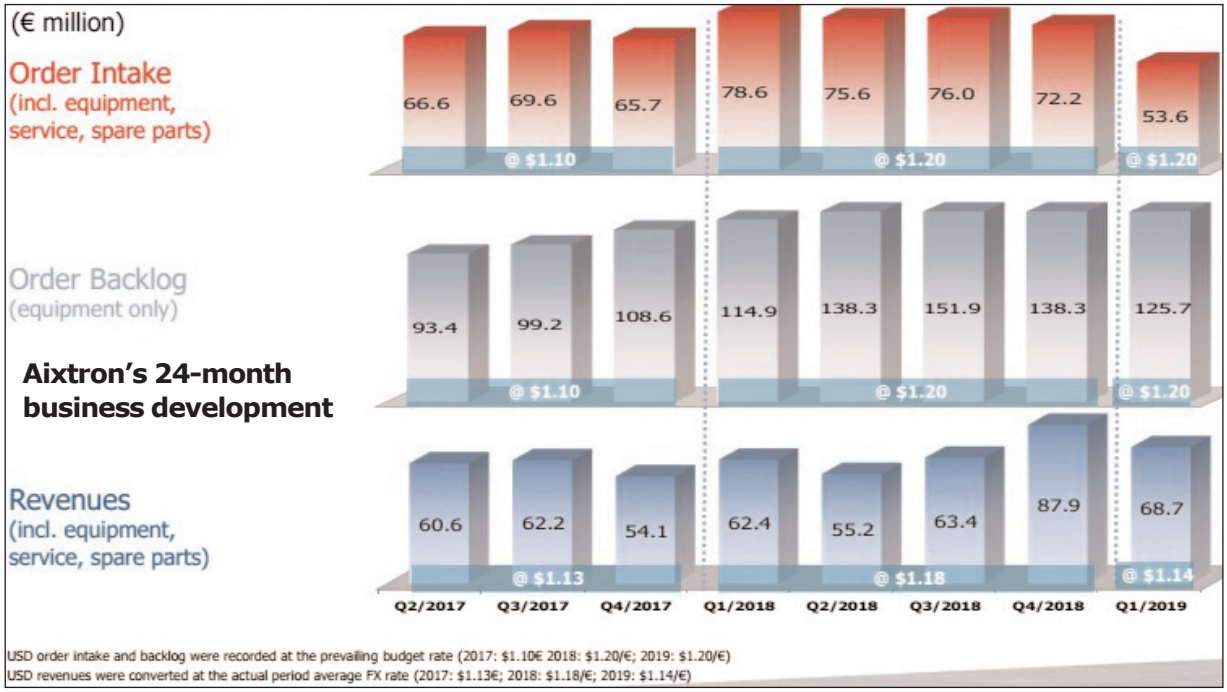
"There has been no change in the medium- and long-term positive assessment of our core markets," believes president Dr Felix Grawert. "We remain firmly convinced that Aixtron will benefit from numerous forward-looking technology trends due to its product portfolio. As market and technology leader in optoelectronics, we are excellently positioned in laser and special LED applications as well as in power electronics, where we will be launching a new generation of systems this year," he adds.

Also in Q1/2019 subsidiary APEVA took a further step towards qualification of organic vapor phase deposition (OVPD) technology with the commissioning of the firm's Gen2 organic light-emitting diode (OLED) system on a customer pilot-production line. In the coming months, the facility is expected to deliver test results that will serve as the customer's decision basis, support its decision-making process, and further advance the development of the technology.

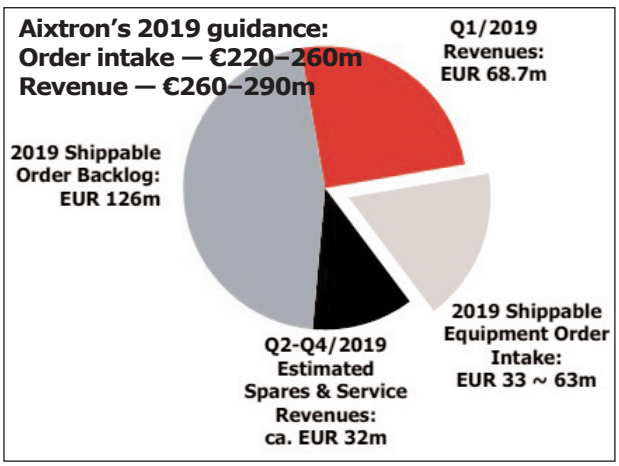
Based on Q1/2019 results and internal assessment of the development of demand, Aixtron maintains its forecast for full-year 2019 that it gave in February's annual report. Accordingly, compared with 2018, the firm expects stable to slightly growing sales development.

Based on the budget exchange rate of US$1.20/€, Aixtron expects orders of €220–260m for full-year 2019 (down from €302.5m in 2018). This includes an expected order from the OLED customer for a large-scale test system as part of the ongoing qualification process for OVPD technology for the OLED display industry. With anticipated sales revenue of €260–290m (compared with €268.8m in 2018), Aixtron expects gross margin of 35–40% (down from 2018's 44%) and EBIT of 8–13% of revenue (down from 15%). Furthermore, the firm should generate free cash flow of €15–25m (up from 2018's €4.4m). Expectations for 2019 include the results of the APEVA subsidiary, including all necessary investments to continue OLED development activities.

www.aixtron.com



Aixtron's 24-month business development



Aixtron leads MOCVD market for third consecutive year, at 46% share

According to the report 'Market Share: Semiconductor Wafer Fab Equipment, Worldwide, 2018' by Gartner, for a third consecutive year Aixtron maintained its position as market leader for MOCVD equipment, with a 46% share, ahead of the USA's Veeco at 27% and China's AMEC at 23%, while the MOCVD market grew from $401m in 2017 to $553m in 2018.

Aixtron's MOCVD systems are used in the high-volume production of lasers for applications such as 3D sensing and optical data communications as well as specialty LEDs, compound solar cells and gallium nitride (GaN) power electronics or GaN RF applications, in particular for the build out of the new 5G communication network.

"We focus on our core competence in MOCVD technology and have achieved market leadership in a number of highly attractive growth markets due to the strong performance of our systems," says president Dr Bernd Schulte. "Our continued success is based on an application understanding developed over decades in cooperation with our customers," he adds. "This strongly serves the continuous further development of our portfolio to best meet the specific requirements of the end markets — highest quality epitaxial layers combined with high efficiency in handling the precursors used for MOCVD processes. Thus we offer the lowest cost of ownership for high-volume manufacturing of compound semiconductor devices."

www.gartner.com/en/documents/3907152

SMI delivers two 2D metal dichalcogenide systems

Structured Materials Industries Inc (SMI) of Piscataway, NJ, USA — which provides chemical vapor deposition (CVD) systems, components, materials and process development services — has delivered metal-organic chemical vapor deposition (MOCVD) research systems to two US universities. The two MOCVD systems are part of the NanoV CVD and NanoH CVD series and are configured primarily for the growth of 2D transition metal dichalcogenide materials, of which a variety are under investigation (for optoelectronic devices, solar cells, photodetectors, light-emitting diodes and photo-transistors) including MoS_2, WS_2, $MoSe_2$ and WSe_2.

One system features a dual-reactor arrangement of a NanoV CVD and a NanoH CVD. The east-coast research professor's group focuses on integrating, assembling and characterizing atomic-scale materials into electronic and photonic devices for various applications. The vertical and horizontal reactors allow for significantly different process phase spaces to be investigated in optimizing 2D materials. This is the second such tool for this professor.

An SMI-designed and -fabricated NanoH CVD system.

The second tool is a single NanoH CVD research system for a professor at a California university. Similarly, this professor had used an SMI-built system as a post-doc at his previous university. His group specializes in areas such as the systematic design of oxide, carbide and sulfide materials for materials synthesis of multi-dimensional device architectures in applications such as energy conversion and storage.

"There is always a need for custom versatile tools that can robustly and reproducibly produce advanced materials that are at the forefront of research and development efforts — such as, in the present case, high-quality 2D materials," says president Dr Gary S. Tompa. "Also important are the size scalability of the tools. The standard capabilities of these tools — such as the multi-zoned temperature-controlled furnace or field-recalibratable mass flow controllers or a versatile researcher-oriented control system such as SMI's SmartCVD PLC control system — allow for easily switching amongst the most promising growth materials, processes, and tool configurations," he adds. "We designed these specific tools to be both flexible and to address the exacting needs of growing the latest 2D materials that are associated with forming stable monolayer, single-unit-cell-thick films to easily produce materials for advanced device research and prototype manufacturing.

www.smicvd.com

Strem's HQ re-certified under ISO 9001:2015 standards

Strem Chemicals Inc — a privately held manufacturer of high-purity specialty chemicals (including catalysts, ligands, organometallics, metal carbonyls and nanomaterials) for both R&D and commercial-scale applications — says that its corporate headquarters in Newburyport, MA, USA has been re-certified under ISO 9001:2015 for the Quality Management System (QMS) standard.

International Organization for Standardization (ISO) certification is based on quality management principles including consistently documented processes, strong focus on customer service, maintaining quality standards, continual review and improvement of process approach, as well as a dedicated management commitment to upholding all facets of the ISO 9001 QMS. The ISO 9001:2015 standard is the latest certification available from ISO and upholds the organization's emphasis on quality management systems and performance. This standard is built around quality management principles such as: process approach, customer focus, leadership, engagement of people, improvement, sound decision making and relationship management.

"I am proud of the hard work and dedication of our employees to maintain continued commitment to our quality standards,," says CEO Dr Ephraim S. Honig. "The attainment of this ISO 9001:2015 recertification illustrates our mission and is driven by our pledge to our customers to provide high-quality products and services," he adds.

Strem is certified as meeting the requirements of ISO 9001:2015 for the following scope: Manufacturing and Marketing Specialty Chemicals of High Purity. To be certified as ISO 9001 compliant, Strem underwent an evaluation process that included quality management system development, management system documentation review, pre-audit, initial assessment and clearance of non-conformances. To maintain this certification, NQA will perform audits to ensure compliance and to assess initiatives for continued improvement.

www.strem.com

SEMI partners with imec, CEA-Leti and Fraunhofer

SEMI of Milpitas, CA, USA (the industry association representing the global electronics manufacturing and design supply chain) says that, in the three months since nanoelectronics research centre imec of Leuven, Belgium joined SEMI as a Strategic Association Partner under a memorandum of understanding (MOU) announced at the SEMI Industry Strategy Symposium (ISS) in January, two additional leaders in nanoelectronics research — CEA-Leti of Grenoble, France and Germany's Fraunhofer — have agreed to join forces by signing similar agreements. SEMI says that, by partnering with imec and now CEA-Leti and Fraunhofer, it brings global scale to three of the world's top technology research and innovation centers to support and inspire the development of new products and technologies by its more than 2100 member companies.

Under the MOUs, SEMI will partner with imec, CEA-Leti and Fraunhofer to drive innovation and deepen industry alignment on technology roadmaps and international standards while adding technology depth to the more than five SEMI vertical application platforms including Smart Transportation, Smart MedTech, Smart Manufacturing, Smart Data and IoT.

"The addition of these premier technology research and innovation hubs epitomizes SEMI's mission to connect, collaborate and innovate throughout the global electronics supply chain," says SEMI's president & CEO Ajit Manocha. "In return, SEMI provides access on our global platform to the $2 trillion global electronics manufacturing and design supply chain to enable new levels of innovation across the industry and bring new opportunities and greater value to our members," he adds.

Under the agreements, the organizations will work to advance technology roadmaps, industry standards and cutting-edge technologies including Internet of Things (IoT), artificial intelligence (AI) and machine learning that enable new capabilities across healthcare, automotive and other electronics manufacturing ecosystems. The aim is for that work will bring SEMI members closer to new customers, research partners and deep technical expertise.

As part of its commitment to its 600 plus partners globally, imec works to ready the ecosystem for innovation. SEMI and its members are part of this ecosystem and, by working with SEMI, imec aims to benefit its partners.

The CEA-Leti technology research institute has expertise, from sensors to data processing, artificial intelligence and computing solutions. It pioneered fully depleted silicon-on-insulator (FDSOI) low-power platforms for IoT, microsystem technology for low-cost multi-sensor solutions, and smart integration for highly connected and cost-effective devices. CEA-Leti's mission is to pioneer disruptive technologies, enabling solutions that create value and strengthen its industrial partner's competitiveness. By signing the agreement with SEMI, CEA-Leti continues working in that direction, reinforcing its relationships with its ecosystem.

As Europe's largest application-oriented research organization, Fraunhofer's research is geared entirely to people's needs: health, security, communication, energy and the environment.

Imec, CEA-Leti and Fraunhofer join the growing SEMI family of Strategic Association Partners, which includes the Electronic System Design Alliance (ESD Alliance), FlexTech, the Fab Owners Alliance (FOA) and the MEMS & Sensors Industry Group (MSIG).

www.semi.org
www.leti.fr
www.imec.be

Palomar expands Southeast Asia Innovation Center

Latest 6532HP die bonder added for assembly of photonics packages

Photonics and microelectronic device assembly & packaging equipment maker Palomar Technologies Inc of Carlsbad, CA, USA has expanded its Innovation Center in Singapore to further meet the growing demands of photonics companies designing and launching new high-performance packages that enable the Internet-of-Things (IoT) and 5G wireless networks.

The expansion has provided the opportunity to add the firm's latest die bonder (the 6532HP) designed for the demanding assembly needs of advanced photonics packages (being said to exceed industry standards for placement accuracy and production speed).

Opened last November in partnership with the Singapore-based Lux Photonics Consortium and DenseLight Semiconductors, Palomar Technologies' Innovation Center — Asia is targeted at addressing a vital market need from global new product introduction (NPI) teams: process development, device package prototyping, test & measurement, process maturation and low-volume production. It also creates a path for customers to enable a seamless transfer to high-volume production, usually performed in Asia, says Palomar.

Palomar's Innovation Center in Singapore.

"The photonics market is exploding and, for the many companies with little to no experience in assembling photonics device packaging or the equipment capabilities, they face a high risk of successfully launching their product — most will die in the proverbial 'Valley of Death' because they simply don't understand how to manufacture their device cost-effectively," says Rich Hueners, VP of global sales & managing director, Asia Pacific. "By partnering with the Palomar Innovation Center, customers have the advantage of easily bridging from NPI to high volume with significantly lower costs," he adds. "Palomar has over 40 years of deep industry experience in the design and assembly of photonics and microelectronics devices. Companies new to this market gain exponentially from our experience."

The value of light-enabled products and services is estimated to be $7–10 trillion annually, so photonics represents about 13% of the world's economy (according to a National Academy of Sciences report 'Optics & Photonics: Essential Technologies for our Nation'), notes Palomar. With the push towards smart cities, autonomous vehicles and 5G, the demand for connected devices and higher-capacity networks is steadily growing, increasing the need for light-enabled products and services, the firm concludes.

www.palomartechnologies.com/6532hp-die-bonder-data-sheet
www.luxphotonicsconsortium-sg.org
www.denselight.com

Ferrotec sells Temescal UEFC-4900 evaporator system and Auratus process to II–VI

Materials, component and precision system supplier Ferrotec Corp of Santa Clara, CA, USA (whose Temescal division of Livermore, CA, USA makes electron-beam evaporative coating systems) says that engineered materials and optoelectronic component maker II–VI Inc of Saxonburg, PA, USA has procured a Temescal UEFC-4900 system and Auratus deposition process enhancement methodology.

The firm says that II–VI and its customers will benefit from the improved film uniformity and reduced materials consumption offered by the Auratus process.

"We rely on the expertise of Ferrotec and their ability to deliver high-quality metallization processes in production scale for our compound semiconductor manufacturing platform," comments Utpal Chakrabarti, VP, Optoelectronic and Wide Bandgap Devices, at II–VI.

"Ferrotec was pleased to offer an effective demonstration of the Temescal systems to the II–VI team, demonstrating the benefits that the Auratus process offers in delivering unmatched film quality and operating efficiency," says Gregg Wallace, managing director of Temescal Systems at Ferrotec.

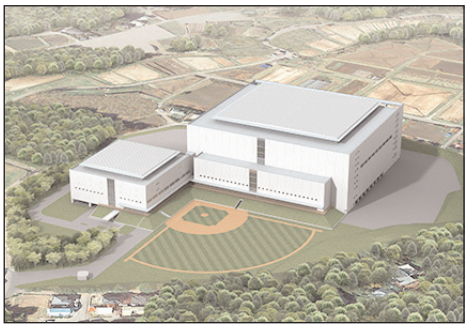
www.temescal.net
www.ferrotec.com
www.ii-vi-photonics.com

DISCO constructing new building at Nagano Works Chino Plant

Floor space being expanded from 20,293m² to 131,920m²

Tokyo-based equipment maker DISCO Corp — which makes semiconductor manufacturing equipment including chemical mechanical polishing (CMP) systems and laser-based ingot slicing equipment and processes for silicon carbide (SiC) — is investing about JPY17.5bn to construct a new 10-story building ('Building B') at its Nagano Works Chino Plant in Chino City.

With the introduction of fifth-generation (5G) communication systems accelerating, the semiconductor and electrical components markets — including the development of the Internet of Things (IoT), self-driving systems and remote medical technology — are expected to grow. Demand for DISCO's precision processing equipment (for cutting, grinding and polishing silicon wafers etc) and tools



(consumables) is also expected to increase accordingly. In response to the expected growth of these markets, DISCO is already expanding its Kuwabata Plant in Kure City, Hiroshima. However, it has been determined that further expansion of production capacity will be required.

In addition, most of the precision processing equipment and tools are currently produced in the Kure and Kuwabata Plants in Hiroshima. Seismically isolated structures have been adopted in the buildings at both plants, and construction to ensure an independent water source has been conducted to safeguard against future water outages. However, the distance between the two plants is only about 10km so, to prevent a situation where both plants cannot function should a disaster affect the entire area, resources need to be divided further, notes DISCO, hence the new building in Nagano.

Construction of the new seismically isolated Building B will begin in July and complete in December 2020, boosting the building area from the existing 4018m² to 16,280m² (and total floor space from 20,293m² to 131,920m²) within a site area of 71,044.4m².

www.disco.co.jp

Taiwan's NCTU boosts micro-LED brightness using Picosun ALD passivation technology

Atomic layer deposition (ALD) thin-film coating technology firm Picosun of Espoo, Finland has reported results in boosting μLED performance using ALD passivation.

Micro-LEDs present a challenge to existing display technologies such as LCDs (liquid-crystal displays), OLEDs (organic light-emitting diodes) or conventional LEDs. Offering compact size, low power consumption, superior brightness and energy efficiency, greater contrast and color saturation, ultra-high resolution, flexibility and good reliability, micro-LEDs are being studied and developed by leading electronics manufacturers and R&D institutes worldwide, says Picosun. They are typically used for small screens such as those in tablets, smartphones and smart watches, and the first large-area displays have also been demonstrated.

However, micro-LED technology has drawbacks that have been hindering its full-scale commercial breakthrough. The micro-LED screen consists or minuscule pixels producing green, blue and red light. Some steps in the manufacturing process of these pixels can easily cause damage to their nano-scale structures, leading to loss of light intensity. ALD has now been proven to effectively fix this damage, not only restoring light intensity but actually boosting it to superior levels, says Picosun. At the site of customer National Chiao Tung University (NCTU) in Taiwan, the light-emitting intensity of micro-LEDs has been enhanced by 143.7% by using ALD passivation layers deposited with Picosun ALD equipment, it is claimed (Chen et al, Photonics Research, vol.7 no.4, p416 (2019)).

"Picosun ALD equipment has been an integral part of our facilities for a long time, and we are always impressed by their performance and the superior ALD film quality obtained with them," comments NCTU professor Hao-Chung Kuo. "Picosun's customer support is also impeccable, which is very much appreciated considering we collaborate extensively with industries," he adds.

"Micro-LED technology has immense potential to disrupt the solid-state lighting market, and our Asian customers — both in industries and R&D — will surely lead the forefront of this development," reckons Edwin Wu, CEO of Picosun Asia Pte Ltd.

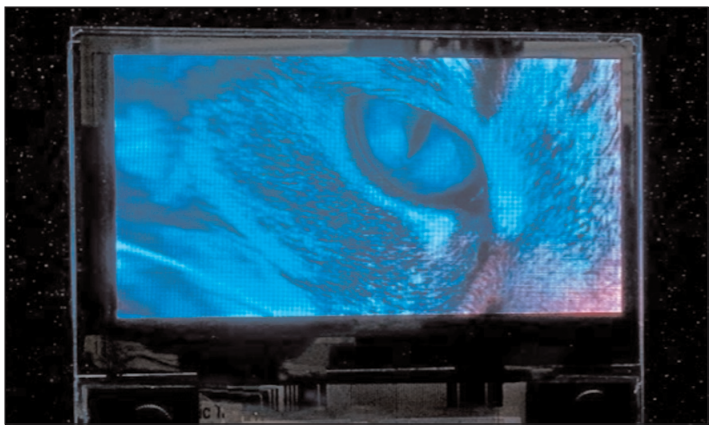
www.picosun.com

X-Celeprint implements BluGlass' RPCVD p-GaN technology in micro-LED display prototypes

BluGlass Ltd of Silverwater, Australia and its foundry customer X-Celeprint of Cork, Ireland — a subsidiary of XTRION N.V. of Tessenderlo, Belgium that utilizes facilities at Ireland's Tyndall National Institute and in Research Triangle Park, NC, USA to develop and license patented micro-transfer printing (μTP) and related technology — have implemented BluGlass' unique remote-plasma chemical vapor deposition (RPCVD) p-GaN technology in high-performance micro-LED display prototypes.

BluGlass is commercializing its proprietary RPCVD technology in the LED, micro-LED and power electronics industries, for which patented hardware and processes are claimed to offer manufacturers unique performance advantages due to its low-temperature and low-hydrogen growth conditions.

X-Celeprint is using RPCVD deposition for its unique technology demonstrations. X-Celeprint's active-matrix micro-LED displays that use RPCVD p-GaN have demonstrated luminance with colour uniformity, quantum efficiency and forward voltage that equals existing high-performance commercial applications of 2000cd/m^2.



X-Celeprint's 2000cd/m^2 micro-LED display, using RPCVD p-GaN, showing good colour uniformity quantum efficiency and forward voltage.

X-Celeprint (which provides custom design services for micro-transfer printing stamps and printers) says that its μTP is a cost-effective and scalable manufacturing platform for integrating microscale devices such as lasers, LEDs or integrated circuits onto non-native substrates. The firm has been a long-standing customer of BluGlass' foundry services and was the first adopter of RPCVD for micro-LED demonstrations.

"X-Celeprint works with BluGlass to demonstrate our micro-transfer printing capability for micro-LED displays," says X-Celeprint's VP of displays Matt Meitl. "BluGlass' creativity in epiwafer design, unique capabilities in epitaxial growth, and dedication to continued product improvement make them a valuable development partner. We continue to use these advantages in our micro-LED development," he adds.

"It's rewarding, after many years of developing RPCVD p-GaN, to see our technology being trialed in customer devices, particularly for the emerging micro-LED display market," comments BluGlass' chief technology officer Dr Ian Mann. "This micro-LED prototype demonstrates good performance, and X-Celeprint are seeing the advantage of using RPCVD in their innovative products."

X-Celeprint continues to use BluGlass' RPCVD foundry services (early-stage, fee-for-service revenue) to advance the technical demonstrations of its active-matrix micro-LED displays, and is actively marketing its high-performance display technology in the emerging micro-LED market.

www.bluglass.com.au

HexaTech achieves defect-free 2"-diameter AlN substrate

As part of its R&D program (combined with the direct support of its strategic business partners), HexaTech Inc of Morrisville, NC, USA — which manufactures single-crystal aluminium nitride (AlN) substrates for long-life UV-C LEDs in disinfection applications, deep UV lasers in biological threat detection, and high-voltage power switching devices in efficient power conversion as well as RF components in satellite communications — has announced what it reckons is the first demonstration of a defect-free 2"-diameter AlN substrate.

"This is the largest known single-crystal AlN substrate that is completely free of macroscopic defects, and accomplishes a long-standing goal as part of our 2" product development," says co-founder & chief technology officer Dr Raoul Schlesser. "Full-substrate reflection x-ray topography confirms this achievement, which will support and accelerate commercial production of high-quality 2" material," he adds.

"Less than a year from our first 2" demonstration, reaching this level of perfection is a testament to the efforts of the entire HexaTech team," says CEO John Goehrke. "This capability establishes a new baseline for sustaining our vision of continued diameter expansion and greater market adoption."

HexaTech's 2"-diameter substrates, in addition to 35mm and 25mm substrates, are available now with standard lead times.

www.hexatechinc.com

UniversityWafer introduces AlN-on-sapphire and AlN-on-silicon wafers

UniversityWafer Inc of South Boston, MA, USA, along with its partners, has introduced a new line of 50.8mm, 100mm and 150mm UV-grade aluminium nitride (AlN) on c-plane single-side-polished (SSP) sapphire and AlN-on-silicon prime-grade for high-electron-mobility transistor (HEMT) templates.

A major use of AlN-on-sapphire is ultraviolet LEDs. Some of the most powerful applications include irradiating hospital rooms and foundry cleanrooms, since AlN-on-sapphire LEDs disinfect instruments and can purify air and water of germs and bacteria without using chemicals.

The electricity savings of using LEDs instead of traditional CCFLs (cold-cathode fluorescent lamps) can reach 70%. Also, unlike CCFLs, AlN LEDs do not contain mercury, allowing environmentally friendly disposal. AlN LEDs can also be used for non-line-of-sight communications.

Currently, the newest-generation AlN-on-sapphire LEDs technology is approaching 50,000 hours of life, compared with just 10,000 hours for existing AlN-on-sapphire LEDs. The cost saving will only increase with time, adds the firm.

UniversityWafer says it carries a large inventory of AlN-on-sapphire substrates, and can also quote unique client specs in small quantities that make it feasible for budget-strapped researchers to obtain the substrates at a reasonable cost. Delivery time is short, notes the firm. UniversityWafer hence caters to researchers wanting both small quantities and short lead-times, with staff trained to handle even the most difficult low-volume requests.

For production, AlN-on-sapphire can be ramped up to meet a client's demands in a timely and affordable manner, UniversityWafer adds.

www.universitywafer.com/aluminum-nitride-silicon.html

VerLASE extends IP base to mass-transfer technology for micro-LED displays

VerLASE Technologies LLC of Bridgewater, NJ, USA (spun off from technology development firm Versatilis LLC of Shelburne, VT, USA in 2013) is developing unique technologies for massively parallel assembly of micro-LED dies or films (the central challenge in micro-LED display manufacturing hindering wide-spread adoption of micro-LEDs).

Many observers point to inherent advantages of micro-LEDs such as brightness, efficiency, robustness, and a vision of modular panels that can be tiled into displays of any size. Despite being a superior technology in theory which, for example, overcomes the many problems surrounding OLED displays, micro-LED displays have been bedeviled by practical manufacturing aspects, notes VerLASE. Among these, perfectly assembling the micro-LED subpixels (which can be 10μm or even smaller) in a commercially viable way on a switching backplane remains a huge, unsolved problem.

Several firms (including a few start-ups) have shown various approaches to solving this problem at trade shows and conferences. However, the proposed methods seem too slow to be cost effective and generally offer no apparent way of repair and replace, since displays must be perfect with no misplaced pixels, notes VerLASE. Micro-LED display prototypes shown so far also tend to have lower resolutions (PPI) than might be needed today, e.g. for a typical smartphone display or 8K display.

VerLASE says that it is focused on practical methods that use well-proven semiconductor and MEMS industry methods and existing tools in novel ways to enable deterministic, massively parallel transfers of micro-die, yet with provisions that allow selective repair. The methods employ well-developed techniques used daily in ink-jet printing (although it is not printing per se). Comprehensive patent filings cover multiple variations of the firm's proprietary core Large Area Assembly Process (LAAP). "In levering the ink-jet industry, our solution offers a quick path for micro-LEDs to disrupt the displays industry," believes Ajay Jain, chief technology officer and inventor of the technology.

The firm is working on demonstrating the base principles of its solution while being in discussions with potential investors. VerLASE had previously been focused on color conversion technology for micro-LEDs and related applications (which remains a core capability) but decided to broaden the horizon, given its novel solution to the mass-transfer problem. It has seven US patents now issued covering various aspects in color conversion (including some in Japan, Korea and China) with others pending. The firm has now also filed a suite of IP relating to its mass-transfer solution.

The patents that are issued encompass VerLASE's Chromover branded color conversion technology, which can efficiently downconvert colors from inexpensive, widely available blue/violet light sources such as LEDs, micro-LEDs or laser diodes to any color in the visible range for a wide variety of applications, to novel materials used both passively (as phosphors) and actively (as the electroluminescent layer in light engines of the near future).

www.verlase.com

Vuzix and Plessey enter into long-term micro-LED supply agreement

An exclusive display device design and long-term supply agreement will support the development and production of next-generation augmented reality (AR) products and solutions combining the micro-LED light source technology of UK-based Plessey with the expertise and IP in smart glasses and essential optics technologies of Vuzix Corp of Rochester, NY, USA.

Vuzix has already developed an evolving family of smart glasses culminating in the Vuzix Blade, a next-generation smart display with a see-through viewing experience via its proprietary waveguide optics. Formed from glass with precision nanostructures, the waveguide enables users to see high-resolution computer-generated graphics, images and information superimposed over images from the physical or real world.

Plessey says that its micro-LED solution will simplify existing smart glasses' complex optical system of red, green and blue light sources and their additional optics by replacing it with a single self-emitting display that has integrated micro-optical elements. Size, weight and power reduction are key considerations in the AR wearables market. Existing light source systems have considerable losses all the way through to the waveguide and the optical systems around them are bulky and complex, whereas an emissive micro-LED has simple optical requirements, allowing a much smaller footprint with minimal system losses by placing the light source directly in front of the waveguide.

"Micro-LED technology represents a key part of the solution needed to bring the form and functionality of Vuzix next-generation smart glasses to the look and feel of fashion forward glasses," believes Vuzix's president & CEO Paul Travers.

"By overcoming the difficulties of manufacturing micro-LEDs on a commercial scale, Plessey is playing a central role in providing next-generation technology to the augmented reality and display markets," says Plessey's president of corporate and business development Mike Lee.

www.vuzix.com
www.plesseysemiconductors.com/products/microleds

CEA-Leti develops CMOS-driven micro-LEDs with simplified transfer process that eliminates TFT backplane

New concept creates all-in-one RGB micro-LEDs, eliminates transfer steps to receiving substrate

On 14 May during Display Week 2019 in San Jose, CA, USA, micro/nanotechnology R&D center CEA-Leti of Grenoble, France has presented a paper on new technology for fabricating high-performance gallium nitride (GaN) micro-LED displays for applications ranging from smart watches to TVs with no size limit.

The approach fabricates elementary units of all-in-one red, green, blue (RGB) micro-LEDs on a CMOS driving circuit, and transfers the devices to a simple receiving substrate. The units are fabricated with a full semiconductor, wafer-scale approach.

"This new process, in the proof-of-concept stage, paves the way to commercial, high-performance micro-LED displays," reckons François Templier, CEA-Leti's strategic marketing manager for photonic devices. "The CMOS-based approach provides higher-brightness and higher-resolution micro-LEDs and is a game changer for very large TVs," he adds.

While they promise exceptional image quality and better energy efficiency than existing liquid crystal display (LCD) and organic light-emitting diode (OLED) technologies, micro-LED displays currently face significant barriers to commercialization.

One of the biggest challenges is improving the performance of the driving electronics, which require more power to deliver brighter images and more speed to support continuously increasing demands for high display resolution. Faster electronics are required to power millions of pixels in a fixed-frame time in micro-LED displays, but existing thin-film transistor (TFT) active-matrix driving display technology cannot provide the necessary current and speed.

CEA-Leti's new approach fabricates CMOS-driven, high-performance GaN micro-LED displays with a simplified transfer process that eliminates the use of the TFT backplane. RGB micro-LEDs are stacked directly onto a micro-CMOS circuit, and each unit is transferred onto a simple receiving substrate. Then, the RGB micro-LEDs and the backplane are fabricated on a single semiconductor line.

In addition to increasing power and driving speed — and improving display performance — this process avoids several costly steps needed with existing technology to make electrical and mechanical contacts between micro-LEDs and the receiving substrates.

www.leti.fr

Jasper Display and Plessey demo first GaN-on-Si monolithic full-HD micro-LED bonded displays

Plessey Semiconductors Ltd of Plymouth, UK, which is developing micro-LED technology for augmented-reality and mixed-reality (AR/MR) display applications, has announced a milestone in development of its monolithic micro-LED displays alongside its backplane partner Jasper Display Corp (JDC), a fabless semiconductor company based in Taiwan with R&D in Santa Clara, CA, USA.

Following a continued partnership with JDC including an extensive capital investment in a complete tool set (enabling wafer-to-wafer bonding), Plessey has succeeded in wafer-level bonding of its gallium nitride on silicon (GaN-on-Si) monolithic micro-LED wafers with JDC's eSP70 silicon patented backplane technology, resulting in micro-LED displays that contain addressable LEDs. Wafer-level bonding poses significant technical challenges and has not previously been achieved between a GaN-on-Si LED wafers and a high-density CMOS backplanes, says Plessey.

Plessey initially achieved what it claims was the first mechanically successful wafer to wafer bond in early April. This has now been followed by a fully functional, electrical and mechanical bond, resulting in a fully operational micro-LED display.

Plessey's micro-LED display features an array of 1920x1080 (FHD) current-driven monochrome pixels on a pitch of 8µm. Each display requires more than 2 million individual electrical bonds to connect the micro-LED pixels to the controlling backplane. The JDC backplane provides independent 10-bit single-color control of each pixel — bonding a complete LED wafer to a CMOS backplane wafer incorporates over 100 million micro-level bonds between the wafers.

"This is what the industry has been waiting for and opens up a new market for micro-LED emissive display applications," reckons Dr Wei Sin Tan, Plessey Semiconductors ' director of Epitaxy and Advanced Product Development.

"Plessey's monolithic micro-LED array is a great match to JDC's high-density silicon backplane," comments T.I. Lin, JDC's VP marketing & product management. "Our JD27E series demonstrates our ability to deliver what our valuable partner Plessey and the wider industry has been waiting for — silicon backplanes that have been designed with their micro-LED display requirements in mind."

At the Society for Information Display (SID) Display Week 2019 event in San Jose, CA, USA (12–17 May), Plessey is unveil its micro-LED technology and demonstrating why its scalable and repeatable GaN-on-Si monolithic process is the only solution for next-generation AR/MR display products, head-up/head-mounted (HUD/HMDs), smartphones and other micro-LED-based display applications.

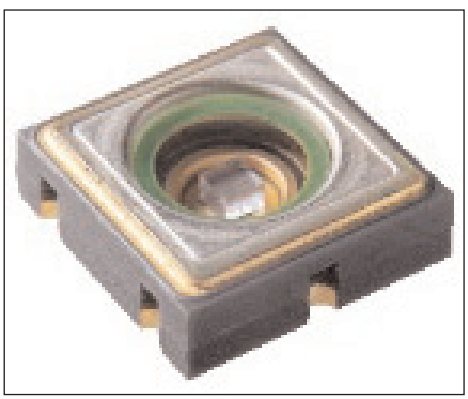
www.jasperdisplay.com
www.plesseysemiconductors.com/products/microleds

Nichia launches 280nm UVC LED for water purification and air sterilization

Nichia Corp of Tokushima, Japan has launched the NCSU334A deep ultraviolet (UV) LED.

Following success over the years with UVA LEDs (specifically in conventional resin curing applications), Nichia's new 280nm UVC NCSU334A will be able to address mass-market applications of solid-state lighting in water purification and air sterilization. With its small size (6.8mm x 6.8mm) and strong performance (55mW typical optical power at 350mA), the NCSU334A allows for system miniaturization and longer lifespan compared with previous technologies.

Conventional UVC LEDs (200–280nm) have the problems of more complex crystal growth and a shorter life than UVA LEDs (365–405nm). Nichia says that, through its unique crystal growth technology (cultivated for many years in UVA LEDs), it has developed high-radiant-flux, long-life UVC LED. The NCSU334A achieves a significant lifetime improvement versus conventional UV lamps. Additionally, it uses a newly developed hermetically sealed package, making it highly reliable as it is not as susceptible to external environmental conditions and can therefore be used in various harsh environments.



Nichia's new NCSU334A deep UV LED.

Nichia expects the LED to contribute to the complete replacement of mercury lamps. The firm aims to continue to improve the characteristics of its UVC LED portfolio.

www.nichia.co.jp

Cree's quarterly revenue grows 22% year-on-year, driven by Wolfspeed's organic growth of 40%

LED revenue to fall 5% next quarter due to market softness in Asia

For its fiscal third-quarter 2019 (to end-March), Cree Inc of Durham, NC, USA has reported revenue from continuing operations of $274m, down on $356m a year ago. However, this is up 22% on $225.2m excluding (as discontinued operations) the Lighting Products business unit (LED lighting fixtures, lamps and corporate lighting for commercial, industrial and consumer applications), which Cree agreed on 14 March to sell for about $310m to IDEAL Industries Inc of Sycamore, IL, USA. (After receiving early termination of the waiting period under the Hart–Scott–Rodino Act in April, the transaction is expected to close by the end of fiscal Q4.)

LED Product sales were $132.8m (48.5% of total revenue), down 8.5% (more than the expected 5%) on $145.2m last quarter and down 7% on $143.3m (63.6% of total revenue for continuing operations) a year ago. LED gross margin was 27.8%, down from 30% last quarter but up from 26.4% a year ago (and above the targeted 27%) as a result of strong execution and a strategy to focus on business where the firm thinks its products are differentiated and valued.

Revenue for the Wolfspeed business (Power & RF devices and silicon carbide materials) was $141.3m (51.5% of total revenue), up 4% on last quarter's record of $135.3m and up 72% on $81.9m a year ago (just 36.4% of total revenue for continuing operations) — or up over 40% organically (excluding revenue from the Infineon RF Power business, acquired on 6 March 2018). Wolfspeed gross margin was 48.7% (better than the targeted 48%), up from 47.8% last quarter and 48% a year ago, as it continues to balance rapidly increasing capacity while maintaining yield. "Wolfspeed is now our largest business and represents two-thirds of our gross profit from continuing operations," says CEO Gregg Lowe.

Overall gross margin (on a non-GAAP basis) was 37.9%, up from 34% a year ago (for continuing operations). "We are also very pleased to have recorded gross margin improvements across the business while addressing some softness within our LED business," says Lowe.

With the anticipated completion of the Lighting divestiture during this quarter, Cree will be well positioned for faster growth and higher margins with a cash balance approaching $1bn upon closing

Operating expenses were a slightly better-than-targeted $80m. Net income was $20.4m ($0.20 per diluted share), up from $16.7m ($0.17 per diluted share) a year ago, and exceeding the midpoint of the targeted range due to the record revenue combined with margin improvement for Wolfspeed.

Operating cash flow was $60.7m. Capital expenditure (CapEx) was $37m. Free cash flow was hence $24m, driven by strong working capital management as well as an upfront payment related to Cree's silicon carbide (SiC) wafer supply agreements. With zero borrowed on the firm's line of credit and convertible debt with a face value of $575m, cash and short-term investments rose during the quarter to $789m.

The LED market is experiencing softness in demand as global trade uncertainties persist... If needed, we will shift manufacturing capacities to Wolfspeed, should the LED market continue to soften

"With the anticipated completion of the Lighting divestiture during this quarter, Cree will be well positioned for faster growth and higher margins with a cash balance approaching $1bn upon closing. This transaction will allow us to sharpen our focus to accelerate Wolfspeed's growth," says Lowe. "This transaction benefits all stakeholders as it unlocks value, increases management focus on the core business and supports our mission to accelerate silicon carbide and gallium nitride adoption," he adds.

For its fiscal fourth-quarter 2019 (to end-June), Cree expects revenue to fall slightly to $263–271m. Wolfspeed revenue should still grow nearly 30% year-on-year (due to strong materials and RF demand) but only about 1% quarter-to-quarter. "In our power device business [while still seeing strong growth year-on-year], we are seeing some near-term softness due to the uncertainty around the reduction in EV [electric vehicle] incentives in China, but we remain confident in the EV market and we'll continue to grow over the long-term," reckons chief financial officer Neill Reynolds. "LED revenue is expected to be down about 5% sequentially due to market softness, primarily in Asia [versus normal seasonal growth of 5–10% coming out of Chinese New Year]."

Cree targets gross margin of 37%, based on the following segment trends: Wolfspeed margin of 49% (up both year-on-year and sequentially) and LED margin of 25% (down from fiscal Q3, driven mainly

by lower sales volume and lower factory utilization).

Operating expenses should rise slightly sequentially to $81m to support continued growth in the Wolfspeed business. Cree expects net income to fall to $12–17m ($0.12–0.16 per diluted share, including a $0.02 decrease from the ongoing impact of trade tariffs).

"The LED market is experiencing softness in demand as global trade uncertainties persist," notes Lowe. "We remain focused on our target markets, where we believe our customers value technology. We work with these customers to continue bringing innovations to the market," he adds. "If needed, we will shift manufacturing capacities to Wolfspeed, should the LED market continue to soften."

"For fiscal 2019, we target capital investment of about $175m, primarily driven by expanding Wolfspeed's production capacity to support forecasted long-term customer demand," notes Reynolds. "The underlying investment plan for fiscal 2019 remains unchanged, but the investment is below our prior target [of $220m], primarily due to the timing of receipts and payments for equipment orders," he adds. "As we continue to ramp this new capacity, we expect some variability in our initial production yields and factory utilization that may reduce our near-term Wolfspeed gross margins," he cautions.

"Over the last 18 months or so, we've made great progress towards our goal of creating a semiconductor powerhouse in silicon carbide and gallium nitride technologies. We've grown Wolfspeed by more than 100%, acquired the Infineon RF Power business, more than doubled our manufacturing capacity of silicon carbide materials, jointly announced with Valeo an innovative forward lighting solution for the automotive industry, and signed multiple long-term silicon carbide materials agreements [with major customers, including STMicro and Infineon], which in aggregate should generate revenues in excess of $500m… We're currently discussing long-term supply agreements with additional partners and hope to finalize a few over the coming few quarters," says Lowe. "Our materials business continues to grow, as the shift from silicon-based power and RF products move to SiC and GaN technologies at an accelerating pace," he adds. "We are well positioned to meet the growing demand for next-generation silicon carbide solutions over the next five years that support a variety of mega trends including the auto industry's transition to electric vehicles and the rapid deployment of faster 5G wireless networks."

We've grown Wolfspeed by more than 100%, acquired the Infineon RF Power business, more than doubled our manufacturing capacity of SiC materials, jointly announced with Valeo an innovative forward lighting solution for the automotive industry, and signed multiple long-term SiC materials agreements, which in aggregate should generate revenues in excess of $500m

"In RF, the wireless telecommunications market is rapidly moving towards GaN, which enables faster 4G and the transition to 5G. This is driven by GaN's inherent ability to provide wider bandwidth, higher frequency and higher efficiency and the outlook is very promising," continues Lowe. "Recent reports suggest momentum is building for 5G rollouts in North America, China, Latin America and South Korea. As such, we are in the process of adding GaN production capacity to meet the increasing demand we are seeing. We will work very hard to expedite this capacity addition, but we anticipate demand exceeding supply for the next few quarters."

www.cree.com

Cree completes sale of Cree Lighting to Ideal Industries

Cree Inc of Durham, NC, USA has completed the sale (announced on 15 March) of its Lighting Products business unit (Cree Lighting, including the LED lighting fixtures, lamps and corporate lighting solutions business for commercial, industrial and consumer applications) to Ideal Industries Inc of Sycamore, IL, USA.

"This represents a pivotal chapter for Cree as we sharpen our focus to become a semiconductor powerhouse in silicon carbide (SiC) and gallium nitride (GaN) technologies," says CEO Gregg Lowe. "Cree's technologies are helping to power major transitions in our economy, whether it's the automotive industry's transition to electric vehicles or the telecommunications sector's move to faster 5G networks," he adds. "Our leadership in SiC and GaN positions us well to help customers improve performance and realize greater efficiencies."

Cree will use the proceeds from the sale to accelerate the growth of its Power & RF business Wolfspeed and to expand its semiconductor operations. The firm recently unveiled plans to invest up to $1bn in the expansion of its silicon carbide capacity to meet the growing demand for SiC and GaN-on-SiC technologies. The expansion includes the development of an automated 200mm silicon carbide fabrication facility and a materials mega factory at its US campus in Durham.

www.idealindustries.com

New technique could pave way to simple color tuning of monolithically integrated GaN LEDs

Changing time sequence of pulsed current injection mixes 620nm and 545nm emission from Eu^{3+} dopant with 430nm emission from GaN

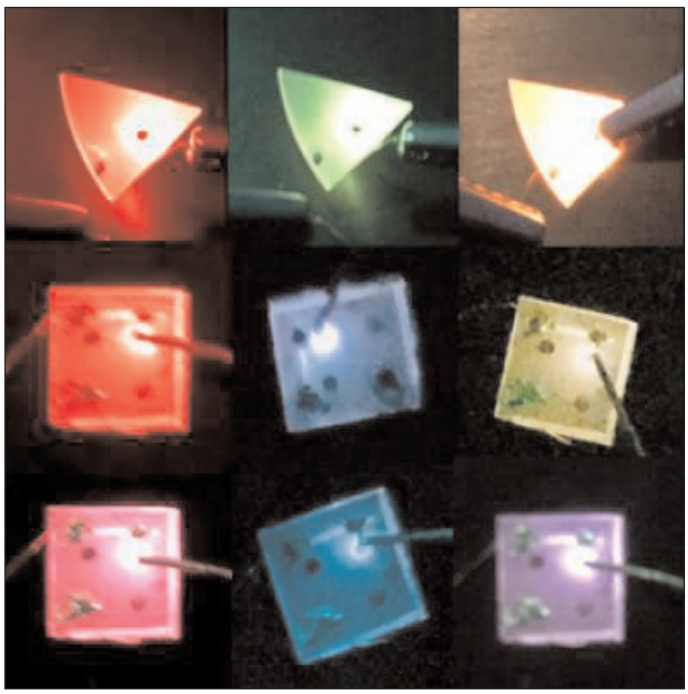
A team at Lehigh University, West Chester University, Osaka University and the University of Amsterdam has demonstrated a new technique that could enable simple color tuning of gallium nitride (GaN)-based LEDs simply by changing the time sequence at which the operating current is provided to the device (ACS Photonics, 'Color-Tunablility in GaN LEDs Based on Atomic Emission Manipulation under Current Injection').

Notably, the technique is compatible with current LEDs that are at the core of commercial solid-state LED lighting. "This work could make it possible to tune between bright white and more comfortable warmer colors in commercial LEDs," says Volkmar Dierolf, Distinguished Professor and Chair of Lehigh's Department of Physics, who worked on the project.

Lead author Brandon Mitchell is a former graduate student in Dierolf's lab, now an assistant professor in the Department of Physics and Engineering at West Chester University in Pennsylvania.

In existing active LED displays, different colors are produced by three to four individual LEDs placed close to each other that create the different fundamental colors needed to produce the full color spectrum.

"We demonstrate that this can be achieved by a single LED," says Dierolf. "We show that is possible to attain red, green and blue emissions originating from just one GaN LED structure that uses doping with a single type of rare-earth ion, europium (Eu)," he adds. "Using intentional co-doping and energy-transfer engineering, we show that all three primary colors can emit due to emission originating from two different excited states of the same trivalent Eu^{3+} ion (620nm red/orange and 545nm green) mixed with near-band-edge emission from GaN centered at ~430nm (blue/violet). The intensity ratios of these transitions can be controlled by choosing the current injection conditions such as injection current density and duty cycle under pulsed current injection."



Top row is a GaN:Eu LED, which can be tuned from red-yellow due to red and green light mixing from different Eu states. Middle and bottom rows are of a GaN:Eu LED with additionally added Si/Mg, which adds blue emission. Each picture is under a different current injection/filtering condition. Courtesy: West Chester University.

Materials used in previous research on color-tunable LEDs did not allow for easy integration with current LED technology.

This work is compatible with existing GaN-based LEDs that are at the core of commercial solid state LED lighting

In other words, the team achieved color-tunability in a single GaN-based LED through the manipulation of the emission properties of an atomic-type dopant.

"The main idea of this work — the simultaneous active exploitation of multiple excited states of the same dopant — is not limited to the GaN:Eu system, but is more general," notes Mitchell. "The presented results could open up a whole new field of tunable emission of colors from a single dopant in semiconductors, which can be reached by simple injection current tuning," he adds.

The research could benefit those looking for more comfortable 'warmer' white light from LEDs. "It could pave the way for monolithic integration for simple color tuning of a light bulb," says Dierolf. "It would also be beneficial for micro-LED displays, since it allows for higher density of pixels."

The materials used in previous research on color-tunable LEDs did not allow for easy integration with current LED technology, he adds. This work is compatible with existing GaN-based LEDs that are at the core of commercial solid state LED lighting.

https://pubs.acs.org/doi/10.1021/acsphotonics.8b01461

https://physics.cas2.lehigh.edu

Lumileds tailors LUXEON IR LED family for cost-conscious high-power applications

Lumileds LLC of San Jose, CA, USA has launched the LUXEON IR 2720 Line of high-power infrared LEDs in an industry-standard package for seamless integration in existing designs.

The emitters provide high radiant power of up to 1300mW at 940nm or 1250mW at 850nm wavelength and feature high efficacy and a popular 120º beam angle. The 2.75mm x 2.0mm LEDs are undomed and especially useful for applications with package height limitations that prevent the use of domed solutions. The emitters address a wide array of cost conscious infrared applications, from surveillance and machine vision to iris scanning and health monitors.

"Infrared LED uses such as CCTV cameras and machine vision are especially cost-sensitive markets, so high-performance emitters with high reliability are very much in demand," says product manager Ryan Dong. The LUXEON IR 2720 package enables drop-in upgrades in applications that require high punch, long range and high uniformity including positioning and depth measurement, and industrial automation.

The 4ºC/W thermal resistance package effectively solves thermal challenges and ensures system reliability that has been thoroughly tested during Lumileds' qualification process, says the firm.

The LUXEON IR 2720 Line of 940nm emitters addresses applications such as biometric identification, military and law enforcement, and traffic and railroad signaling applications. The 850nm emitters are workhorses for machine-vision cameras and CCTV cameras.

www.lumileds.com/products/infrared-emitters/luxeon-ir-2720-line

Lumileds launches LUXEON Fusion technology for white light tuning and selection with simplified fixture manufacturing process

Lumileds has launched LUXEON Fusion, a platform technology that delivers what is claimed to be unprecedented white color selection while streamlining fixture manufacturing.

Combining the needs of many tuning technologies, including dim to warm and dynamic tuning for human centric lighting, LUXEON Fusion addresses correlated color temperatures (CCTs) from 1800K to 10,000K with high color-rendering index (CRI >90 over 95% of range) and high color fidelity. Customers who previously were forced to rely on disparate solutions to achieve the desired results can now leverage the LUXEON Fusion platform technology, which unites white color selection, dim-to-warm capability, SKU reduction and dynamically tunable white lighting — all designed for mass adoption, in a single solution.

"LUXEON Fusion is really designed to open up color tuning for mass adoption in all indoor lighting environments because it offers superior dim-to-warm consistency down to 1800K, white light color choice, high efficiencies and consistent light output over dynamic tuning ranges," says Steve Barlow, senior VP & general manager of Lumileds LED Solutions.

Human-centric lighting applications

When lighting hospitals, restaurants, offices or retail venues, designers often wish to adjust color temperature on-site or program it to adjust light levels throughout the day to complement a changing ambient environment. Available on the Lumileds Matrix Platform (which custom configures LUXEON LEDs and advanced technologies on substrates to fit manufacturers' specific requirements), LUXEON Fusion can be integrated with a variety of wired and wireless approaches — e.g. Digital Addressable Lighting Interface (DALI), Digital Multiplex (DMX), Wi-Fi — for on-demand tuning.

"White light tuning in the past was limited and could not, for instance, tune along the blackbody curve or just below the blackbody curve, a range that enables vivid color depiction," notes Matt Everett, senior director of Matrix Platform Integrated Solutions. Programming in such ranges is enabled by LUXEON Fusion.

The first implementation of LUXEON Fusion involves modules for downlights, spotlights, troffers and linear applications — achieving system efficacy and color stability comparable to that of LUXEON LEDs. "We boosted LED utilization by 25–100% over standard two-LED or three-LED solutions, and achieve consistent light output over the tuning range — something customers value and other color tuning systems struggled to deliver," says Greg Tashjian, senior director of R&D.

An advantage to LUXEON Fusion is more efficient fixture development. For example, a fixture that is offered with CCTs of 2700K, 3500K and 5000K, each with specific light engines and SKUs, can now utilize one engine for all the fixtures and CCT can be set later — even after fixture installation. Another use involves high-impact retail environments, where companies select a signature CCT and brand all stores worldwide with one color tone.

Lumileds exhibited LUXEON Fusion at the LIGHTFAIR International 2019 trade fair in Philadelphia, PA, USA (21–23 May).

www.lumileds.com/fusion

Osram launches its first quantum dot LED

At the LIGHTFAIR International 2019 trade show in Philadelphia, PA (19–23 May), Osram Opto Semiconductors GmbH of Regensburg, Germany showcased its first quantum dot (QD) LED.

Due to their very small size, the light that is re-emitted when blue LED light hits nanoparticles depends on their size: QD particles that are roughly 3nm in size produce green light, while particles about 7nm emit red light. Osram is using such tunable light conversion technology for the first time in its new Osconiq S 3030 QD mid-power LED, which will lead to more QD LEDs for the general lighting market in the future. The Osconiq S 3030 QD was specially developed to enable users to design luminaires with high efficacy and color rendering for area lighting and downlight applications.

When manufacturing conventional white LEDs, the main objectives are efficacy and product quality. Achieving both at the same time is particularly challenging, especially

Osram's Osconiq S 3030 QD LED.

with very high color rendering indexes (CRI), says Osram. The advantage of using quantum dots is that the existing LED manufacturing processes remain the same. QDs are simply used instead of conventional phosphors when the converter material is applied.

More than a year ago, Osram acquired Pacific Light Technologies (PLT), which develops and manufactures optical nanomaterials. Osram says that the PLT QD technology is enabling it to begin to close the efficacy gap that exists between CRI 80 and CRI 90 LEDs today. The new Osconiq S 3030 includes a specially developed QD phosphor solution that enables CRI 90 to achieve an efficacy value of 173lm/W at 3000K — which is claimed to be a best-in-class value for 0.2W high-performance LEDs. The compact dimensions of 3.0mm x 3.0mm and the low thermal resistance enable simple system design. The Osconiq S 3030 QD is also available in various color temperatures, from 2700 to 6500K.

Osram says that another unique feature of the PLT QD technology is that the quantum dots are encapsulated to protect them from moisture and other external influences that pose the greatest risk to the functionality of an LED. The special encapsulation technology allows the QDs to reliably master the demanding conditions of on-chip operation within the LED component, the firm adds.

www.lightfair.com
www.osram.com

Luminus adds 11 high-intensity IR LEDs with 40–130° viewing angle options for emerging applications

Luminus Devices Inc of Sunnyvale, CA, USA — which designs and makes LEDs and solid-state technology (SST) light sources for global illumination markets — has significantly expanded its portfolio of high-power infrared (IR) LEDs with 11 emitters designed to address the rapid expansion of automotive, consumer, machine vision, medical and security applications.

The IR SST LEDs are now offered in three wavelengths — 810nm, 850nm and 940nm — and six beam angle options ranging from 40° to 130°. The high radiometric power output and low thermal resistance allow system designers to reduce the number of emitters and overall footprint for a broad range of infrared applications.

Nine of the new IR products are based on dual-junction technology, which nearly doubles the power density and keeps efficiency virtually unchanged. This makes it easier to develop solutions with much higher radiant intensity and more compact designs, says Luminus. The IR SST product line delivers high radiometric power of up to 1600mW typical at 850nm and 1A drive current, and radiant intensity in excess of 1300mW/sr.

"Our dual-junction technology allows us to double the power density in the same footprint," says Yves Bertic, senior director of global product marketing. "Now, product designers can address applications that need longer reach and more intense and focused beams."

The range is designed to support the increasing variety of infrared applications. The small 40° beam angle is a suitable replacement for legacy 2–5mm through-hole IR LEDs, and the broadest beam angle 130° is suitable for flood illumination that is more common in security applications.

Whether for biometric applications or monitoring for security, the latest generation of IR LEDs supports ongoing industry development and reduces time to market, says Luminus.

The IR SST products are industry-standard 3535 surface-mount packages with low thermal resistance and are drop-in replacements. All Luminus IR SST emitters are rated as 'Risk-Free' for eye safety according to the IEC Photo-biological Test (IEC/EN 62471 standard).

www.luminus.com

SmartVIZ project exploring high-resolution visualization technologies using micro-LEDs

Osram, ASM AMICRA and Fraunhofer IISB working on brighter, more robust and more efficient lighting than LCDs or OLEDs

Osram Opto Semiconductors GmbH of Regensburg, Germany says that, together with Regensburg-based ASM AMICRA Microtechnologies GmbH and the Fraunhofer Institute for Integrated Systems and Device Technology (IISB) of Erlangen, Germany, it is part of the project SmartVIZ — which began in November 2018, funded by the Bavarian State Ministry for Economic Affairs, Regional Development and Energy — that is exploring the principles of high-resolution visualization solutions using micro-LEDs (µLEDs).

There is still no standard definition for the term µLED, only a loose guideline for the opto chip's dimension to include edge lengths smaller than 100µm. Since µLED technology can produce extremely high luminance over a wide dynamic range, it can play a key role for future megatrends such as augmented reality (AR) applications, says the firm. The project's focus is on automotive interior applications. It is expected to complete in October 2021, when an initial demonstrator will be presented.

Imaging devices based on direct-emitting µLED pixels are considered to be a disruptive development in the visualization market and have the potential to sideline technologies such as liquid-crystal displays (LCD) or organic light-emitting diodes (OLEDs). These rather conventional technologies are constrained by their fundamental limits in energy efficiency, contrast, luminance, functionality and other associated restrictions, says Osram Opto. Over the next two and a half years, SmartVIZ aims to provide the basis for future transparent, high-resolution, direct-emitting visualization solutions using µLED technologies.

The work packages will focus on three key technologies:
(1) the design of efficient µLED light sources;
(2) their handling on the sub-component level; and
(3) final assembly.
Red, green and blue µLED structures will perform as efficient high-luminance image pixels. Implementation of such concepts and applications requires in-depth study of the underlying physical principles that are, in part, entirely different from existing macro-LED chips.

The project will also conduct research addressing the component integration of µLEDs using a novel approach for transparent and flexible image encoders. Transparent substrates based on indium gallium zinc oxide thin-film transistors (IGZO TFTs) will be the focus for controlling the individual pixels. This approach allows for quasi-transparent surfaces, which can be filled with content only if the µLEDs are switched to active. Employing such an active-matrix backplane for the driver electronics allows image rendering with µLEDs to produce visualization scenarios with ultra-high resolution.

Another work package will target processing concepts to enable rapid transfer of large quantities of µLED chips from a source wafer to the backplane driver electronics via automated parallel assembly. The key requirement is a positioning accuracy of about 1.5µm. Researching accurate transfer methods for such small chips (with an edge length smaller than 40µm) will require entirely new technological approaches, which will be addressed in the project.

The project consortium reckons that partners have the necessary expertise to realize the envisioned technical breakthrough. For example, ASM AMICRA has expertise in production automation, especially in photonic applications. The firm has in-depth knowledge of the micro-assembly of photonic components. The Fraunhofer Institute for Integrated Systems and Device Technology (IISB), which specializes in power electronics and technologies for producing semiconductor devices, will design and manufacture transparent electronic circuits for their final installation in micro-pixel visualization components.

Hubert Halbritter, SmartVIZ project leader at Osram Opto Semiconductors, described his company's role "as a project partner with in-depth experience in micro-pixel imaging components that will research efficient, high-luminance pixels. Along with our partners, we aim to gain technology leadership in one of the key future technology markets."

www.osram-os.com

University of Illinois' Micro and Nanotechnology Laboratory renamed after Nick Holonyak Jr

The University of Illinois at Urbana-Champaign (UIUC) says that (pending board of trustees approval) its Micro and Nanotechnology Laboratory (MNTL) is to be renamed the Nick Holonyak Jr Micro and Nanotechnology Laboratory, in honor of the three-time Illinois alumnus (BSEE in 1950, MSEE in 1951, PhD in 1954), who was the first graduate student of two-time Nobel Laureate John Bardeen.

After productive stints with Bell Labs and GE and service in the US Army Signal Corps in Japan, Holonyak joined the Illinois faculty in 1963, establishing a research program in the Electrical Engineering Research Lab.

ECE (Electrical & Computer Engineering) Emeritus professor Nick Holonyak is credited with inventing the first practical light-emitting diode. During the next four decades, he and his students produced technology advances such as the world's first quantum-well laser, the impurity-induced layer disordering technique for high-power lasers, and the stable native oxide for vertical-cavity surface-emitting lasers (VCSELs), leading to brighter and more efficient LEDs and lasers used in fiber-optic communications, CD and DVD players, optical storage, medical diagnosis, surgery, ophthalmology and other applications.

In 2004, Holonyak, fellow ECE professor Milton Feng, post-doctoral researcher Gabriel Walter and graduate student Richard Chan invented the transistor laser, a three-terminal device that simultaneously delivers both an electrical signal and a coherent laser output. The transistor laser, which incorporates quantum wells into the base region of a high-speed heterojunction bipolar transistor (HBT), may lead to higher-speed electronic-photonic integrated circuits (EPICs) for much faster computers and electronics.

ECE Emeritus professor Nick Holonyak.

Although he retired in 2013, Holonyak continues to collaborate and consult with Feng on transistor laser research. Holonyak is both a member of the US National Academy of Sciences (NAS) and the National Academy of Engineering (NAE). He and his former students, Russ Dupuis and George Craford, received the 2015 Charles Stark Draper Prize (aka the Nobel Prize for engineering) and the 2002 National Medal of Technology for their invention, development and commercialization of LED technology.

"He continues to have an impact on our students and faculty 50 years after he joined our faculty," comments Rashid Bashir, Dean of the College of Engineering. "His semiconductor innovation is the precursor to work being conducted at MNTL, so it is fitting that his name adorns the facility."

Opened in 1989 at 208 North Wright Street in Urbana, the Micro and Nanotechnology Laboratory is known for its III-V compound semiconductor device and processing research. Over the years, its mission has broadened to include advances that intersect engineering and other fields. Its faculty and students are conducting research that advances a broad range of applications, including high-speed data communications, high-efficiency lighting, solar power, flexible electronics, biosensors for drug discovery, biomedical imaging, disease diagnostics, vaccine delivery strategies, environmental monitoring and novel microelectronics/photonics concepts for next-generation computing architectures.

"MNTL was built on the semiconductor legacy left by engineering giants like Nick Holonyak," notes its director Brian Cunningham. "In the same spirit, we are producing innovations — in photonics, microelectronics, biotechnology and nanotechnology — that we anticipate will have similar positive impact to future generations."

https://ece.illinois.edu/directory/profile/nholonya

Luna receives large purchase order for tunable lasers from robotics company

Luna Innovations Inc of Roanoke, VA, USA (which makes high-speed fiber-optic-based test products for the telecoms industry and distributed fiber-optic-based sensing products for the aerospace & defense and automotive industries) is to supply an "industry-leading" robotics company with a significant number of its Phoenix tunable lasers worth more than $6m, to be delivered over four years (with deliveries beginning this summer).

Designed with systems integration in mind and suited to a wide range of fiber-optic sensing instrumentation, the Phoenix is a miniaturized, tunable external-cavity laser offering high performance in a compact footprint, which provides improved scalability, ruggedness and speed compared with similar lasers on the market, it is claimed. These features are suited to robotics applications because they enable the maximum precision and repeatability needed to measure and control very fine movement.

Laser-based fiber-optic sensing systems are now widely deployed across many industries due to the benefits of optical fiber over traditional techniques in terms of precision and scalability. Advanced robotics increasingly relies on optical-based measurement systems as a core component. Luna says that the Phoenix laser delivers the high performance needed to maintain maximum precision and reliability for these applications.

"Luna's collaboration with an industry-leading robotics company demonstrates how far our optical sensing technology has advanced," says president & CEO Scott Graeff. "The technology has matured to the point where it is being used in precise applications – requiring the ultimate in performance, reliability and quality," he adds. "From a commercialization standpoint, an order of this magnitude, combined with our existing platform, will allow us to achieve greater economies of scale on our existing and future products."

Princeton Infrared Technologies awarded AFRL SBIR Phase II contract for coherent LADAR detectors

Princeton Infrared Technologies Inc (PIRT) of Monmouth Junction, NJ, USA — which specializes in shortwave-infrared (SWIR) linescan cameras, visible-SWIR science cameras, and 1D and 2D imaging arrays based on indium gallium arsenide (InGaAs) — has been awarded a Small Business Innovation Research (SBIR) contract with the US Air Force Research Laboratory (AFRL) that will fund development of detector arrays for coherent laser detection and ranging (LADAR).

Princeton Infrared Technologies will focus on developing detector arrays using multi quantum well (MQW) materials enabling detection at 0.9–2.4μm with low dark current and high quantum efficiency. This will enable a new generation of high-resolution cameras that can image at, or near, room temperature while allowing high sensitivity in the shortwave-infrared spectrum. The new arrays will be high speed, enabling next-generation coherent LADAR using arrays versus single-element detectors.

The SBIR Phase II project is a $750,000, two-year effort that will concentrate on new material development. Princeton Infrared Technologies and its' subcontractors will be conducting research on the development of new MQW materials, in addition to strained superlattice materials manufactured on indium phosphide (InP) substrates. The R&D work will be supported by the AFRL at Wright-Patterson Air Force Base, Ohio.

"Utilizing multi quantum well materials will enable high-sensitivity detectors to image beyond what lattice-matched InGaAs detectors can detect in the SWIR range," says PIRT's president Martin H. Ettenberg Ph.D. "These next-generation detector arrays will benefit long-range LADAR used by the Air Force to identify targets. Current systems require cryogenic cooling while these materials will not, thus vastly lowering costs, size, weight and power," he adds. "The material development will also be useful in the commercial sector for spectroscopy and industrial imaging."

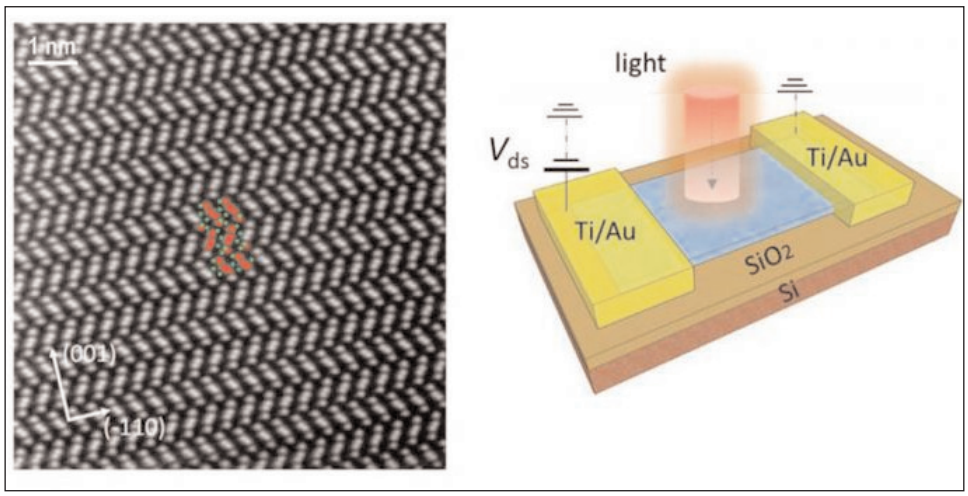
www.princetonirtech.com

Tailoring defects in bismuth sulfide yields highly sensitive CMOS-compatible broadband IR photodetector

Spain's ICFO and University of Zaragoza supported by EC's Graphene Flagship initiative

There is keen demand in the consumer electronics sector for infrared optoelectronics including light-emitting diodes and photodetectors. But, to date, infrared optoelectronics have been served by costly CMOS-incompatible III–V semiconductors. Recently, a new class of semiconductors that address the CMOS compatibility issue has emerged based on colloidal quantum dots. For consumer electronics the use of RoHS-compliant materials is a prerequisite and there is hence a strong need for the development of high-performance devices based on environmentally friendly elements (which had remained elusive in the infrared).

To address this challenge, Institut de Ciències Fotòniques (ICFO – the Institute of Photonic Sciences) in Barcelona, Spain has discovered that, by controlling defects in materials, one can extend the semiconductor's spectral reach beyond its bandgap, expanding the material availability for the infrared part of spectrum ('Engineering Vacancies in Bi_2S_3 yielding Sub-Bandgap Photoresponse and Highly Sensitive Short-Wave Infrared Photodetectors', Advanced Optical Materials; DOI: 10.1002/adom.201900258). In work supported partially by the European Commission's Graphene Flagship initiative, ICFO researchers Dr Nengjie Huo, Dr Alberto Figueroba, Dr Y. Yang, Dr Sotirios Christodoulou, Dr Alexandros Stavrinadis, led by ICFO's ICREA (Catalan Institution for Research and Advanced Studies) Research Professor/group leader Gerasimos Konstantatos, in collaboration with professor C. Magén of University of Zaragoza, have reported the development of an infrared detector using bismuth sulfide. This has proven to have fast and high photo-response levels in the short-wave infrared range due to the formation of defects in the material.



Left: STEM image of crystal: red and green balls represent bismuth and sulfur atoms. Right: schematic illustration of Bi_2S_3 detector on Si/SiO_2 substrate.

In the experiment, the team fabricated a photoconductive detector, depositing a very thin layer of Bi_2S_3 flakes onto a Si/SiO_2 substrate. It was then observed that the Bi_2S_3 flakes were sulfur-deficient (with sulfur vacancies or defects in the material), creating extended in-gap states, which allowed increased absorption of light below the bandgap value of Bi_2S_3 (i.e. sub-bandgap). Such features led to a high-gain, low-noise and, consequently, a high-sensitivity photodetector.

To give insight into the sulfur deficiency mechanism, the team fabricated a second photodetector and synthesized the Bi_2S_3 crystal by performing a sulfurization process (changing the proportions of Bi and S in the crystal) and subsequently refilling the sulfur vacancies. The photodetector was seen to have a much faster response time but was limited to the near-infrared spectral range. Thus, to improve the response time without sacrificing its spectral coverage into the infrared, the team carried out a mild chemical treatment on the sulfur-deficient-based detector, through a process of surface passivation of the crystal. It was then seen that the response time had reached about 10ms for the infrared and visible light range, 50 times faster than the original sulfur-deficient-based detector.

Results of the study provide new insight into the role that atomic vacancies play in electronic structure and how sub-bandgap photoresponse effects can enable ultra-sensitive, fast and broadband photodetectors

It is reckoned that the results of the study provide new insight into the role that atomic vacancies play in electronic structure and how sub-bandgap photoresponse effects can enable ultra-sensitive, fast and broadband photodetectors.

https://onlinelibrary.wiley.com/doi/abs/10.1002/adom.201900258
www.icfo.es/lang/research/groups/groups-details?group_id=30
www.icrea.cat/Web/ScientificStaff/gerasimos-konstantatos-216875
www.graphene-flagship.eu

VPIphotonics, LiGenTec and VLC streamline design process for SiN photonic integrated circuits

Simulation software provider VPIphotonics GmbH of Berlin, Germany says that designers using the All-Nitride (AN) technology of LIGENTEC SA of Lausanne, Switzerland (which provides manufacturing foundry services in silicon nitride) can now benefit from a workflow that starts from a graphical photonic integrated circuit (PIC) design and system simulation environment, which seamlessly couples to layout design tools for scripted layout design and DRC capabilities. The new workflow is based on LIGENTEC- and VLC Photonics-verified reference designs with the simulation software by VPIphotonics using verified measurements of fabricated chips.

This workflow is enabled by the new VPItoolkit PDK LIGENTEC — a pluggable toolkit extension to VPIcomponentMaker Photonic Circuits by adding the support of the 800nm silicon nitride process AN800 offered by LIGENTEC for dedicated shuttle runs and multi-project wafer (MPW) runs.

With the mode fully confined in the waveguide, the thick silicon nitride waveguides supported by the AN800 process with 800nm LPCVD silicon nitride offer very tight bending radius (< 0.005dB for 10 turns), very low coupling losses (<1.5dB/facet), very low propagation losses (<0.1dB/cm) and very high power handling (up to 10W tested).

VPIcomponentMaker Photonic Circuits is a simulation and design environment for large-scale PICs that offers a large mix of general-purpose photonic, electrical and opto-electronic device models, together with circuit optimization and yield analysis capabilities. The library extension VPItoolkit PDK LIGENTEC adds foundry-certified simulation compact models for the standard building blocks supported by the AN800 process and enables a layout-aware schematic-driven PIC design workflow, including chip layout optimization according to its required optical functionality. Importantly, it allows designers to construct their own hierarchical and custom building blocks, effectively expanding the foundry PDK to fit individual needs. The layout for the designed PICs can be automatically exported to either IPKISS by Luceda Photonics or OptoDesigner by Synopsys for DRC verification and GDS mask generation.

The mature library of photonic building blocks, available at the process design kit (PDK), has been developed by LIGENTEC and VLC Photonics over several iterations to obtain mature devices with repeatable performance. The capability of embedding these blocks into the VPIphotonics software framework enables the simulation and modeling of complex PICs with a high degree of reliability, it is claimed.

www.vlcphotonics.com/mpw
www.ligentec.com
www.VPIphotonics.com

LIGENTEC's board gains photonics & sensors executive

LIGENTEC, which manufactures photonic integrated circuits (PICs) and chip-based components, has appointed Dr Thomas Hessler as a member of its board of directors.

"His leadership skills and insights are to be put to good use to support the next stage of growth for LIGENTEC," says co-founder Dr Michael Zervas. "Thomas brings with him his holistic approach and hands-on knowledge, built over years of experience growing a company, along with an extensive network of professionals and makers," he adds.

"He not only brings his knowledge of the Swiss ecosystem and his worldwide connections to key market players, but also understands the technology and its potential to open new market areas that still have to be developed," comments co-founder Dr Michael Geiselmann.

Hessler has over 20 years of experience in executive management in the high-tech business-to-business environment (namely photonics and sensors). After obtaining a PhD in applied optics, he started a corporate venture, leading to Axetris AG, and developed the firm into a market leader for micro-optics, optical gas sensing components and specialty MEMS foundry services with applications in the automotive, medical, analytical and industrial space.

LIGENTEC has matured a proprietary silicon nitride process that can achieve ultra-low propagation losses. "Our process is able to deposit thick-film silicon nitride, from 100nm to 2500nm, overcoming the challenge of crack formation due to stress in the material," says Zervas. The process can also scale up to production volumes using 8" wafers and stepper lithography. The proprietary low-loss waveguide technology, together with the low bending losses that thick-film nitride enables, paves the way to new integrated applications, says LIGENTEC. Thick silicon nitride chips can thus scale down four-fold in cost compared to thin-film silicon nitride, it is reckoned.

"LIGENTEC's groundbreaking all-nitride-core technology combines low propagation loss with small device structures," says Hessler. "It offers the best of two worlds compared to conventional photonic integration technologies," he adds. "Its possibility to be integrated easily with fibers and active functionalities will be key to achieve success in many PIC applications such as datacom, space, LiDAR and sensing."

EU project PLASMOfab completed

PICs and CMOS-compatible plasmonics integrated for optical data communications and biosensing

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 PLASMOfab, a three-year collaborative project funded by the European Union's Horizon 2020 ICT research and innovation program (under grant agreement No 688166), has been completed to enable mass manufacturing of high-performance plasmo-photonic components.

Launched in 2016, the project brought together ten industrial partners and academic and research institutes in the photonic integrated circuit (PIC) and opto-electronics value chain, including coordinator Aristotle University of Thessaloniki (Greece), ams (Austria), AMO (Germany), PhoeniX Software, now part of Synopsys' Photonic Solutions (Netherlands), ETHZ (Switzerland), Micram (Germany), University of Saarland (Germany), Austrian Institute of Technology (Austria), University of Burgundy (France) and Mellanox (Israel)

PLASMOfab has advanced the state of the art in PICs and CMOS-compatible plasmonics for optical data communications and biosensing for point-of-care applications, consolidating PICs with electronic ICs in volume manufacturing. The project focused on CMOS-compatible metals and photonic structures that are harmonically co-integrated with electronics using standardized CMOS processes. As part of project validation, the PIC platform was used along with advanced peripherals to develop predominant functional modules with what is claimed to be unprecedented performance.

A key achievement was the development of an ultra-compact plasmonic transmitter, with a footprint of 90µm x 5.5µm, to transmit 0.8TBit/s (800Gbit/s) through four individual 0.2TBit/s transmitters. The project also demonstrated CMOS-compatible plasmonic waveguides with the lowest possible losses, as described in Nature's Scientific Reports in September 2018.

PLASMOfab has advanced the state of the art in PICs and CMOS-compatible plasmonics for optical data communications and biosensing for point-of-care applications, consolidating PICs with electronic ICs in volume manufacturing

"PLASMOfab's main goal has been to address the ever increasing needs for low-energy, small-size, high-complexity and high-performance mass-manufactured PICs," says Nikos Pleros, assistant professor at the Aristotle University of Thessaloniki. "We have achieved this by developing a revolutionary yet CMOS-compatible fabrication platform for seamless co-integration of active plasmonics with photonic and electronic components."

When the best of all three worlds of plasmonics, photonics and electronics converge in a single integration platform, PICs with unprecedented performance and functionality will be realized, targeting a diverse set of applications and industrial needs while meeting mass-production requirements

As a result of PLASMOfab, two new companies have been launched to commercialize the new technologies:

- bialoom Ltd will further explore plasmo-photonic biosensors in multi-channel and high-sensitivity point-of-care diagnostics by combining plasmonic sensors with integrated Si3N4 photonic functionalities, electrical controls, bio-functionalization techniques, and microfluidics.
- Polariton Technologies Ltd specializes in new photonic and electronic technologies for the testing, sensing and telecoms market. Their energy-efficient and low-footprint plasmonic modulator will convert microwave signals to optical signals.

"Further development of CMOS-compatible plasmonic components with CMOS fabrication processes and photonics technologies will demonstrate plasmonics' clear advantages in PICs," expects Dr Dimitris Tsiokos, principal researcher at the Aristotle University of Thessaloniki. "When the best of all three worlds of plasmonics, photonics and electronics converge in a single integration platform, PICs with unprecedented performance and functionality will be realized, targeting a diverse set of applications and industrial needs while meeting mass-production requirements," he adds.

"We are pleased to have been working closely with the partners in this project and especially with AMO and ams to develop R&D PDKs [process design kits] for the new PLASMOfab integration technology," says Twan Korthorst, director of Synopsys' Photonic Solutions. "The PDKs are supported by our PIC design platform, which provides the industry's only full design flow from photonic device level to PIC to system levels," he adds.

www.plasmofab.eu
www.synopsys.com/

POET's annual revenue grows 39%

Margins to rise for 2019 as non-recurring engineering becomes higher proportion of revenue with fab-light strategy to sell DenseLight

POET Technologies Inc of Toronto, Canada and San Jose, CA, USA — a designer and manufacturer of opto-electronic devices, including light sources, passive waveguides and photonic integrated circuits (PIC) for the sensing and datacom markets — has reported full-year revenue growth of 39% from US$2.8m in 2017 to US$3.9m in 2018.

Fourth-quarter 2018 revenue was US$1.6m, up 72% on US$0.9m last quarter and 117% on US$0.7m a year ago, primarily reflected a combination of higher product sales and non-recurring engineering (NRE).

Gross margin has risen further, from 46% a year ago and 58% last quarter to 67% in Q4/2018. Full-year gross margin has grown from 52% in 2017 to 62% in 2018.

Full-year net loss before taxes rose from US$13.1m ($0.05 per share) in 2017 to US$16.6m ($0.06 per share).

However, although still up from US$2.9m ($0.01 per share) a year ago, quarterly net loss before taxes was US$3.7m ($0.01 per share) in Q4/2018, cut from US$5m ($0.02 per share) in Q3/2018.

Capital investment in plant, equipment and patents rose from US$1m in 2017 to US$3.7m in 2018.

At the end of fourth-quarter 2018, the backlog of open orders (for delivery in subsequent quarters) was US$3.7m.

"Our significant revenue growth over the past year demonstrates the initial success of our strategy to grow non-recurring engineering (NRE) revenue from leading customers in data communications," says CEO Dr Suresh Venkatesan. "We continue to advance the development and qualification of customized Optical Interposer-based product solutions with these customers, with the expectation that POET's solutions will be included in their current and future product lines," he adds. During Q4/2018, the first orders were received for POET's Optical Interposer-based solutions from leading global networking companies, including sales and development contracts exceeding US$3m.

"As part of our focused strategy centered around the Optical Interposer platform, we are also making meaningful progress toward reaching a binding agreement on the proposed sale of our [Singapore-based] DenseLight subsidiary [which makes photonic sensors for test & measurement applications]," says Venkatesan. After the end of Q4/2018, POET signed a non-binding letter of intent (LOI) for the sale of DenseLight Semiconductors which (subject to approval by a majority of shareholders and the satisfaction of certain key conditions) should close in September, generating cash proceeds of US$26–30m. "This transaction would enable us to adopt a fab-light model, resulting in significantly reduced operating and capital expenses and providing an accelerated path to profitability," he adds.

To finance operations, including the continued development of the Optical Interposer platform and for general working capital requirements between year-end and the close of the sale [of DenseLight], POET has announced a private placement of up to about US$10m of 12% unsecured convertible debentures to qualified investors in multiple tranches

To finance operations, including the continued development of the Optical Interposer platform and for general working capital requirements between year-end and the close of the sale, POET has announced a private placement of up to about US$10m of 12% unsecured convertible debentures to qualified investors in multiple tranches. The first tranche closed on 4 April. In addition, the firm arranged for a US$5m secured credit facility from Espresso Capital Ltd and took its first eligible draw from the facility of US$2m on 23 April. This, plus the first tranche convertible debentures, raised US$3.4m collectively. "Our goal was to minimize dilution to shareholders as we bridge to the sale of DenseLight, a transaction which will provide the capital needed to grow our Optical Interposer business globally," notes Venkatesan.

"Looking forward, as we execute on our 100G and 400G optical engine product roadmap during the remainder of 2019, we expect meaningful revenue growth from a combination of a ramp of our data communications business opportunities and increasing sales of sensing products at DenseLight," notes Venkatesan. POET expects that revenue from DenseLight will grow to US$8–10m for full-year 2019. Historically, and until the completion of the anticipated sale of DenseLight, all revenue generated by the firm is regarded as sales from DenseLight. Gross margin should also rise, as NRE revenue (which is typically higher margin, given that existing engineering and operational resources are not allocated to individual projects) becomes a higher percentage of POET's consolidated revenue.

www.denselight.com
www.poet-technologies.com

Tencent completes 200G IP over DWDM demo over 80km using Acacia's CFP2-DCO modules

Acacia Communications Inc of Maynard, MA, USA (which develops and manufactures high-speed coherent optical interconnect products) says that, in a lab demonstration, Tencent has completed 80km fiber transmission of multiple 200G 8QAM signals over its OPC-4 open line system (OLS) using Acacia's CFP2-DCO modules on third-party switch platforms.

To emulate the higher fiber loss in its metro networks, Tencent added additional 10dB optical attenuators to the tested link, and was still able to achieve error-free operation in all the ports. OPC-4, which was developed by Tencent, meets Tencent's SDN requirements for a disaggregated transport network and is fully integrated into its network controller. Tencent believes this lab demonstration validates the deployment readiness of its IP over DWDM solution using OPC-4 in its metro DCI networks.

The lab demo was performed using Acacia's CFP2-DCO modules with 50GHz channel spacing and 200G 8QAM modulation, which was selected by Tencent to address the challenging fiber loss in its metro DCI applications, and showcases the ability to support transmission of up to 19.2T on a single fiber using Tencent's 96 channel OPC-4 and Acacia's CFP2-DCO modules. With this demonstration, Tencent is highlighting the value of IP over DWDM and disaggregated solutions to cost effectively meet the growing bandwidth needs of its metro DCI infrastructure.

"This demonstration validated that Acacia's CFP2-DCO product has been integrated into switch platforms in terms of mechanical, electrical, power and firmware interfaces. The switch platform was able to configure the CFP2-DCO and access advanced performance-monitoring functionality for the module, as well as the link," says Tencent's senior network architect Jengyi Geng. "With Acacia's 200G CFP2-DCO, our switch platform can support 8 ports, for up to 1.6T per line-card, and our OPC-4 can support transmission of up to 19.2T over a single fiber for metro DCI applications. In addition, the CFP2-DCO form factor provides us with a pay-as-you-grow deployment model," he adds.

"We were impressed by the level of integration in the switch platform and OPC-4 open line system," comments Tom Williams, associate VP of marketing at Acacia. "This lab demonstration underlines the importance of pluggable coherent modules in applications such as Tencent's metro DCI network, potentially creating opportunities for our NEM [network equipment manufacturer] customers to offer differentiated solutions in these applications," he believes.

Acacia's module is compliant with the OIF CFP2-DCO Implementation Agreement, which also includes support for next-generation 400G solutions, further improving board density and fiber capacity. Based on its Meru DSP (digital signal processing) ASIC, Acacia's CFP2-DCO module has been shipping in production since December 2017.

www.acacia-inc.com

Applied Optoelectronics announces sample availability of 400G SR8 transceivers

Applied Optoelectronics Inc (AOI) of Sugar Land, TX, USA — a designer and manufacturer of optical components, modules and equipment for fiber access networks in the Internet data-center, cable TV broadband, fiber-to-the-home (FTTH) and telecom markets — has announced initial sample availability of 400G SR8 high-speed optical transceivers (with volume production expected in third-quarter 2019).

The transceiver employs 4-level pulse amplitude modulation (PAM-4) encoding to deliver 50Gbps data throughput on each of eight separate multi-mode optical channels. Utilizing low-cost vertical-cavity surface-emitting laser (VCSEL) technology, the short-reach transceivers are said to be cost-effective solutions for interconnecting switches within the data center over distances up to 70m over OM3 fibers. As large data-center operators begin to implement switches with net throughput of 12.8Tbps, 400G optical transceivers are expected to be needed in larger quantities.

The transceivers' features include:

- QSFP-DD type1 form factor;
- compliant with IEEE 802.3cd 200GBASE-SR4 and IEEE 802.3bs/400GAUI-8;
- compliant with the latest Common Management Interface Specification; and
- available in both MPO16 and MPO24 optical connector types.

"The newly announced 400G SR8 transceivers are a great complement to our line of intermediate-reach data-center transceivers," says senior sales manager Claire Szuma. "Our large data-center customers need solutions that cover distances as short as a few meters, for example within a single electronics rack, to several kilometres," she adds. "Our growing product line of 400G products is designed to meet these customer needs, with the most cost-effective solution for each use case."

The 400G SR8 transceivers add to AOI's previously announced 400G product family, which includes on-board optics (OBO) modules as well as active optical cables (AOCs).

www.ao-inc.com

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NeoPhotonics' revenue grows 16% year-on-year to $79.4m

Supply constraints on purchased sub-components to be eased by Q3

For first-quarter 2019, NeoPhotonics Corp of San Jose, CA, USA (a vertically integrated designer and manufacturer of hybrid photonic integrated optoelectronic modules and subsystems for high-speed communications) has reported revenue of $79.4m, down 13% on $91.1m last quarter (reflecting the usual seasonal declines related to the Chinese New Year holiday — making it a shorter quarter — plus the impact of annual price reductions, as well as a $2–3m impact from some supply constraints on purchased sub-components) but up 16% on $68.6m a year ago. "Demand continued apace in both the West and China," notes chairman & CEO Tim Jenks.

Shipments to China comprised 57% of revenue (down from 59% last quarter and 61% a year ago). Of this, NeoPhotonics' largest customer Huawei Technologies (including its affiliate HiSilicon Technologies) accounted for 49% (up from 44% last quarter and roughly level with 48% a year ago). The next four customers (which includes Ciena) collectively comprised 37% (down on last quarter's 41% due mostly to the lower revenue from China customers other than Huawei). The Americas fell from 20% to 18% of total revenue while the rest of the world rose from 21% to 25% as Western customers shifted between contract manufacturing locations.

High-Speed products (for data rates of 100G-and-above) have grown further, from 86% of revenue last quarter to 88%. "We are focused on the highest-speed coherent solutions that are well aligned with leading industry trends, which has positioned us to benefit from growing deployments of high-baud-rate systems for 200–600G globally," says Jenks. "These higher-bandwidth systems accentuate the unique value proposition of our ultra-narrow-linewidth lasers and high-performance photonic integrated chips."

On a non-GAAP basis, gross margin was 22.4%, down from 28.6% last quarter but up from 14.7% a year ago. "While Q1 is our traditional low point for the year, this was about 2.5 points lower than [the 23–27%] expected," notes senior VP & chief financial officer Beth Eby. Specifically, product margin fell more than expected, from 31.6% last quarter to 27%, due to the impact of annual price reductions as well as a less favorable product mix (with more mature, lower-margin 100G and 200G products making up a higher-than-expected proportion of sales, while 400G revenue grew less than expected).

Due to R&D expenditure rising by $1.2m (as a result of some important programs to support new chips and components that had near-term spending), operating expenses were $24.2m, up from $22.3m last quarter and $22.9m a year ago (but falling from 33.4% to 30.5% of revenue).

In Q1, appreciation of the Chinese Yuan relative to the US dollar drove a foreign exchange charge of $1.7m. As a result, net loss was $9m ($0.19 per diluted share, worse than the expected $0.17–0.08), compared with net income of $2.4m ($0.05 per diluted share) last quarter but cut from a loss of $14.6m ($0.33 per diluted share) a year ago.

Demand signals from our customers are positive for the year. Because of higher industry-wide demand, notably with the 5G launch, some of our supply constraints [on purchased sub-components] carry forward into Q2 and Q3. They are ameliorating in the second quarter and they should be gone in the third quarter

Cash generated from operations was $8.7m, down from $10.6m last quarter. Free cash flow was $5m.

Net inventory was $54m (76 days), up $1m from last quarter.

During the quarter, cash and cash equivalents, short-term investments and restricted cash rose by $2.2m to $78.9m.

After the end of the quarter, NeoPhotonics closed the sale of its Russia manufacturing operation, as part of its ongoing process to align business with product lines that are strongest and most profitable.

For second-quarter 2019, NeoPhotonics expects revenue to grow by about 15% to $88–93m. Gross margin should recover to 25–29%, driven by higher factory loading without Q1's two-week holiday, plus a few cost reductions taking effect (rather than product mix, as 100G and 200G products will comprise a similar proportion of revenue as Q1). With operating expenses of $24m, diluted earnings per share should range between a $0.06 loss and a $0.04 gain.

"Demand signals from our customers are positive for the year," notes Eby. "Because of higher industry-wide demand, notably with the 5G launch, some of our supply constraints [on purchased sub-components] carry forward into Q2 and Q3," she adds. "They are ameliorating in the second quarter and they should be gone in the third quarter."

"Telecom and metro shipments are reasonably stable, and we are cautiously optimistic about data-center interconnect (DCI) demand in North America for all of 2019," says Jenks. "Much of our DCI deployment volume today is 200G and 400G, with growth coming at 600G. We anticipate that 400G will continue to deploy while our 600G products continue to ramp through this year and next. Subsequently, 600G will coexist with coming

800G, and of course we will be engaged in deployments in each of these data rates," he adds.

"Similarly, we see a positive outlook this year for China. Our largest customer Huawei conducted an analyst conference in April and forecasted meaningful revenue growth in their carrier network business and a significant ramp in 5G deployments. There has been much discussion about China customers' building strategic inventory," continues Jenks. "Based on demand for the products we supply, we are seeing some increases that are in line with what would be consumed with strong tender volumes and we are seeing solid indications of tender activity. We continued to see good progress with design-ins and volume growth for our 64Gigabaud product suite," he adds. "In the West, these products [64Gigabaud] are used by our customers to achieve 600Gb/s on a single wavelength for distances up to about 80km, such as data-center interconnect. In China, these 64Gigabaud components are being utilized initially to double the speeds of long-haul coherent networks from 100G to 200G while keeping largely the same transmission performance. This same technology will be used across the spectrum of networks to increase the data rates and the available fiber capacity… 64Gigabaud is the next major baud-rate node that will see substantial deployment in telecom networks, notably in China. On the telecom side, the adoption of new technologies may be slower, but may have a longer lifecycle and higher aggregate volume than DCI. As a result, NeoPhotonics will benefit from 64 Gigabaud in both DCI and telecom deployments."

We view InP as optimal to support 90–100Gigabaud for up to 800Gb/s on a single wavelength, further increasing data rates across multiple reaches. Moreover, this platform will continue to be the platform of choice at even higher speed targets above

"Building on our success with 64Gigabaud discrete components, we are extending our offerings to 90–100Gigabaud network applications with our recent announcements at the OFC trade show during March. These included our Class 50 integrated coherent receiver (ICR) and coherent driver modulator (CDM), which are based on our indium phosphide (InP) photonic integration platform," says Jenks. NeoPhotonics is now testing initial products for 90–100Gigabaud. "We view indium phosphide as optimal to support 90–100Gigabaud for up to 800Gb/s on a single wavelength, further increasing data rates across multiple reaches. Moreover, this platform will continue to be the platform of choice at even higher speed targets above 100Gigabaud, which we will continue to support."

www.neophotonics.com

Q2 revenue guidance cut from $88–93m to $75–80m

Restructuring options evaluated to be cash neutral at lower revenue

As a result of the US Department of Commerce's Bureau of Industry and Security (BIS) adding Huawei Technologies Co Ltd and 68 of its affiliates to its 'Entity List' prohibiting the sale to Huawei of products covered by the Export Administration Regulations (EAR) without obtaining an appropriate export license, NeoPhotonics has updated its business outlook for second-quarter 2019 and announced a write-down of certain inventories.

"This action creates a material impact on NeoPhotonics and many others in the optical communications market and related industries," says chairman & CEO Tim Jenks. "We are fully complying with the restrictions and have ceased shipments of products subject to EAR," he adds. "Our objective is now to move rapidly to lower manufacturing and operating expense levels to be cash positive at a lower revenue level."

Taking these actions into account, the firm is cutting its non-GAAP second-quarter 2019 guidance for revenue from $88–93m to $75–80m, for gross margin from 25–29% to 22–26%, for operating expenses from $23.5–24.5m to $22–23m, and for earnings per share from between a net loss of $0.06 and net profit of $0.04 to a net loss of $0.15–0.05.

This excludes the impact of expected inventory write-downs of $8.6m, the anticipated impact of stock based compensation of $3.5m, accelerated depreciation of $0.9m, amortization of intangibles of $0.3m and a $0.8m gain on asset sales.

On 20 May, the BIS announced a Temporary General License (TGL) that would allow shipment of certain categories of products to Huawei for a period of 90 days. Should NeoPhotonics receive additional orders from Huawei or its designated affiliates that are compliant with the Temporary General License, this could favorably impact the revised second-quarter outlook.

NeoPhotonics says it remains focused on preserving working capital in the near-term and is evaluating restructuring options to be cash neutral at a lower revenue level. As of 31 March, the firm had a net working capital balance of $111m, which is above the amounts needed to cover outstanding debt.

Lumentum's growth in ROADM & fiber-laser capacity outweighs drop in 3D sensing laser revenue

For fiscal third-quarter 2019 (to end-March), optical and photonic optical component and subsystem maker Lumentum Holdings Inc of Milpitas, CA, USA has reported revenue of $432.9m, up 15.8% on $373.7m last quarter and 44.9% on $298.8m a year ago, boosted by a full quarter of revenue from the acquisition on 10 December of optical communications component and module maker Oclaro Inc of San Jose, CA, USA plus continued strong growth in Telecom transport products and Commercial Lasers.

Optical Communications segment revenue was $377.9m (87.3% of total revenue), up 16.1% on $325.4m last quarter and 53.4% on $246.3m a year ago. Of this:

- Telecom revenue was $243.4m, up 41% on $172.5m last quarter and almost doubling from $122.6m a year ago, driven by the acquired Oclaro telecom revenue and by double-digit quarter-on-quarter growth in both telecom transport sales and reconfigurable optical add/drop multiplexers (ROADMs, which grew 80% year-on-year to $200m). "Chinese customers are an increasing portion of our ROADM revenue, which should be expected given the limited historical deployments of ROADMs in China. However, their contribution is still well below their share of the market," says president & CEO Alan Lowe. "We continue to add ROADM capacities, but demand outstripped our ability to supply… this will continue throughout the fourth quarter." With the full quarter contribution from Oclaro, telecom revenue mix is now about 40% transmission and 60% transport (more balanced than Lumentum's historically heavy transport mix, and closer to the overall telecom market). This mix could further balance out over time as new higher-speed transmission products, including DCO (digital coherent optics) modules, ramp later this year. "The telecom market should be strong, based on the continued growth in global network bandwidth requirements and the needed infrastructure for 5G," believes Lowe.
- Datacom revenue was $57.3m (including chip revenue of $20m), up 72% on $33.4m last quarter and 58% on $36.3m a year ago.
- Industrial & Consumer revenue (which includes 3D sensing) was $77.2m, down 35% on $119.5m last quarter (due to usual seasonality in the consumer electronics market) but also down 11.7% on $87.4m a year ago. "We continue to make excellent progress with Android customers and additional new design wins on both front and the world-facing applications," says Lowe. "For the first time, we had a single Android customer drive more than $10m of revenue in the quarter… They are in the very, very early stages. So, I expect that 3D sensing for Android customers will grow more rapidly than it has in the past, as we look out over the next four quarters."

Commercial Laser segment revenue was $55m (12.7% of total revenue), up 13.9% on $48.3m last quarter and 4.8% on $52.5m a year ago, driven by growth in fiber-laser sales. "We benefited from capacity expansion and further ramp volumes of our newest fiber-laser products," says Lowe. "We again achieved record revenues from our kilowatt-class fiber lasers [up 23% sequentially and 135% year-on-year]."

"Q3 continued a theme that started more than a year ago for our ROADM and fiber-laser product lines," says Lowe. "For the fifth quarter in a row, we achieved double-digit sequential quarterly revenue growth and new record revenues for these product lines, driven by strong customer demand for our new and differentiated products."

Growth in ROADM and transport revenue has outpaced the telecom transmission revenue growth for several reasons, says Lowe:

- In new network deployments, the transport equipment is installed first and then individual transmission wavelengths are lit up over time.
- With the new colorless, directionless, contentionless (CDC) network architectures, the number of ROADMs per network node and the number of ports per ROADM (and therefore the average selling price) are increasing. These more advanced ROADMs enable customers to achieve the needed network reconfigurability and capacity. Additionally, ROADMs are pushing into new geographies and applications: Chinese domestic deployments have started (significantly increasing the addressable market over time) and ROADMs are pushing further towards the edge of the network (replacing fixed optical add-drop multiplexers).

On a non-GAAP basis, gross margin was 39%, down from 40.1% last quarter (due to product mix) but up from 36.3% a year ago. Specifically, Optical Communications margin fell from 39.7% last quarter to 38%, due to lower Industrial & Consumer revenue (3D sensing lasers) in the product mix, albeit still up from 33.7% a year ago. In contrast, Commercial Lasers margin was 46%, down from 48.4% a year ago but up from 42.7% last quarter (due to higher volumes and product cost reductions). "We moved pump laser production to our new facility in Thailand, which is achieving lower cost than our prior manufacturing location," says Lowe. Production in Shenzhen, China will stop by the end of fiscal Q4 and that capacity will be moved to Thailand to raise capacity there to the full run rate over the next couple of quarters (increasing Lumentum's peak run rate for pump lasers by 20–30%).

Operating expenses were $91.8m (21.2% of revenue), up from $67.5m (18.1% of revenue) last quarter due to having a full quarter of the acquired Oclaro business as well as the seasonal impact of new calendar year resets of labor fringe rates.

Operating margin was 17.8%, down from 22% last quarter but up from 16.5% a year ago. Likewise, net income was $69.9m ($0.91 per diluted share), down from $78.3m ($1.15 per diluted share) last quarter but up from $50.6m ($0.78 per diluted share) a year ago.

During the quarter, cash and short-term investments rose from $684.1m to $697.5m.

"Q3 was the first full quarter since completion of the acquisition of Oclaro. We made solid progress on integrating the companies and attaining synergies," says Lowe.

"We announced to our telecom customers two strategic actions catalyzed by the Oclaro acquisition. First, we are rationalizing overlapping product lines, which we expect to have minimal impact to revenue. This rationalization should result in gross margin improvement once completed over the next few quarters. Second, we are discontinuing some legacy telecom product lines where growth and profitability forecasts are inconsistent with our long-term goals. Revenue from these products is about $15m per quarter at present, and will decline to zero once we satisfy our customers last-time-buying needs over the coming three to four quarters," reckons Lowe.

Also, during fiscal third quarter and in the fiscal fourth quarter to date, Lumentum executed a series of strategic actions related to a fundamental shift in its datacom strategy (announced in early March at the OFC 2019 trade show). "We are now focused on datacom chip sales and will stop selling datacom transceivers over time," states Lowe. These actions include (on 18 April) completing the divestiture of several datacom transceiver product lines (manufactured by subsidiary Oclaro Japan Inc) to Shanghai-based Cambridge Industries Group (CIG) in exchange for a long-term strategic supply agreement for Lumentum's photonic chips.

"We expect sales of our remaining datacom transceiver product lines to ramp down to zero as we bleed down inventory with only chip sales remaining in the future," says Lowe. "This process could take up to 4–5 quarters." Currently, datacom chip revenue is about $20m per quarter. "Since the announcement of the transaction and our clarification on our datacom strategy, we have seen increased interest from new customers for our datacom chips as we will no longer compete with them at the transceiver level," he adds. "We are investing in new datacom chip development and expect sales of chips to customers serving the datacom and 5G markets to grow."

For fiscal fourth-quarter 2019, Lumentum expects revenue to fall to $405–425m. This includes a rise in Telecoms (driven by continued market growth and capacity expansion). However, due mostly to the product line divestiture plus continuing declines in remaining datacom transceiver sales, Datacoms will drop by $20–25m to $32–37m (just $12–17m from transceivers plus the $20m from chip sales). Industrial & Consumer (including 3D sensing) should be flat to slightly down, driven by the seasonal low for existing products not being fully offset by initial ramps for new product cycles (although this should ramp up again this summer and into the fall). Commercial Lasers should fall by 15–20% (to $47m). "Our largest fiber-laser customer has communicated that their inventory of our products has reached targeted levels," says Lowe. "We are making healthy investments in new laser product development, targeting higher-growth material processing applications," he notes.

"Switching to telecom transmission; we continue to make progress on our high-speed coherent products, including indium phosphide photonic integrated circuit (PIC)-based components, 200G DCO modules and future 400Gb/s and 1.2Tb/s DCO products," says Lowe. "We expect these products to ramp in volume and to be a growth driver later this year," he adds.

"When we announced the [Oclaro] acquisition, we expected synergies would be in excess of $60m per year within 12–24 months," notes chief financial officer Wajid Ali. "Through Q3, we have achieved more than $20m in annual expense synergies. We expect synergies to continue to grow in the fourth quarter [driving OpEx lower] and into fiscal year 2020." Despite lower revenue from higher-than-average-margin 3D sensing and Commercial Lasers product lines, operating margin should rise to 18–20% in fiscal Q4 (the seasonally weakest quarter).

www.lumentum.com

Lumentum is complying with the US Department of Commerce's imposed license requirements for the export, re-export and/or in-country transfer of items to Huawei Technologies Co Ltd of Shenzhen, China and designated affiliates that have been added to its 'Entity List'. Lumentum has hence discontinued all shipments to Huawei and says it cannot predict when they can resume.

Huawei contributed 11% of revenue for full-year fiscal 2018 (ended 30 June 2018), 18% for fiscal Q3/2019 (to 30 March), and 15% for fiscal 2019 year-to-date.

Guidance provided on 7 May for Lumentum's fiscal Q4/2019 (to 29 June) did not contemplate this order, discontinuation of sales to Huawei or the time required to repurpose manufacturing capacity to other customers. It has hence cut its expectations for net revenue from $405–425m to $375–390m, for operating margin from 18–20% to 15.5–17%, and for diluted net income per share from $0.85–1.00 to $0.65–0.77.

Open Eye MSA formed to advance 50–400Gbps PAM4 data-center interconnects based on CDR architectures

The Open Eye industry consortium has announced the establishment of its multi-source agreement (MSA) outlining its mission to standardize advanced specifications for lower-latency, more power-efficient and lower-cost optical modules for data-center interconnects over single-mode and multi-mode fiber.

The MSA aims to accelerate the adoption of 4-level pulse amplitude modulation (PAM4) optical interconnects scaling to 50Gbps, 100Gbps, 200Gbps and 400Gbps by expanding on existing standards to enable optical module implementations using less complex, lower-cost, lower-power and optimized clock & data recovery (CDR)-based architectures in addition to existing digital signal processing (DSP) architectures.

Minimizing the need for digital signal processing in optical modules has many advantages including significantly lowering latency, power consumption and cost. The Open Eye industry consortium says that it is committed to investing its collective innovation and engineering resources for the development of an industry-standard optical interconnect that leverages seamless component interoperability among a broad group of technology providers, including electronics, lasers and optical components.

"Sales of next-generation Ethernet products will exceed $500m in 2020," forecasts Dale Murray, principal analyst at market research firm LightCounting. "However, this is only possible if suppliers can meet customer requirements for cost and power consumption. The new Open Eye MSA addresses both of these critical requirements. Having low latency is an extra bonus that HPC [high-performance computing] and AI [artificial intelligence] applications will benefit from."

The Open Eye MSA consortium's approach is a natural evolution of existing high-volume optical nodes, enabling users to scale to next-generation baud rates. The initial Open Eye MSA specification will focus on 53Gbps-per-lane PAM-4 solutions for 50G SFP, 100G DSFP, 100G SFP-DD, 200G QSFP and 400G QSFP-DD & OSFP single-mode modules. Subsequent specifications will aim to address multi-mode and 100Gbps-per-lane applications.

Formation of the Open Eye MSA was initiated by MACOM and Semtech Corp, with 19 current members in Promoter and Contributing membership classes.

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

Contributors include: Accelink, Cloud Light Technology, InnoLight, Keysight Technologies, Maxim Integrated, O-Net, Optomind, Source Photonics and Sumitomo Electric.

The initial specification release is planned for Fall 2019, with product availability to follow later in the year. Companies interested in joining the Open Eye MSA can e-mail admin@openeye-msa.org.

www.openeye-msa.org

OIF completes two new implementation agreement interoperability specs for CFP2-DCO & HB-CDM modules

Optical Internetworking Forum (OIF) — the global industry forum accelerating market adoption of advanced interoperable optical networking solutions — has completed two new implementation agreements (IAs):

- CFP2-Digital Coherent Optics Module (CFP2-DCO) IA; and
- High Bandwidth - Coherent Driver Modulator (HB-CDM) IAs.

"As a member-driven organization, OIF's work is based on our members' needs," says Karl Gass, OIF, PLL Working Group – Optical vice chair. "The CFP2-DCO IA is in direct response to feedback from a network operator that needed an IA to fill an interoperability gap in their network. The HB-CDM IA addresses a performance need by creating a component that can be used for much higher-performance links."

CFP2-DCO

The IA for CFP2-DCO defines the additional information needed in order to implement the DCO function in the CFP2 module. The CFP2-DCO module contains all the required functions to perform dual-polarization coherent optical signaling. The module can also provide different bit rates such as 100G/200G/300G/400G and support more modulation formats.

HB-CDM

The IA for HB-CDM targets modulation and data-rate-agnostic coherent applications having nominal symbol rates up to 64Gbaud. It defines a small-form-factor electro-optic component that integrates the HB-polarization multiplexed-quadrature (HB-PMQ) modulator plus the RF drive functions for the high-baud-rate and low modem implementation penalty segment of the coherent market. Additionally, the IA identifies and specifies the common features and properties of coherent transmitters to enable them to broadly meet the needs of existing and future coherent systems.

www.oiforum.com/wp-content/uploads/2019/01/OIF-CFP2-DCO-01.0.pdf

MACOM announces first analog CDR-based PAM-4 portfolio, targeting compliance with Open Eye MSA

MACOM Technology Solutions Holdings Inc of Lowell, MA, USA (which makes semiconductors, components and subassemblies for RF, microwave, millimeter-wave and lightwave applications) has announced a complete analog and silicon photonics portfolio for seamless integration in 50Gbps, 100Gbps, 200Gbps and 400Gbps optical modules targeted for compliance with the newly formed Open Eye multi-source agreement (MSA).

Optimized for volume-scale deployment in high-density cloud data-center links, MACOM's new components aim to enable faster, lower-cost and more power-efficient optical modules. as defined by the upcoming Open Eye MSA industry standard.

MACOM's end-to-end transmit and receive portfolio features low-cost, low-power extensions to its existing lineup of clock & data recovery (CDRs), drivers and transimpedance amplifiers (TIAs), adding a companion integrated 200G FR4 L-PIC (photonic integrated circuit with integrated lasers) optimized to reduce module costs through improved ease of assembly, calibration and test. These components are designed to eliminate the need for expensive, power-hungry signal processing and 53Gbps externally modulated lasers (EMLs), enabling streamlined optical module architectures targeted at 200G and 400G connectivity.

MACOM's full CDR-based and L-PIC-based portfolio comprises the MAOM-38053 four-channel transmit PAM-4 CDR with an integrated driver and an L-PIC transmitter and, on the receive side, a MATA-03819 quad TIA, MACOM BSP56B photodetectors and the MASC-38040 four-channel receive PAM-4 CDR. This approach is expected to deliver over 25% reduction in power consumption while simultaneously driving the cost per gigabit down compared with existing CWDM4 and digital signal processing (DSP)-based PAM-4 solutions. Cloud customers can now double their link rate with only minor, incremental power and cost.

"MACOM is proud to be part of an ecosystem that enables seamless component interoperability among a broad group of industry-leading technology providers, including providers of electronics, lasers and optical components," says Preet Virk, senior VP & general manager, Networks. "MACOM is committed to enabling the Open Eye MSA's charter, in part by leveraging our comprehensive portfolio of high-performance analog components and L-PICs to help customers achieve optimal performance, power efficiency and cost structures," he adds. "Our extensive application expertise and industry leadership in PAM-4 enabling technologies will help to ensure a seamless migration from 100G CWDM4 to industry-standard 200G and 400G PAM-4 module architectures," he believes.

The Open Eye MSA group aims to accelerate the adoption of data-center interconnects scaling to 50Gbps, 100Gbps, 200Gbps and 400Gbps by expanding existing standards to enable optical module implementations using multiple technologies including optimized CDR-based architectures in addition to existing DSP architectures.

All of the MACOM products highlighted in this CDR and LPIC-based portfolio are sampling to customers now.

www.macom.com/data-center

Emcore's revenue grows 16.7% year-on-year to $21.7m

Margins recovering following costs of DFB to L-EML transition

For its fiscal second-quarter 2019 (ended 31 March), Emcore Corp of Alhambra, CA, USA — which provides indium phosphide (InP)-based optical chips, components, subsystems and systems for the broadband and specialty fiber-optics markets — has reported revenue of $21.7m, down 9.4% on $24m last quarter but up 16.7% on $18.6m a year ago.

Broadband products fell from 72% of total revenue last quarter to 65% as typical winter seasonal softness was seen in cable TV (which fell from 62% to 49% of total revenue). Conversely, non-CATV broadband products (Satcom video & wireless) were strong, with Satcom growing 33% quarter-on-quarter and 227% year-on-year (boosted by the shipment of several large projects).

Chip product sales fell back from 18% of total revenue last quarter to 16%, but this was due mainly to a combination of a strong preceding quarter and the impact of Chinese New Year. Year-on-year revenue growth is 20%, driven by a combination of both legacy 2.5G GPON (Gigabit passive optical network) products for the Chinese market as well as non-GPON-related products.

Navigation products rose from 10% of total revenue last quarter to 19%, with revenue growing 66% quarter-on-quarter and doubling year-on-year.

"We saw strong sequential growth, driven largely by our navigation product," notes president & CEO Jeff Rittichier. "We continued to deliver on our revenue diversification initiatives," he adds.

On a non-GAAP basis, gross margin was 27.3%, level with a year ago and up from 24.7% last quarter, due to the seasonally lower volumes being outweighed by cost improvements.

"Decreased volumes did cause under-absorption, which depressed gross margins by 560 basis points below our standard margin," says Rittichier. "However, we eliminated the overwhelming majority of costs associated with transitioning [from legacy distributed feedback (DFB) products] to the L-EML [linear externally modulated lasers] technology [which had been a headwind in prior quarters]," he adds. "With transition cost behind us, the only thing that prevents us from returning to more historically normalized margin is cable TV volume."

Operating expenses have hence been cut slightly from $11.6m last quarter to $11.3m, with an increase in R&D spending from $4m to $4.3m being outweighed by a reduction in selling, general & administrative (SG&A) spending from $7.6m to $7m, despite Emcore continuing to incur similar litigation expense of $2.6–2.7m.

Pre-tax loss from operations has been cut from $2.4m ($0.09 per diluted share) last quarter to $2m ($0.07 per diluted share), which is also a slight improvement on $2.1m ($0.08 per diluted share) a year ago.

Capital expenditure (CapEx) was $3.6m (up from $2.8m last quarter) as the firm continues to invest in the upgrade of its wafer fab and in modernizing its campus. Depreciation was steady at $1.6m. During the quarter cash and cash equivalents hence fell by $6.7m from $57.3m to $50.6m.

Decreased volumes did cause under-absorption, which depressed gross margins by 560 basis points below our standard margin. However, we eliminated the overwhelming majority of costs associated with transitioning [from legacy DFB products] to the L-EML technology [a headwind in prior quarters]

CapEx will remain at an elevated level, before falling back at some point next year. "Emcore's fab was built when it was Nortel in the late 1980s and some of the pieces of equipment are still running… The original reactors here were installed 20–25 years ago and, because of that, when you go to put new reactors in, all of the building issues, safety systems that were grandfathered now have to be completely upgraded," notes Rittichier. "There's the cost of the equipment and then there's the facilitation expense," he adds. "We have two reactors coming in. One is complete and in checkout; the second one is close behind it. Those are $1.6m a piece; a significant amount of that has already been paid as typically you get to this stage, you're at sort of 10% final acceptance payments."

For fiscal third-quarter 2019 (to end-June), Emcore expects revenue of $21–23m, which reflects CATV orders returning to normal late in the quarter along with Chip and Navigation products being roughly steady. Again, the firm expects Chips to have strong double-digit growth year-on-year and Navigation to roughly double year-on-year (putting this product line on track to double its full-year revenue once again from fiscal 2018 to fiscal 2019).

Satcom backlog remains strong into fiscal Q3 and includes the program to modernize air traffic control towers with Emcore technology. Also, Emcore continues to make progress on its new Wireless product initiatives within the DAS and 5G market segments, with production revenue likely to be a late fiscal 2019 to 2020 event when 5G deployments move beyond trial phases, believes Rittichier.

Regarding Chips, new product initiatives remain on track, with various phases of sampling occurring on a variety of 25G parts for the data center and more advanced components for the telecom markets. "As these new products are

released into the market and begin to generate production volume level, we expect to see an even greater shift in mix to non-GPON products in the quarters ahead, which will have a positive impact on margins," believes Rittichier.

"Over the past several quarters we faced cost headwinds resulting from faster-than-expected ramp up in our L-EML product line and its associated accounting impacts," notes Rittichier. "As of the end of the second quarter, we have worked through these issues and expect gross margins to increase as volume returns. In addition, as we look out over the next few quarters, we expect to see further improvements in gross margin as we increase profit contribution from new chip products and see significant yield improvements in our manufacturing processes and extended supply chain, which will translate into improvements in final product cost," he adds. "In particular, L-EML yields continue to improve across the board, and at this point we expect those product costs to achieve their targets."

"The only thing that stands in the way of return to profitability is cable TV product volume. CATV is a notoriously cyclical business and the key to developing guidance is understanding the MSOs spending environment, which typically becomes clear right around this time every year," notes Rittichier. "Emcore's market share is nearly 70% in the downstream optical component market, so our CATV revenue generally follows the infrastructure CapEx spend of the MSOs. Recent announcements by one of the major MSOs provided some important visibility and show that the Q1 CATV MSO CapEx was at nearly a 5-year low in first-quarter calendar 2019. This MSO went on to point out that he expected spending to increase over the year, but that their whole fiscal year 2019 infrastructure CapEx would be lower than fiscal year 2018. Therefore, we should expect to see an uptick in CATV starting at the tail end of Emcore's current fiscal quarter progressing through the end of calendar year 2019," he adds.

"Regarding our campus upgrade initiatives, those remain on track and are already helping us become more efficient as we free up space in the cramped Alhambra campus," says Rittichier. "These efforts will free up 20,000ft^2 of floor space and allow us to finally group our personnel logically. Our upgraded fiber-optic gyroscope (FOG) manufacturing space should be completed in the current quarter and new Navigation laboratory space build out will start after that," he adds.

Regarding the ongoing litigation, Emcore has now entered the post-hearing phase with respect to a majority of the claim, so it expects the litigation costs to decline significantly in fiscal Q3.

www.emcore.com

Alta Devices launches Anylight Solar for HALE product for high-altitude long-endurance UAVs

Alta Devices of Sunnyvale, CA, USA (a subsidiary of Hanergy Thin Film Power Group Ltd of Beijing, China) has announced a new solar solution designed to meet the specific needs of unmanned aerial vehicles (UAVs) that can serve as platforms for cellular and Internet of Things (IoT) connectivity. Combining the firm's solar cell technology with several new inventions yields features that can maximize power, minimize weight and provide sufficient protection from the harsh environment commonly found in the Earth's stratosphere (at 60,000ft).

High-altitude long-endurance (HALE) UAVs that fly at stratospheric levels — or high-altitude pseudo satellites (HAPS) — comprise an important new aircraft category and can include airplanes, airships, and/or balloons that can fly at altitudes of 20km (60,000ft) for extended periods of time. In addition to being used for communications (such as cell phone connectivity etc), these aircraft can be used for intelligence surveillance & reconnaissance (ISR), search & rescue, border patrol, mapping and many other applications. Solar power is critical for these aircraft, particularly because the objective is to fly for years without refueling.

Flight at this altitude demands solar technology that is different from the type used in terrestrial installations or in space. For example, at 60,000ft, ultraviolet radiation from the sun is more intense than on the earth's surface. Unlike in space with zero gravity, the generation of lift is important for stratospheric vehicles. To allow the aircraft to carry a useful payload and enough batteries for night flight, the solar technology used must be extremely light-weight. In contrast to both terrestrial and space applications, at 60,000ft mechanical stresses during flight can be very tough on the aircraft surface and solar panels, so the solar material must be flexible and durable.

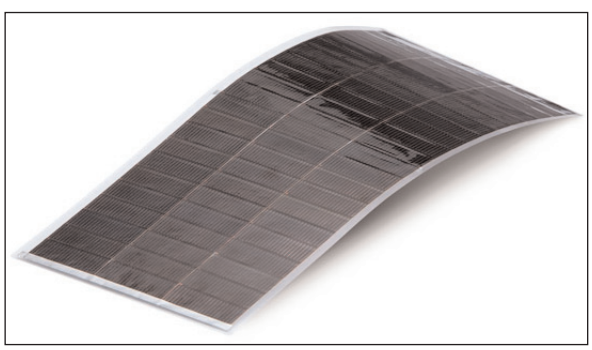
NASA's Helios Prototype solar HALE UAV.

Alta Devices' new 'Anylight Solar for HALE' product (available now) uses its record-efficiency (29.1%) single-junction gallium arsenide (GaAs) solar cells (unveiled in December), producing what is claimed to be industry-leading power per unit area of over 300W/m^2 under high-altitude operating conditions. Alta says it has worked with its HALE aerospace customers to solve critical challenges related to the mechanical and electrical integration of the technology onto multiple aircraft platforms. The firm developed special, lightweight packaging that protects the solar cells from the extreme UV, ozone and thermal environment of the stratosphere while maintaining a smooth, aerodynamic surface.

Other crucial challenges addressed by Alta include designing for mechanical stresses and vibration expected during flight and developing techniques for co-curing into lightweight composite structures. Optimizing a solar array for an aircraft requires complex configurations that maximize cell-packing factor (providing industry-leading packing density of up to 94% including diodes and connectors), minimize electrical mismatch and allow the design to utilize the maximum surface area for solar. Alta says that it worked with its customers to understand these requirements and developed module designs that address these issues, providing an easy-to-integrate solution that maximizes system performance while reducing the work required during installation.

"Our aerospace customers need to innovate every aspect of these new and complex aircraft systems," says CEO Jian Ding. "With our new HALE solar solution, they now have one less thing to worry about," he adds. "This will simplify the design process and significantly reduce the complexity involved in manufacturing these aircraft."

Alta Devices says that engineers with extensive expertise in integration are available for customer support and advice on optimal integration techniques such as co-curing or adhesives. Finally, it is ramping its production capability in response to its customers, who plan to manufacture a multitude of HALE aircraft in the near future, the firm adds.



Alta Devices' AnyLight Solar for HALE UAVs.

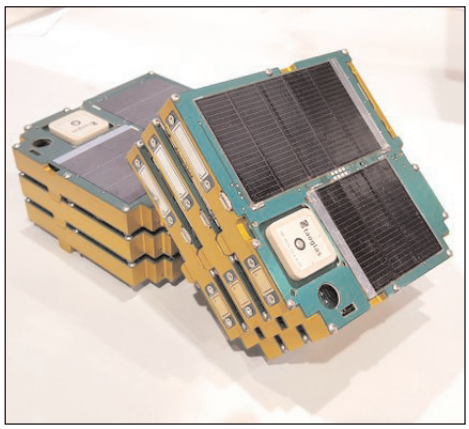
www.altadevices.com/solar-product-for-hale-haps-uavs

Alta Devices solar cells powering ThinSats on Cygnus satellite launch

The NG-11 mission launched on 17 April from the NASA Wallops Flight Facility carrying the Cygnus cargo spacecraft to deliver supplies to the International Space Station (ISS) and transport 60 small satellites (ThinSats) into space. These satellites are powered by gallium arsenide (GaAs) solar cells made by Alta Devices of Sunnyvale, CA, USA (a subsidiary of Hanergy Thin Film Power Group Ltd of Beijing, China) and will carry various electromagnetic, radiation and inertial sensors for scientific analysis of the atmosphere.

The ThinSats are part of a program whose goal is to set a new standard for STEAM (science, technology, engineering, the arts and mathematics) education in the USA. Dozens of teams of high-school and college students were engaged in preparation of the satellite hardware and analysis. The satellites are being deployed into low-earth orbit and will allow live data transmission.

In the future, the ThinSats can be deployed into constellations and expanded to larger sizes for hosting larger payloads.



Alta Devices flexible GaAs solar cells power the ThinSat design.

The ThinSat Program is managed and funded by Virginia Commercial Space Flight Authority (Virginia Space) with Twiggs Space Lab LLC (TSL) operating as the general contractor, NearSpace Launch Inc (NSL) of Upland, IN, USA as the primary spacecraft designer and manufacturer, and Alta Devices as the solar cell provider.

"Until now, no commercial solar technologies could match the improvement in cost, weight and ease of use that other components of small-satellite technology have achieved," says NSL co-founder Hank Voss. Specifically, most solar cells are expensive, fragile, rigid and difficult to encapsulate and robustly attach to spacecraft, he adds.

In contrast, Alta Devices says that its solar cells are flexible, easy to encapsulate and mount, and provide high power conversion efficiencies. For example, cells can be mounted to low-mass deployable structures including coiled carbon-fiber booms, flat-packed, polymer-based accordioned arrays or even inflatable structures, allowing creative design approaches to maximizing onboard solar power. Alta Devices adds that its solar cells can empower autonomy by providing mechanical and design flexibility for the small-satellite industry.

www.altadevices.com
www.vaspace.org/index.php/thinsat-program
www.twiggsspacelab.com
www.nearspacelaunch.com

Midsummer launches solar tile for Sweden's most popular roof shingle

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 launched a solar panel exclusively developed for Sweden's largest manufacturer of roof tiles, Benders, and its most popular Palema model.

The new solar panel is integrated with the Palema roof tile and can be installed on both existing and new Benders roofs. The panel will be manufactured by Midsummer and will be marketed and sold by Benders.

The new solar roof panels will be integrated with Benders' most popular 2-barrel Palema model. Orders for the new Palema solar tile are accepted with immediate effect and deliveries will begin in October.

"Solar panels have had tremendous growth in Sweden and the rest of the world in the last few years," says Midsummer's CEO Sven Lindström. "For this development to continue and to attract even more consumers to install solar panels, we need easily assembled products that are aesthetically attractive," he adds. "In this particular case we have used Midsummer panels' unique properties, flexibility and freedom of our solar panels to adapt the shape and size to the customer's needs. With these panels developed for Sweden's most popular roof tiles, we hope to speed up the process so that more people are tempted to install solar panels on their existing and new roofs in the Nordic market."

The partnership with Benders forms part of Midsummer's new strategy to develop and manufacture solar panels in-house and through contract manufacturers and sell them via selected partners, in addition to its core business of producing manufacturing equipment.

www.benders.se/en-gb
www.midsummer.se

InGaAs quantum well transistors on silicon

Researchers claim highest combined radio frequency cut-off parameters on silicon that also outperform silicon CMOS.

IBM Research Zürich in Switzerland claims the highest combined values of high-frequency cut-off for radio frequency (RF) III–V metal-oxide semiconductor field-effect transistors (MOSFETs) on silicon (Si) [Cezar B. Zota et al, IEEE Electron Device Letters, vol40, issue 4 (April 2019), p538]. The team further reports that their device outperforms state-of-the-art silicon RF-CMOS.

The researcher used an indium gallium arsenide (InGaAs) quantum well (QW) channel defined by indium phosphide (InP) barriers that "reduced the impact of border traps on the transconductance within the measured frequency range".

The QW channel material was integrated on silicon on buried oxide (BOX) using direct wafer bonding. The silicon-on-oxide layer was not intentionally doped. The well consisted of 10nm $In_{0.75}Ga_{0.25}As$ sandwiched between InP barrier layers (20nm bottom, 2nm top).

The replacement metal gate fabrication process began with deposition of an amorphous silicon dummy gate. Silicon nitride was used for source/drain spacing. The spacer formation was achieved using a combination of atomic layer deposition (ALD) and reactive ion etch.

Contact extensions beneath the spacers ensured reduced parasitic overlap capacitance and access resistance. The cavities for the contact extensions were formed by 'digital' cycles of controlled oxidation and etching. The digital etch also removed the top InP barrier from the source/drain contact regions. The contact extension cavities were filled with n-InGaAs via metal-organic chemical vapor deposition (MOCVD).

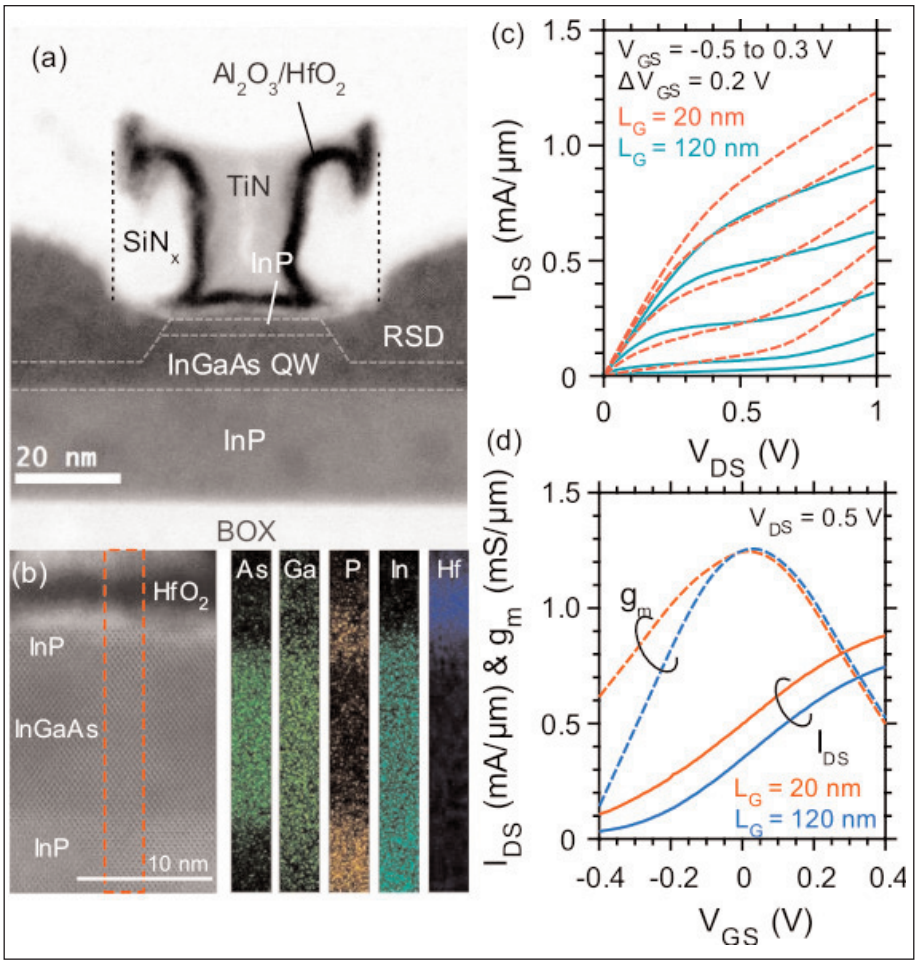


Figure 1. (a) Cross-sectional scanning transmission electron micrograph (STEM) image of 20nm gate-length device before M1-interconnect metallization. (b) High-resolution TEM of channel heterostructure together with energy-dispersive x-ray spectroscopy map of highlighted region. (c) Output characteristics of 20nm and 120nm devices, respectively. (d) Transfer characteristics of same devices.

The dummy gate was then removed and replaced with aluminium oxide and hafnium dioxide high-k gate insulator, and titanium nitride and tungsten gate metal layers (Figure 1).

The output conductance of a 20nm gate-length MOSFET was 50% higher than reference devices without the top InP barrier. The peak transconductance occurred at 0V gate potential — a desirable feature for RF operation due to gate oxide reliability considerations. The presence of the top barrier eliminates defect scattering at the semiconductor/gate oxide interface.

The peak transconductance was 1.25mS/μm for 20nm and 120nm gate MOSFETs. The constancy of the transconductance with gate length scaling was attributed to short-channel effects. The highest peak transconductance measured for devices with gate

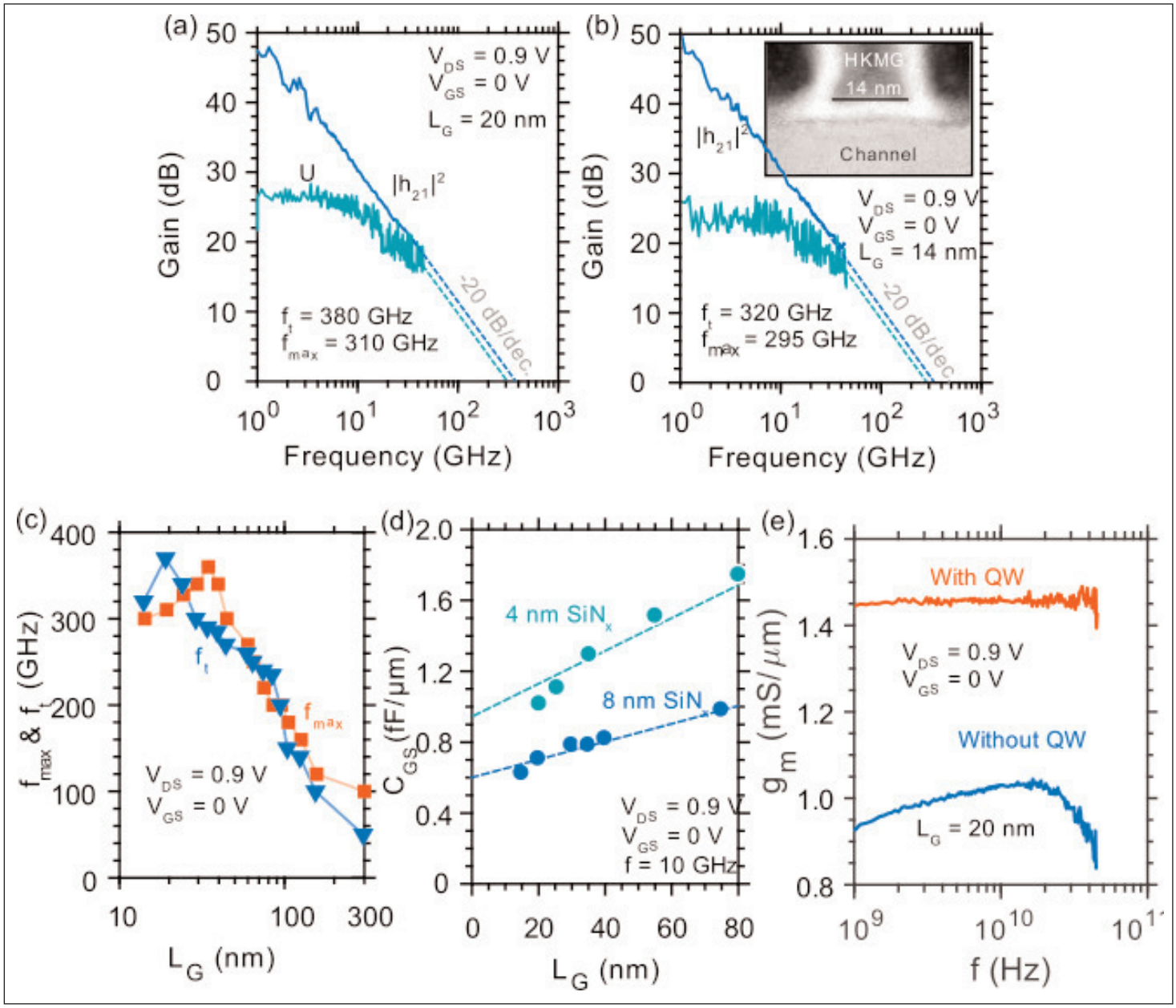


Figure 2. (a) Gain plot of 20nm device under optimal biasing conditions. (b) Gain plot of 14nm device, with the inset showing STEM image of device cross-section. (c) Simultaneous f_T and f_{max} versus gate length (L_G). (d) Gate-to-source capacitance for devices with 4nm and 8nm thick spacers, respectively. (e) Transconductance frequency dependence with and without quantum well.

lengths in the range 20–120nm was 1.4mS/μm (2.1mS/μm intrinsic). The team suggests that gate oxide scaling and process optimization could push this up.

By contrast, transconductance increased with decreased gate length in the reference devices without the top barrier. Devices without any barriers had similar behavior to the reference MOSFETs without the top barrier.

The peak transconductance of the QW MOSFET was 300% greater than that of the reference devices when the gate length was 120nm. The improvement decreased to 60% at the short gate length of 20nm.

The effective mobility of the QW channel was 1500cm^2/V-s, compared with 500cm^2/V-s for the channel without the top InP barrier. The researchers comment: "This difference is attributed to reduced oxide interface traps and surface roughness scattering using the QW."

Frequency-dependent measurements were carried out between 1GHz and 45GHz (Figure 2). The cut-off frequency (f_T) for a 20nm gate-length MOSFET was 370GHz and the maximum oscillation (fmax) was 310GHz. The device had two 4μm-wide gate fingers branching off from a central stem. The team reports that these values "represent the highest combined f_T and fmax reported for a III–V MOSFET on silicon". An even higher f_{max} of 360GHz was achieved with 35nm gate length. ■

https://ieeexplore.ieee.org/document/8656532

Author: Mike Cooke

Indium arsenide quantum dot laser diodes on on-axis silicon

Devices operate in continuous-wave mode beyond 100°C in 1.3μm infrared wavelength optical fiber communications band.

Japan's University of Tokyo has achieved high-temperature continuous-wave laser diode (LD) operation from an active region consisting of indium arsenide (InAs) quantum dots in gallium arsenide (GaAs) grown on on-axis (001) silicon [Jinkwan Kwoen et al, Optics Express, vol27, p2681, 2019].

The laser diode operated at a temperature of 100°C — previous devices on on-axis silicon have only managed performance below this temperature. The use of low-cost on-axis (001) silicon opens up prospects of monolithic integration with silicon photonics and mainstream CMOS electronics. One feature of QD devices is greater tolerance to the presence of dislocations, which tend to have higher density in heterostructures of III–V materials such as InAs and GaAs on silicon.

The researchers used molecular beam epitaxy (MBE) on (001) n-type silicon. The misorientation of the silicon was less than 0.2°. The QD material (Figure 1) consisted of a buffer layer, dislocation filtering by a series of superlattices, and the device layers. The individual QDs extended about 30nm laterally when uncapped. The QD density was about $5x10^{10}/cm^2$. The threading dislocation density was $4.7x10^7/cm^2$. The team believe that the dislocation density could be reduced to less than $10^7/cm^2$ by thermal cyclic annealing techniques.

Laser diodes were fabricated with 7μm-wide mesas. The mesa was narrower than the group's previous work. The resulting improved heat dissipation and current constriction enabled continuous wave (CW) operation up to 101°C.

The p- and n-contacts were both gold-germanium-nickel alloy and then gold. Silicon dioxide insulator coated the mesa sidewalls. The silicon substrate was thinned to 100μm before cleaving the laser diodes into 1.1mm-long devices. The facets were not coated to create high-reflective cavities.

The resulting laser diode had a 27.6mA lasing current threshold ($370A/cm^2$ density, Figure 2). The slope efficiency varied between 53.2W/A at 20°C and 26/3mW/A at 100°C. The characteristic temperature for the shift in threshold current (T_0) was 50K up to 90°C.

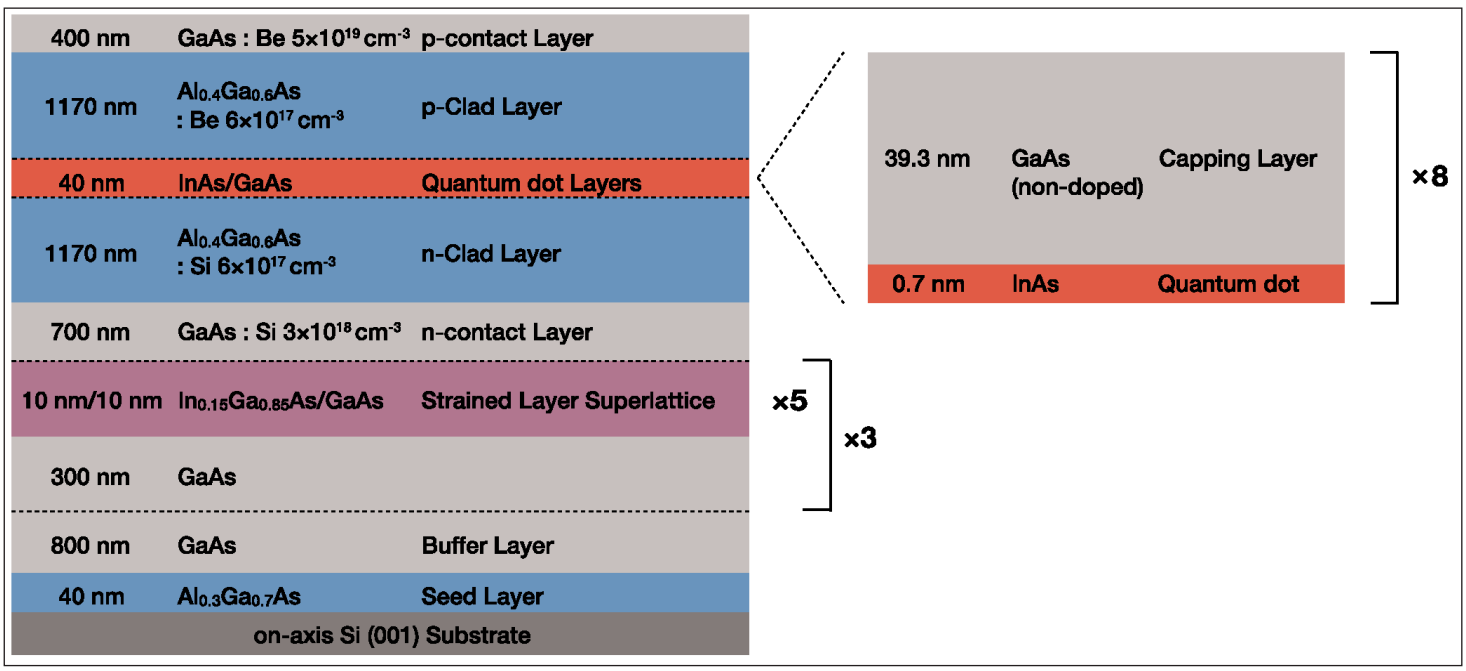


Figure 1. Schematic of epitaxial layers of InAs/GaAs QD laser.

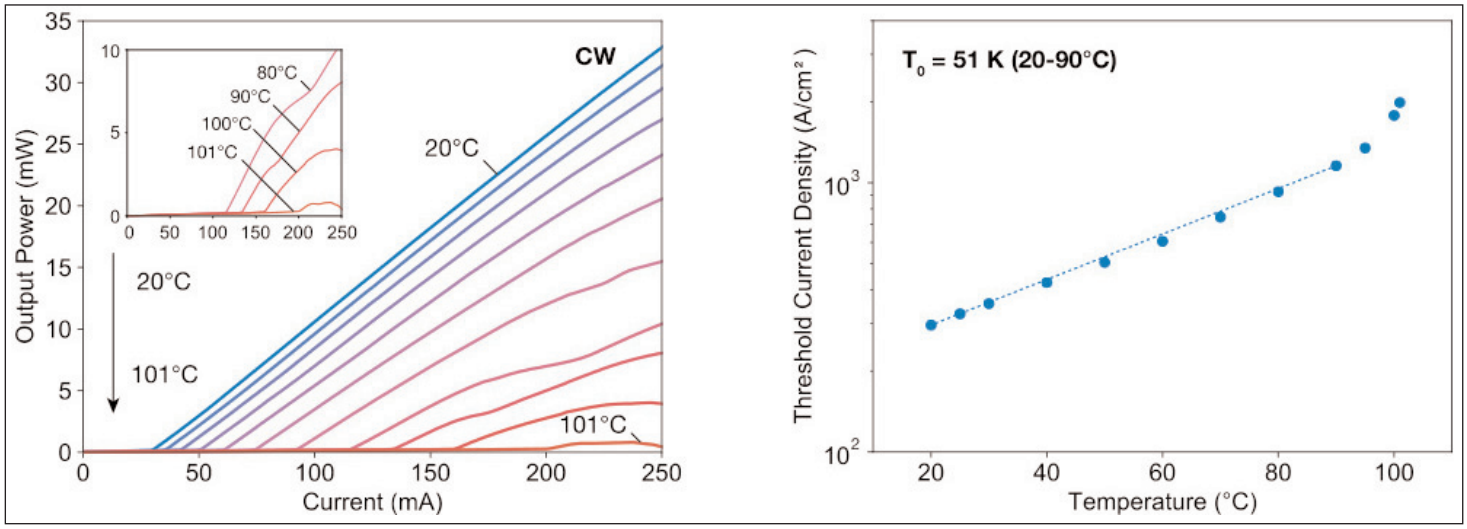


Figure 2. (a) Temperature dependence of light output power versus current characteristics under CW operation for InAs/GaAs QD laser. (b) Temperature dependence of threshold current density.

Under 210mA current injection, the ground-state wavelengths were 1224.6nm and 1272.0nm at 20°C and 101°C, respectively, representing a 0.62nm/K shift rate. ■

https://doi.org/10.1364/OE.27.002681

Author: Mike Cooke

Distributed Bragg reflectors for III-nitride VCSEL structures

Mike Cooke reports on recent research in Japan and USA.

Extending the short-wavelength light-emitting capabilities of III–nitride (III–N) semiconductors to vertical-cavity surface-emitting laser (VCSEL) structures has been the aim of many research groups. VCSELs have a cavity axis perpendicular to the plane of the active region. Traditional edge-emitting laser diodes, by contrast, have lasing cavities in the plane of the active region.

The vertical structure of VCSELs enables multiple lasers to be produced on a single chip in array formations. Other advantages of VCSELs include relatively low threshold currents, high-frequency operation, low manufacturing cost, and high efficiency. More concretely, such features are desired for optical storage, laser printers, projectors, displays, solid-state lighting, optical communications and biosensors.

The original VCSELs were created using III–arsenide (III–As) compound semiconductors using group-III metals such as aluminium (Al), gallium (Ga) and indium (In). A particular feature was the ability to form cavities using conducting distributed Bragg reflectors (DBRs) from alternating layers of AlGaAs with different compositions and a large difference in refractive index. This provides a neat and compact structure for VCSELs that is more simply manufactured.

Such an option is not immediately available in the III–N family of compound semiconductors. The corresponding AlGaN range of alloys has a fairly narrow band of refractive index. This would require many more alternating DBR layers to provide a decent reflectivity.

In III–phosphide (III–P) VCSELs, a dielectric DBR is used, but this leads to more complex structures, adding to production costs. Dielectric DBRs are also commonly deployed in the III–N VCSELs presently under development. One further drawback of III–N VCSELs is the shorter wavelength of the emitted radiation, which therefore tends to prefer shorter cavities to avoid diffraction effects, impacting performance.

Here we look at the work of two research groups attempting to overcome some of these problems for III–N VCSELs.

Sony

Sony Corporation's researchers in Japan have been working on III–N VCSELs for some time [Tatsushi Hamaguchi et al, Appl. Sci., vol9, p733, 2019].
At the same time, Sony Semiconductor Solutions Corp has a range of products and foundry facilities covering various wavelength ranges: 780~850nm (AlGaAs), 635~680nm (AlGaInP) and 900~980nm (GaInAs).

Sony's GaInN VCSEL research aims to cover the 400–530nm region. The Sony group has focused on

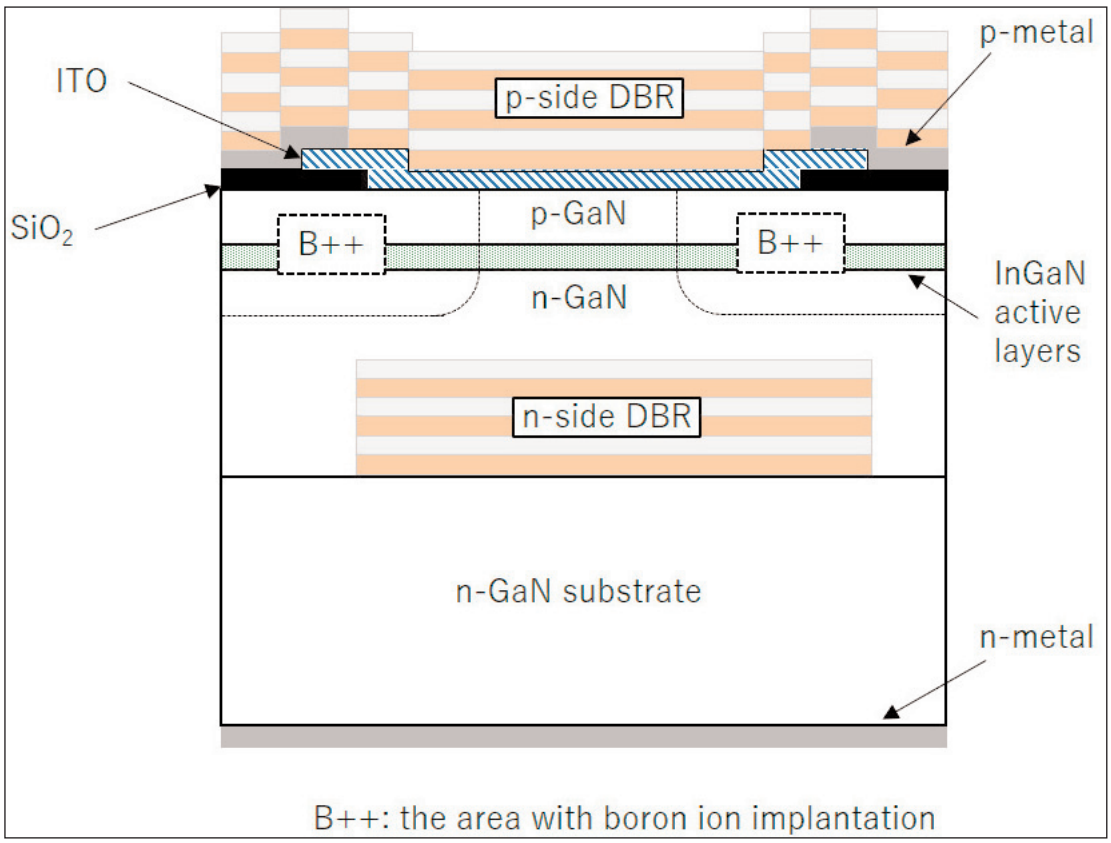


Figure 1. Schematic of all-dielectric DBR GaInN VCSEL in which the bottom reflector is encased in n-GaN using epitaxial lateral overgrowth.

dielectric DBRs. In one piece of work [S. Izumi et al, Appl. Phys. Express, vol8, p062702, 2015], Sony targeted cavity lengths less than 5μm by using epitaxial overgrowth techniques. This involved depositing dielectric on a GaN substrate, and then opening windows in the DBR to seed subsequent growth by metal-organic chemical vapor deposition (MOCVD) — see Figure 1.

A 4.5μm-cavity-length device had a threshold current of 18mA (35.8kA/cm^2 density) and a maximum light output power of 1.1mW. The emission at 20mA was a single longitudinal mode at 453.9nm wavelength. Below threshold there was a series of peaks separated by 6.7nm, consistent with the cavity length of 4.5μm.

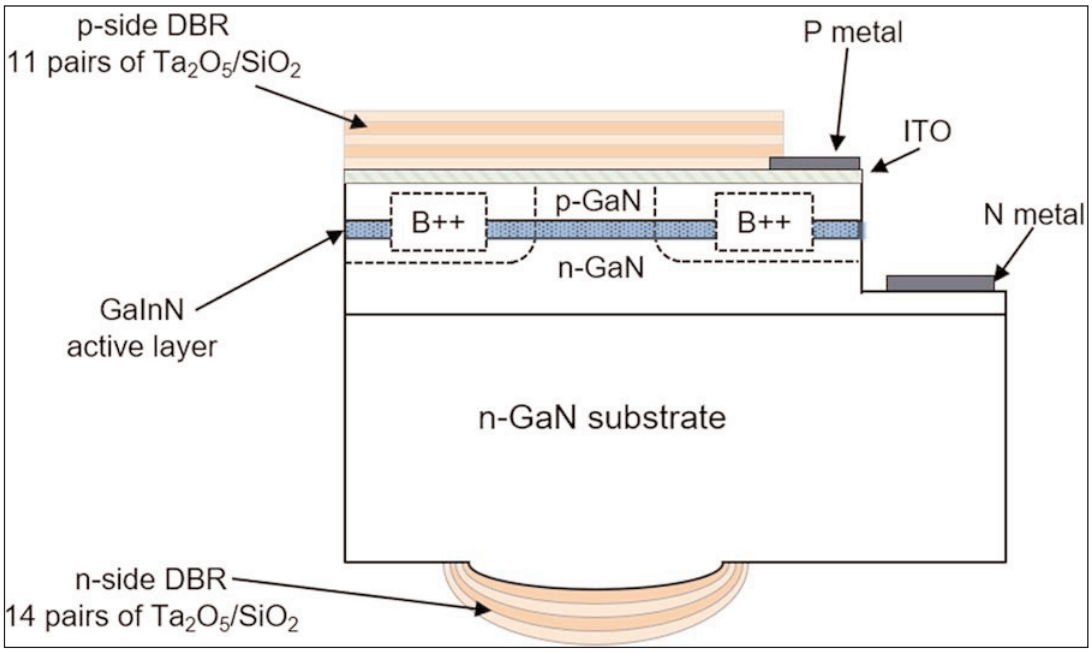


Figure 2. Schematic of VCSEL with curved back-mirror.

Curved mirror

The Sony team also more recently has claimed the lowest threshold current recorded for a GaInN-based blue VCSEL [Tatsushi Hamaguchi et al, Appl. Phys. Express vol12, p044004, 2019].

The researchers say that their achievement was enabled by lateral optical confinement by incorporation of a curved mirror in the vertical cavity structure. The team adds: "According to classical Gaussian optics, the current aperture can theoretically be as small as the diffraction limit, i.e. the order of the light wavelength, which suggests that further miniaturization and reduction of GaN-based VCSELs with curved mirrors could be achieved."

A low threshold was enabled by reducing the current aperture to 3μm. The lateral confinement of the curved mirror reduced the beam waist to 1.3μm on the top planar mirror (Figure 2).

The epitaxial material was grown on a {0001} GaN substrate. The active light-generating region was a GaInN quantum well structure sandwiched between n- and p-type GaN contacts.

Fabrication on the top-side of the wafer added layers of transparent indium tin oxide (ITO) conductor and a DBR constructed from 11.5 tantalum pentoxide/silicon dioxide (Ta_2O_5/SiO_2) pairs.

Boron (B^{++}) implantation restricted current flow to a 3μm-diameter aperture. The metal electrodes on the ITO and n-GaN consisted of titanium/platinum/gold.

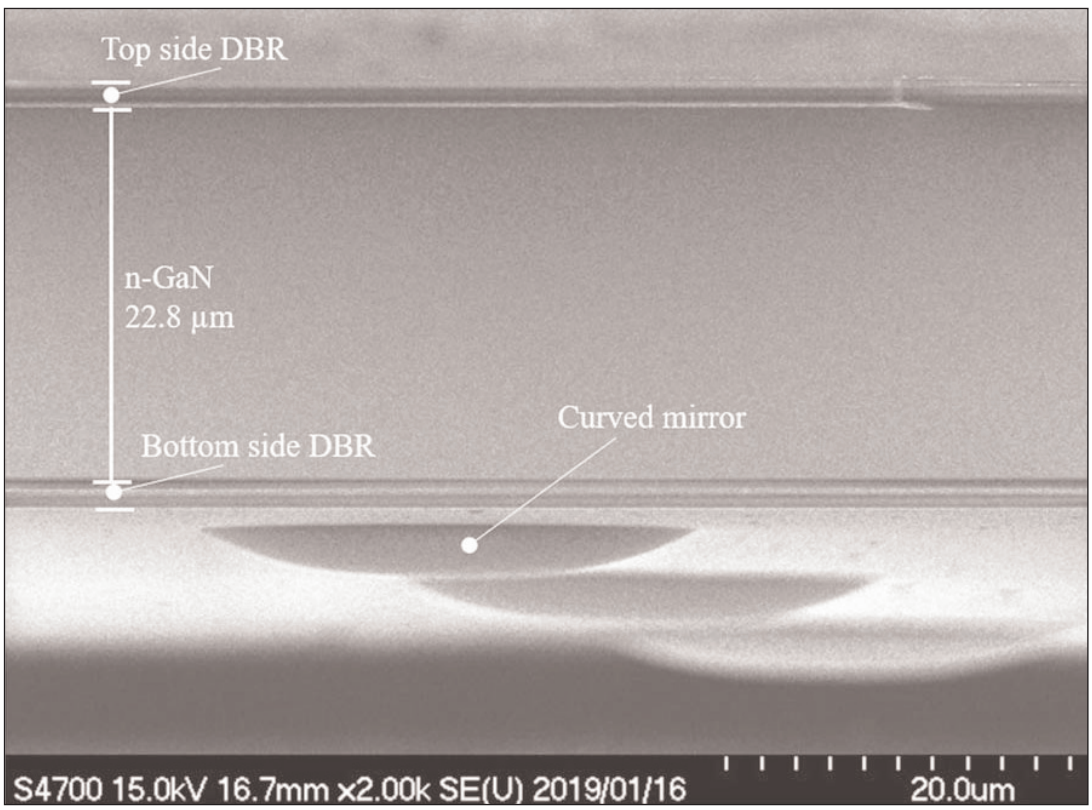


Figure 3. Cross-sectional scanning electron micrograph of device.

The back-side fabrication consisted of substrate thinning to less than 50μm thick, followed by reactive ion etch to form a curved mirror structure (Figure 3). The device was completed by vacuum deposition of 14 Ta_2O_5/SiO_2 pairs to form a curved DBR back-side reflector.

The threshold for continuous-wave lasing came at 0.25mA current (3.5kA/cm^2 density). This value was lower than the researchers' previous achievement of 40mA in a pulsed injection set up. Normally, pulsed injection leads to lower thresholds than continuous-wave operation due to self-heating effects in the latter case.

The improvement in the latest device is variously attributed to factors such as "reduction in the ITO layer thickness and number of quantum wells". The group's previous device had four wells — this was reduced to three in the latest VCSEL. The ITO thickness was decreased from 30nm to 20nm.

The dominant peak had a blue wavelength of 445.3nm (λ). The peak width was at the 0.1nm order of resolution of the spectral analyzer. Other peaks came at 1.27nm separation in wavelength, consistent with a 27μm cavity length based on a refractive index of 2.45 (n) with –0.001/nm variation in wavelength (dn/dλ).

Nanoporous DBR

An approach that results in workable conducting DBRs has been developed by University of New Mexico and Sandia National Laboratories in the USA using nanoporous GaN to achieve refractive index contrast [Saadat M. Mishkat-Ul-Masabih et al, Appl. Phys. Express, vol12, p036504, 2019]. The team claims the first electrically injected non-polar m-plane GaN-based VCSELs with conducting lattice-matched nanoporous bottom DBRs (Figure 4). Optically pumped m-plane GaN VCSELs with nanoporous DBRs had been previously reported by the group, and others have presented c-plane devices.

The epitaxial structure was grown on non-polar m-plane freestanding GaN substrates from Mitsubishi Chemical, processed using metal-organic chemical vapor deposition. The active light-emitting region consisted of six InGaN quantum wells. Electron leakage into the p-type region was blocked by an AlGaN electron-blocking layer (EBL) barrier.

Mesa etching with inductively coupled plasma exposed the n^+-GaN contact layer. A titanium/gold mask was used to define the current aperture that was then created by aluminium ion implantation at Leonard Kroko Inc. The implant mask was removed and a second mesa etched to a depth of 400nm was followed by blanket deposition of 150nm silicon dioxide protection of the epitaxial structure during DBR porosification.

Deep trenches were then etched in the c-direction to expose the bottom DBR sidewalls. An electro-chemical process selectively etched the n^+-GaN layers of the bottom DBR structure to porosify the layer, reducing its refractive index. The DBR consisted of 16 pairs of 41nm/60nm undoped-/n^+-doped GaN. The refractive index difference of the resulting layers was around 0.83.

The blanket silicon dioxide was removed and silicon nitride passivation applied to the active region sidewalls of the first mesa. The top contact structure included 50nm annealed transparent ITO conductor. The metal contacts consisted of titanium/gold and titanium/aluminium/nickel/gold, respectively, for the p- and n-electrodes. The device was completed with a dielectric DBR constructed from quarter-wavelength pairs of silicon dioxide and silicon nitride (SiO_2/SiN_x) on a silicon nitride cavity spacer. The optical thickness of the cavity was designed to be eight wavelengths.

The team reports: "The layer thicknesses were designed to ensure that the active region of the device aligned with a peak and that the ITO aligned with a null of the standing wave profile in the cavity to maximize gain and minimize optical loss."

Pulsed measurements of 50ns width and 0.05% duty cycle were used to characterize the devices (Figure 5).

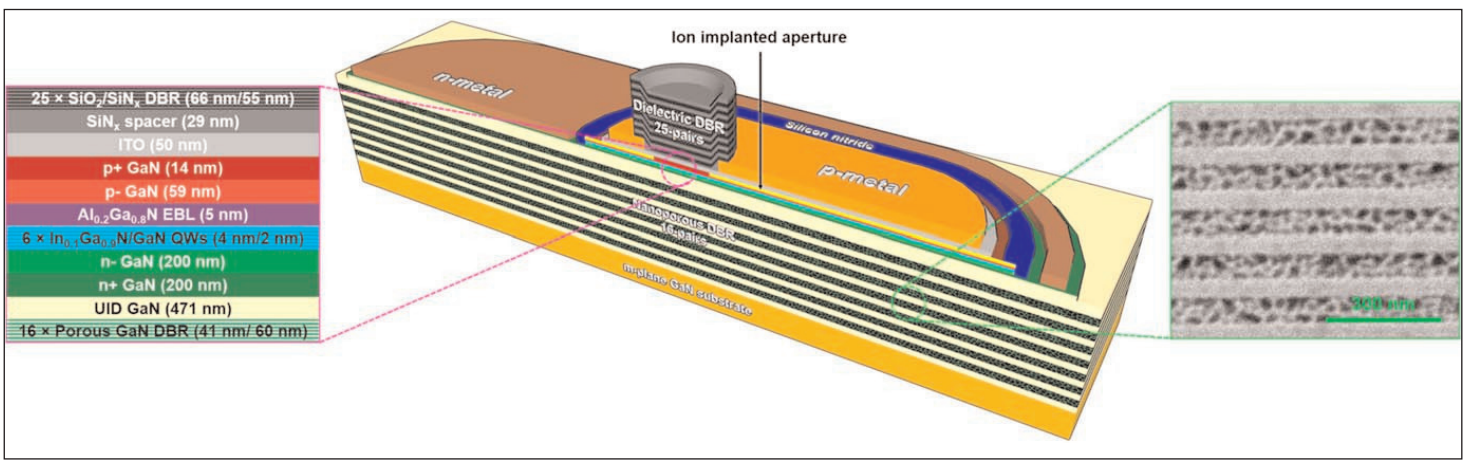


Figure 4. Cross-sectional schematic of m-plane nanoporous VCSEL and scanning electron micrograph of bottom nanoporous DBR.

Pulsed operation avoids self-heating that results in performance degradation. The threshold current density of a device with 20μm-diameter aperture was ~20kA/cm^2. The corresponding voltage was 9.6V. The top DBR had a reflectivity of 99.7%. From the fraction of light emitted from the top and bottom of the device, the researchers estimated the bottom DBR's reflectivity at 99.9%. The maximum output power was around 1.5mW — "higher than any previously reported m-plane GaN-based VCSEL," according to the team.

At twice the threshold current injection the longitudinal mode peak was at 408.7nm with a full-width at half-maximum (FWHM) of ~0.6nm. A secondary peak was seen at 409.1nm, but this is not thought to be from a higher-order mode since the expected spacing based on the cavity length was expected to be about 25.5nm. The researchers comment: "Our previous results indicate that non-uniformities in the optical cavity length due to localized changes in the effective refractive index of the nanoporous layers can lead to locally different single-longitudinal modes with the same mode number but different wavelengths, which could result in multiple peaks within the lasing spectrum."

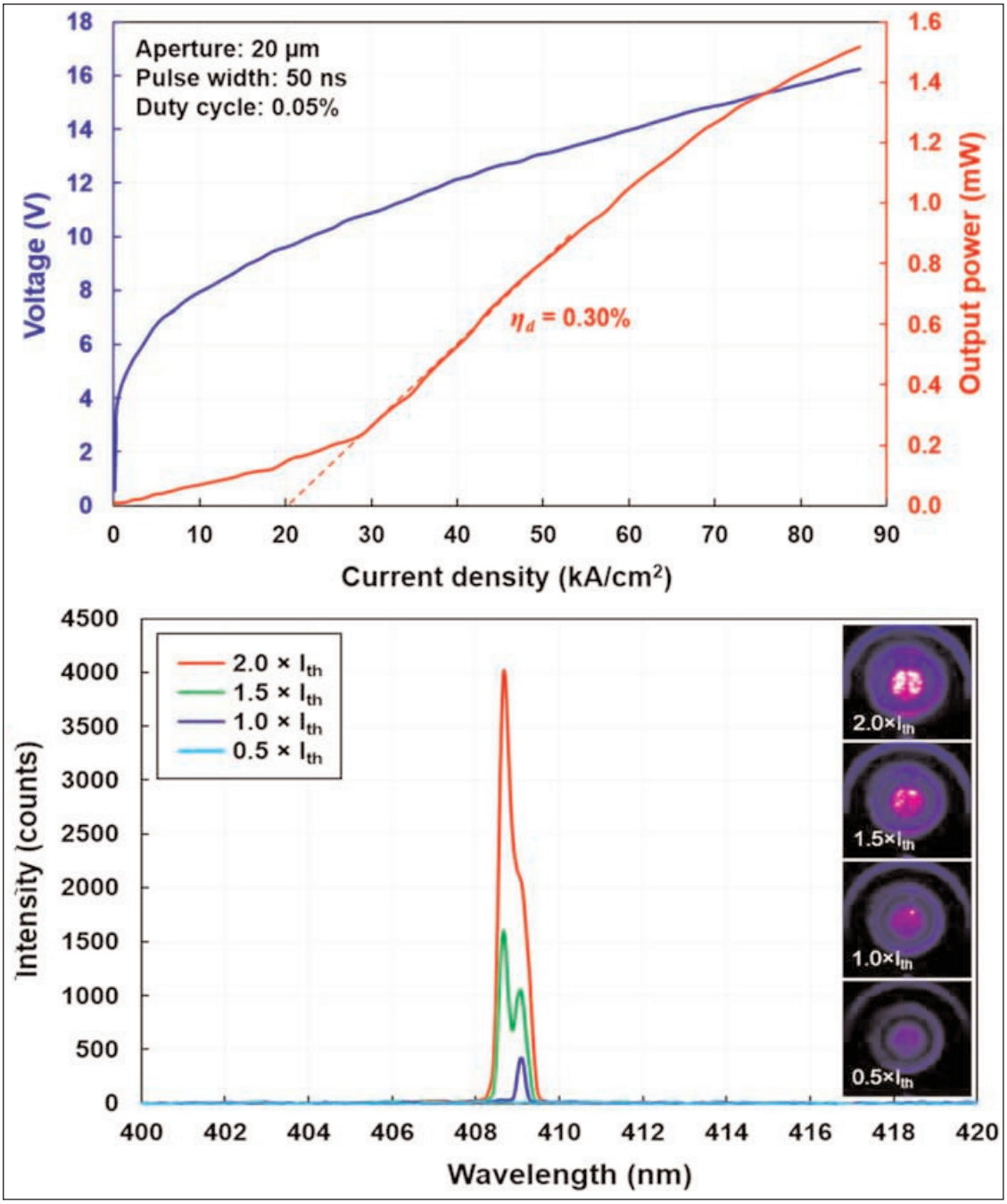


Figure 5. (a) Light output power-current density-voltage plot of 20μm-diameter nanoporous VCSEL under pulsed operation. (b) Emission spectrum under various pump currents and corresponding near-field images of aperture region.

Lasing filaments — 'spots' as seen in near-field images — with different wavelength emissions, are commonly observed in III–N VCSELs. Apart from filamentary non-uniformities, the researchers also saw a discrete divide across the aperture for the emission at twice the threshold. This was seen as being due to "the intersection of the nanopore etching fronts from the positive and negative a-directions forming a break in the aperture". The team hopes that moving the location of the aperture or pore etching from the c-direction could solve this issue.

The polarization of the light was around 94% with the maximum intensity measured when the polarizer angle was perpendicular to the [0001] c-direction — i.e. the polarization was along the [1$\bar{2}$10] a-direction.

In temperature-dependent measurements up to 333K, the characteristic temperature of the threshold current (T_0) was high at 357K. The researchers hope that reduced thresholds will result from use of a tunnel junction rather than ITO contact with the p-GaN hole injector in future devices. ■

Author: Mike Cooke

Eliminating waveguide propagation from III–nitride light-emitting diodes

Researchers seek enhanced photon extraction from ultrathin vertical devices.

Nanjing University of Posts and Telecommunications in China have been experimenting with ultrathin vertical III-nitride light-emitting diodes (LEDs) with a view to enhancing light extraction [Yongjin Wang et al, Appl. Phys. Express, vol12 (2019) 046503].

Thicker III–nitride LEDs tend to trap emitted light into in-plane waveguide mode propagation due to the large refractive index of gallium nitride (GaN) compared with air. The contrast in refractive index narrows the escape cone, meaning light can be trapped by severe-to-total internal reflections at the air/semiconductor interfaces. Thinning the LED should eliminate waveguide modes, forcing light out of the structure.

The transferred thin-film epitaxial material comprised 2200nm of n-AlGaN, 108nm of multiple quantum wells, and 90nm of p-GaN. The material was bonded p-side down on a 2-inch conductive silicon wafer (Figure 1). The metal bonding layers consisted of a nickel/silver p-electrode/reflector and nickel/tin adhesion layers.

The bonded structure was then subjected to inductively coupled plasma etch to reduce the film thickness to around 225nm. Selective etching down to the silver metal with masked areas was then used to define device mesas. More masking was used to create nickel/gold p- and n-electrodes.

The researchers arranged 4 18μmx155μm waveguides on the wafer to enable the assessment of in-plane propagation of emitted radiation. The LEDs could also act as photodiode (PD) detectors. Some of the LEDs were arranged 12μm away from the end of the waveguide end-facet as photodiode monitors.

The dominant output peak wavelength varied between 413.8nm and 411.8nm, respectively, as the forward voltage increased from 3.4V to 4.2V. These wavelengths are in the visible violet range of 380–450nm.

Reflectance measurements on LEDs with 225nm and 1430nm epitaxial layers suggested that the reflectivity of the nickel/silver mirror electrode was greater than 85% over a wide angle range.

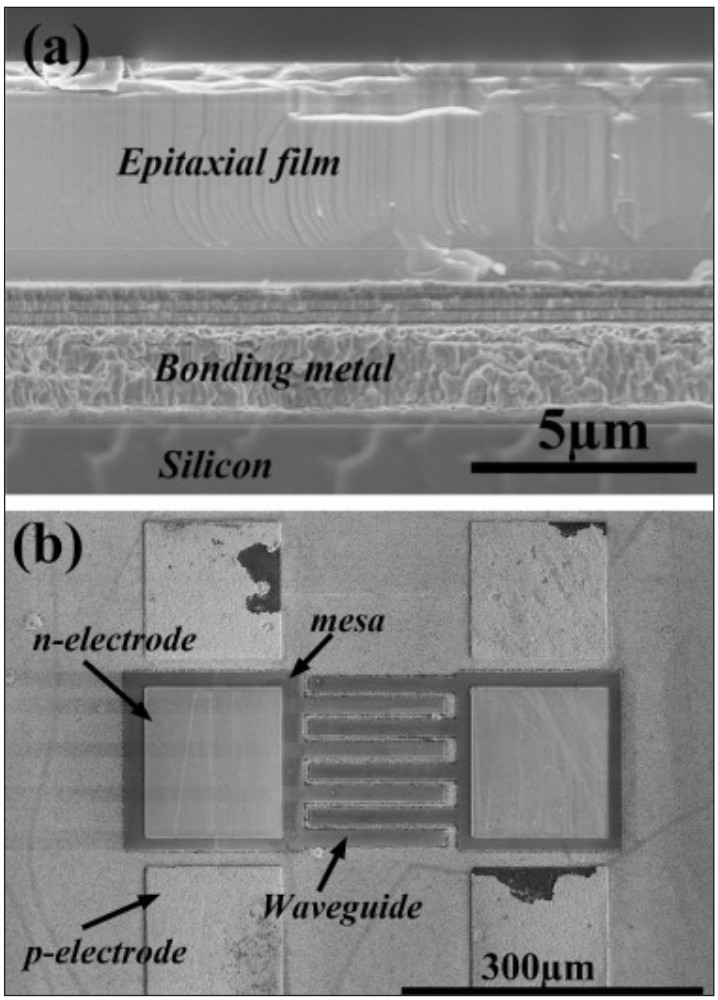


Figure 1. (a) Cross-sectional scanning electron microscope (SEM) image of III–nitride epitaxial films. (b) Plan-view SEM image of fabricated LEDs.

The use of a thin epitaxial layer of 225nm thickness eliminated waveguide modes and enhanced light extraction. Comparison between 225nm-thick and 1430nm-thick LEDs showed a lack of light emanating from the end facets of the waveguides in the former device (Figure 2), unlike in the thicker construction. ■

https://iopscience.iop.org/article/10.7567/1882-0786/ab0664

Author: Mike Cooke

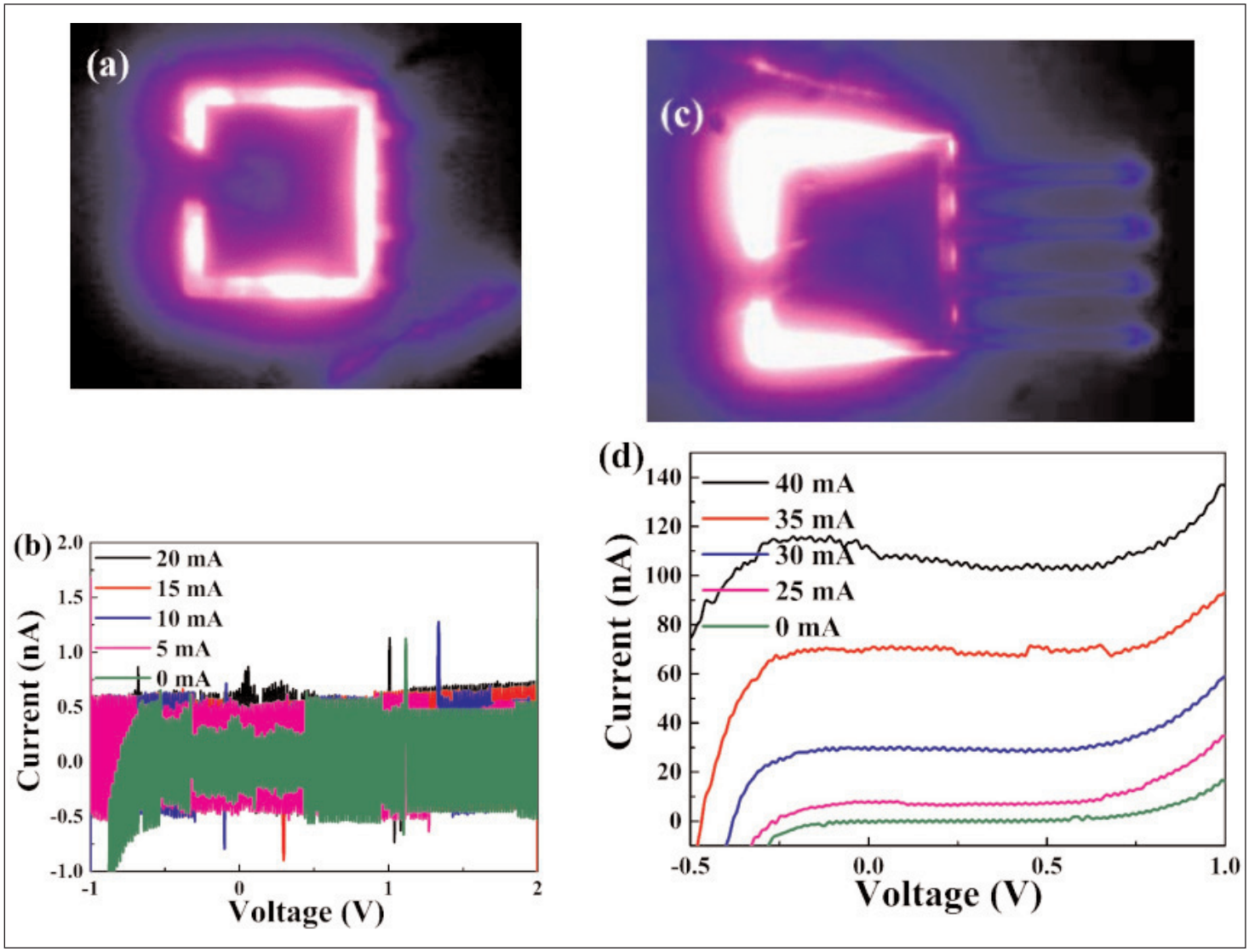


Figure 2. (a) Light emission image of 225nm-thick LED. (b) Measured current (mostly noise) of photodiode as function of LED injection current. (c) Light emission from 1430nm-thick LED. (d) Measured photocurrent of 1430nm structure.

Gallium-doped zinc oxide transparent conductor for gallium nitride LEDs

Reduced strain in active region increases light output power and reduces forward voltage, improving efficiency.

Gwangju Institute of Science and Technology in South Korea has used a gallium-doped zinc oxide (ZnO) transparent conducting layer (TCL) to enhance the performance of indium gallium nitride (InGaN) light-emitting diodes [Sang-Jo Kim et al, Optics Express, vol27, pA458, 2019]. The researchers found that the ZnO TCL reduced strain in the InGaN light-emitting material, increasing light output power and reducing forward voltage, compared with a device using indium tin oxide (ITO) as a TCL.

Another advantage of ZnO over ITO is cost: indium is an expensive rare element. Further concerns about ITO include thermal instability — particularly important in high-power LEDs where junction temperatures tend to be higher. The researchers comment: "Compared with ITO, ZnO boasts the advantages of higher transmittance, lower resistivity, improved temperature stability, lower cost and non-toxicity"

Increasing light output power and reducing forward voltages are key factors in improving the efficiency of LEDs. InGaN LEDs are widely deployed in liquid-crystal display backlight units, full-color displays, automotive lighting, and general illumination.

C-plane sapphire served as substrate for the metal-organic chemical vapor deposition (MOCVD) L ED structure (Figure 1). The InGaN/GaN quantum well active region was designed for a 460nm emission wavelength.

Fabrication began with mesa etching to expose the buried n-GaN contact layer. The Ga-doped ZnO TCL was grown by 650°C MOCVD on the p-GaN, using diethylzinc, oxygen and triethylgallium. Annealing at 700°C removed $ZnGa_2O_4$ interface inclusions that increase series resistance. The structure was etched with hydrochloric acid solution to clear the pad areas of ZnO. Contact electrodes for both and p- and n-sides of the device consisted of titanium/gold.

Raman spectroscopy indicated that increasingly thick ZnO layers relaxed the compressive strain of the active layers. The estimates for biaxial strain from the Raman-shift measurements were –6.76%, –5.67% and –4.57%, for ZnO layers of 0nm (LED A with 180nm ITO TCL), 180nm (B) and 500nm (C), respectively. Relaxing the compressive strain blue-shifted the emitted radiation wavelength peak in photoluminescence (PL) experiments from 464.1nm

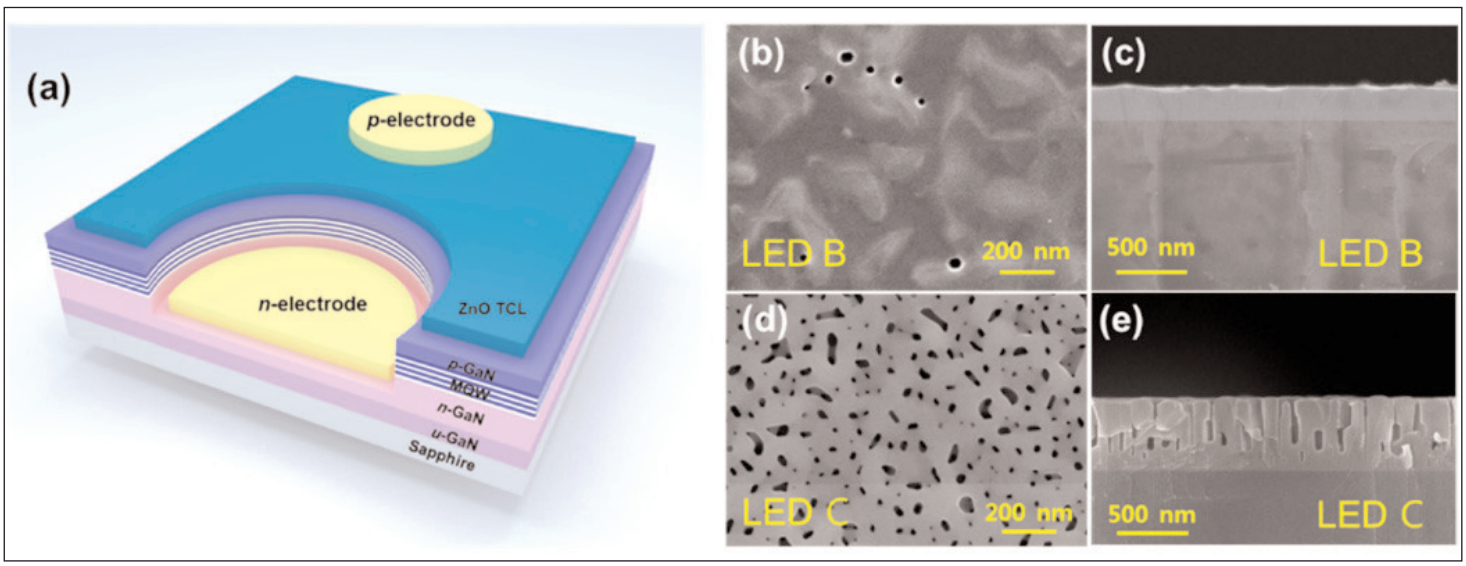


Figure 1. (a) Schematic of LED with Ga-doped ZnO TCL. Top-view and cross-sectional scanning electron microscope images of ZnO TCLs with thicknesses of: (b), (c) 180nm (LED B) and (d), (e) 500nm (LED C).

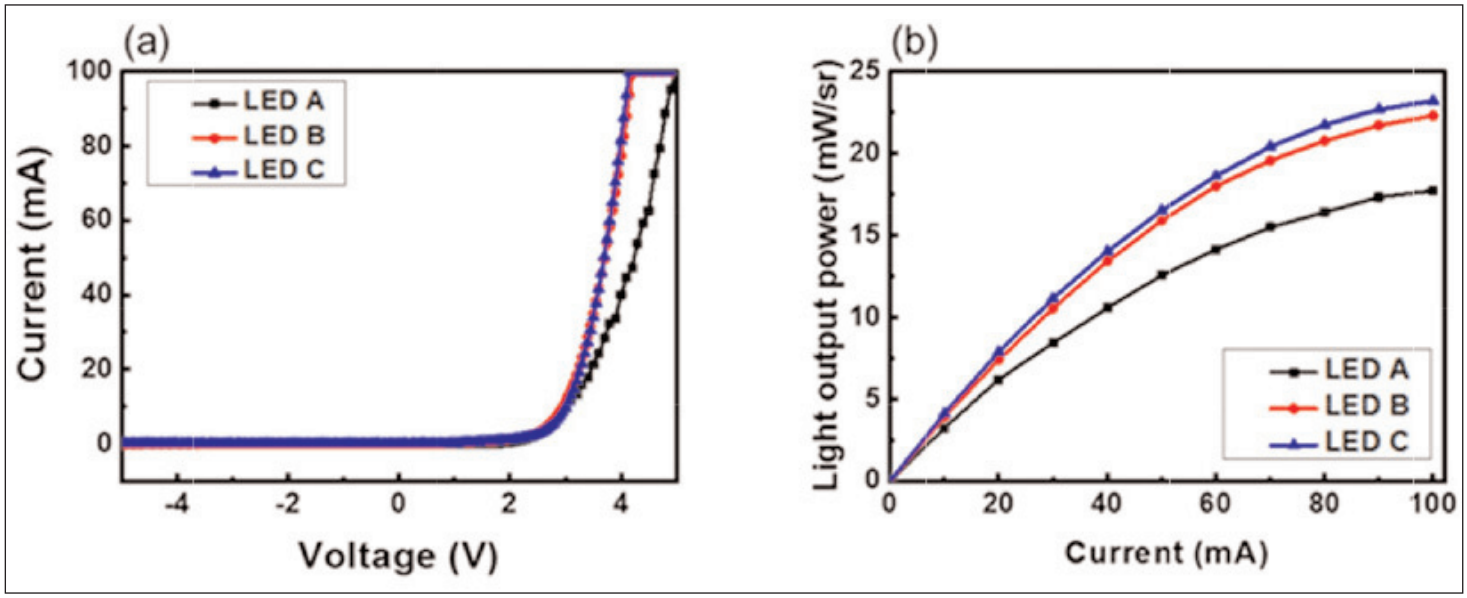


Figure 2. (a) Current–voltage characteristics and (b) optical output power of LEDs A, B and C.

down to 456.9nm. At the same time the estimated internal quantum efficiency (IQE) increased by up to 16.5%.

The researchers comment: "The blue-shift of PL peak and enhanced IQE are attributed to the increased radiative recombination rates caused by the increased overlap of electron and hole wavefunctions owing to the reduced quantum-confined Stark effect (QCSE) in the active region of LED B and C compared with that of LED A".

The QCSE is an energy-level shift arising from the induced electric field in III–nitride structures due to charge polarization of the chemical bonds, which is strongly affected by lattice strain. The electric field also inhibits recombination of the electrons and hole by pulling them apart.

Under electrical bias, the peak wavelengths of the LEDs converged to between 445nm and 454nm at 100mA injection. At 10mA injection, LED A's peak was at 460.3nm, and that of LED C at 455.7nm. The convergence of LED A with a blue-shift of 6.13nm from 10mA injection was due to injected carriers screening the piezoelectric field and filling up the conduction band. LEDs B and C registered far smaller shifts of 1.99nm and 1.93nm, respectively. The smaller shift in B and C reflected the reduced piezoelectric fields due to less strain.

The light output power at 100mA was increased for LEDs B and C by 26.9% and 30.9%, respectively, over LED A's performance (Figure 2). The improvement was attributed to increased radiative recombination due to reduced strain, and enhanced light extraction from the higher refractive index of ZnO compared with ITO. The output power was maintained in repeated experiments over a five-day period.

The electrical performance gave the forward voltage at 20mA as 3.42V, 3.23V and 3.28V for LEDs A–C in order. The lower voltages for B and C indicate reduced power consumption. The researchers attribute the lower voltages to lower resistance of the ZnO TCL, resulting from higher carrier concentration and mobility.

While the TCL of LED C had a higher carrier concentration (2.87×10^{20}/cm^3) than LED B (2.31×10^{19}/cm^3), the mobility order was reversed — 32.8cm^2/V-s for LED B and 23.7cm^2/V-s for C. The carrier density and mobility for LED A were 1.64×10^{19}/cm^3 and 6.07cm^2/V-s. The resistivity of the TCL materials for A–C were, in order, $3.1\times10^{-4}\Omega$-cm, $5.3\times10^{4}\Omega$-cm and $5.2\times10^{4}\Omega$-cm. ■

https://doi.org/10.1364/OE.27.00A458

Author: Mike Cooke

Yellow light-emitting diodes with high wall-plug efficiency

Researchers use device to create color-mixing module with a 2941K correlated color temperature and a 97.5Ra color-rendering index.

Nanchang University and Nanchang Yellow Green Lighting Company Limited in China have claimed a 'breakthrough' in filling the 'yellow gap' through the development of high-indium-content indium gallium nitride (InGaN) light-emitting diodes [Fengyi Jiang et al, Photonics Research, vol7, p144, 2019]. The researchers achieved wall-plug efficiencies (WPEs) of 24.3% at 20A/cm^2 current injection for 565nm light. At a lower injection of 3A/cm^2, the WPE peaked at 33.7%.

The researchers comment: "The success of yellow LEDs can be credited to the improved material quality and reduced compressive strain of InGaN quantum wells by a pre-strained layer and substrate, as well as enhanced hole injection by a 3D pn junction with V-pits."

Yellow light falls roughly in the wavelength range 560–590nm. While the long (red) and short (violet, blue, cyan, green) sectors of the visible spectrum are relatively well served by light-emitting semiconductors, the central portion (yellow, orange) is difficult to reach with efficient devices.

The long-wavelength LEDs use alloys of aluminium indium gallium arsenide phosphide (AlInGaAsP), while the shorter wavelengths are covered by III–nitrides. However, the efficiency of both these systems drops dramatically as they encroach on the compositions needed for the central part of the visible spectrum.

The researchers used a home-made metal-organic chemical vapor deposition (MOCVD) reactor to apply III–N epitaxial layers to a silicon (111) substrate (Figure 1). The (111) crystal orientation presents a hexagonal template that most closely matches that of III–nitride materials. Even so, there is a large ~17% mismatch in lattice parameters that can lead to threading dislocations and cracked material due to stress. Silicon is attractive as a substrate due to its much lower costs compared with sapphire, silicon carbide, or bulk/freestanding GaN.

The bottom n-GaN contact layer was grown on 100nm high-temperature AlN buffer. The n-GaN contact material began with three-dimensional islands with the aim of mitigating lattice strain before recovery layer growth and coalescence.

A superlattice (SL) of 32 pairs of 5nm/2nm $In_{0.1}Ga_{0.9}N$/GaN was designed to release strain and generate V-pits at dislocation sites. The researchers see the V-pits as a positive for device performance: "Carrier transportation of an LED with V-pits is totally different from that of planar pn junction, which should be considered three dimensionally. Simulation and experimental results show that V-pits can help to enhance hole injection from V-pit sidewalls, as the effective barrier from the sidewall of V-pits is lower than that from the flat multiple quantum wells (MQWs) for holes."

The MQW structure used a series of temperature and material steps: a 780°C 0.5nm GaN pre-layer, 2.5nm $In_{0.3}Ga_{0.7}N$ well, 2nmGaN protective cap, and 950°C 11nm GaN barrier. The sequence was repeated to give

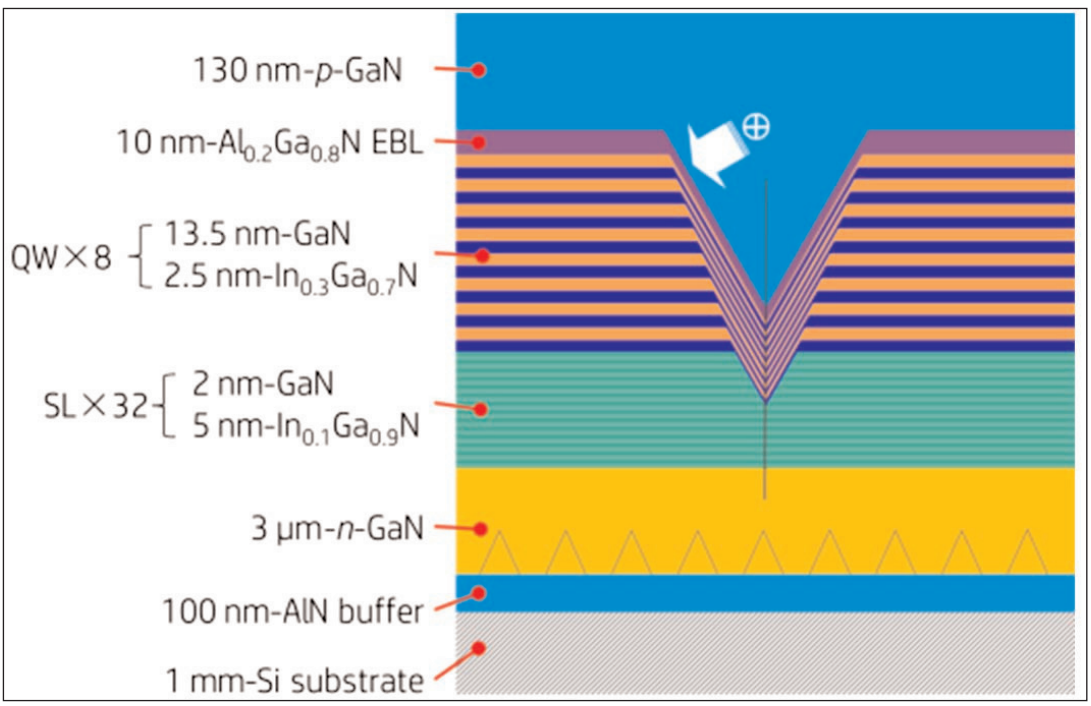


Figure 1. Epitaxial structure of InGaN yellow LED grown on silicon substrate.

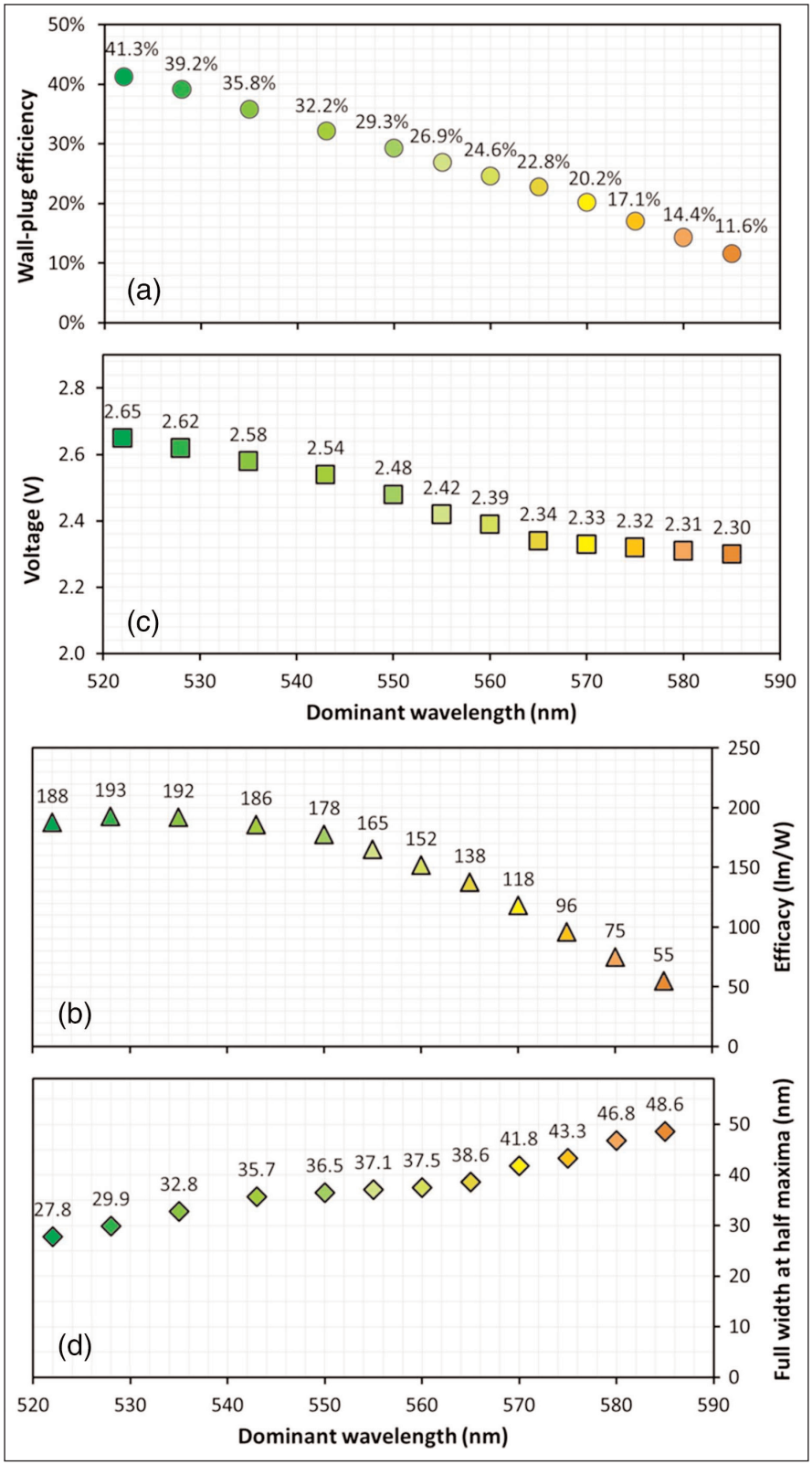


Figure 2. Dependence of (a) WPE, (b) efficacy, (c) voltage and (d) spectral full-width at half maximum on wavelength for InGaN-based LEDs on Si substrate from green to orange emission range.

an 8-period MQW light-emitting region. Most of the layers were slightly doped with silicon to give n-type conduction with a view to reducing the forward voltage of the final device. Only the last barrier layer was undoped. The V-pits were around 150nm deep after the MQW growth.

The structure was completed with a 10nm AlGaN electron-blocking layer (EBL), 50nm of p-GaN, a V-pit recovery/fill layer, and a 20nm p-GaN contact layer. These layers, including the EBL, were variously doped with magnesium.

The epitaxial material was fabricated into vertical thin-film LEDs. The back-side of the 1mmx1mm devices included a silver reflector layer. Wall-plug efficiency (WPE) reached a peak of 33.7% with 3A/cm^2 current density injection. The dominant output wavelength was 574nm. The light output power of the device was 21.2mW with a forward voltage of 2.10V. The external quantum efficiency (EQE) was 32.7% with 192lm/W luminous efficacy. The photon energy was 2.16eV, on average, higher than that acquired from the forward voltage. The researchers speculate that carrier thermal energy effects may contribute to the photon energy.

The device suffered a 28% efficiency droop in moving to a higher current density of 20A/cm^2. The WPE dropped to 24.3% and the EQE to 26.4%. Even so, the WPE value of 24.3% is claimed to be a record for 565nm wavelength. The wavelength, light output power, forward voltage and luminous efficacy were 565nm, 116mW, 2.39V and 149lm/W, respectively. The efficiency droop was more precipitous compared with the respective 10% and 20% values for blue and green LEDs. "The severer efficiency droop for yellow LEDs could be attributed to the stronger piezoelectric field existing in the QWs," the team comments.

The devices are the latest in a sequence of LEDs with different emission wavelengths (Figure 2). The continuous-wave WPE was 41.3% at 522nm wavelength, falling to 11.6% at 585nm. Luminous efficacy, which includes a factor for eye sensitivity with wavelength, had a peak value at 193lm/W at 528nm. Eye sensitivity peaks at 555nm, where the efficacy was 165lm/W.

The researchers have combined blue, cyan, green and yellow InGaN LEDs and red AlGaInP LEDs in a color-mixing module. With 20A/cm^2 injection the color coordinates coincided with the 'Planckian' locus with 2941K correlated color temperature. The color-rendering indices were 97.5Ra (96.2R9). The efficacy was 121.3lm/W. The researchers report that the module is already being commercialized. ■

https://doi.org/10.1364/PRJ.7.000144

Author: Mike Cooke

Fraunhofer IAF enhances functionality of GaN power ICs with integrated sensors

Monolithic integration of power components with sensors and control circuit saves space, reduces assembly and improves reliability.

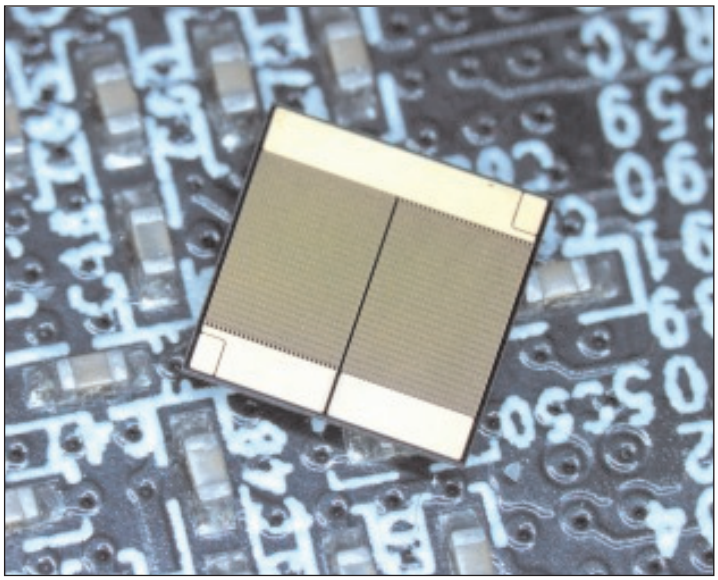
Fraunhofer Institute for Applied Solid State Physics (IAF) of Freiburg, Germany says that it has significantly enhanced the functionality of gallium nitride (GaN) power ICs for voltage converters by integrating current and temperature sensors onto a GaN-based chip, along with power transistors, free-wheeling diodes and gate drivers. The development could pave the way for more compact and efficient on-board chargers in electric vehicles.

For vehicles with electric drive to become a lasting presence in society, there needs to be greater flexibility in charging options, says Fraunhofer IAF. To make use of charging stations using alternating current, wall charging stations or conventional plug sockets where possible, users are dependent on on-board chargers. As this charging technology is carried in the vehicle, it must be as small and lightweight as possible, and also cost-efficient. It therefore requires extremely compact yet efficient power electronics systems such as voltage converters.

Several components on a single chip

Fraunhofer IAF has been conducting research on monolithic integration in power electronics for several years. This requires several components such as power components, the control circuit and sensors to be combined on a single chip. The concept makes use of gallium nitride. In 2014, Fraunhofer IAF integrated intrinsic freewheeling diodes and gate drivers on a 600V-class power transistor. In 2017, a monolithic GaN half-bridge was then operated at 400V for the first time.

The latest research results combine current and temperature sensors and 600V-class power transistors with intrinsic freewheeling diodes and gate drivers in a GaN power IC for the first time. As part of the project GaNIAL ('Integrated and efficient power electronics based on gallium nitride'), the researchers have provided functional verification of full functionality in a GaN power IC, achieving what is reckoned to be a breakthrough in the integration density of power electronics systems. "By additionally integrating sensors on the GaN chip, we have succeeded in significantly enhancing the functionality of our GaN technology for power electronics," says GaNIAL's project manager Dr Patrick Waltereit, deputy head of the Power Electronics business unit at Fraunhofer IAF.



The GaNIAL project is funded by Germany's Federal Ministry of Education and Research (BMBF). Since 2016, this collaboration between Fraunhofer IAF and the BMW Group, Robert Bosch GmbH, Finepower GmbH and the University of Stuttgart has been working to develop powerful, compact GaN-based components for electromobility.

Integrated sensors for direct control

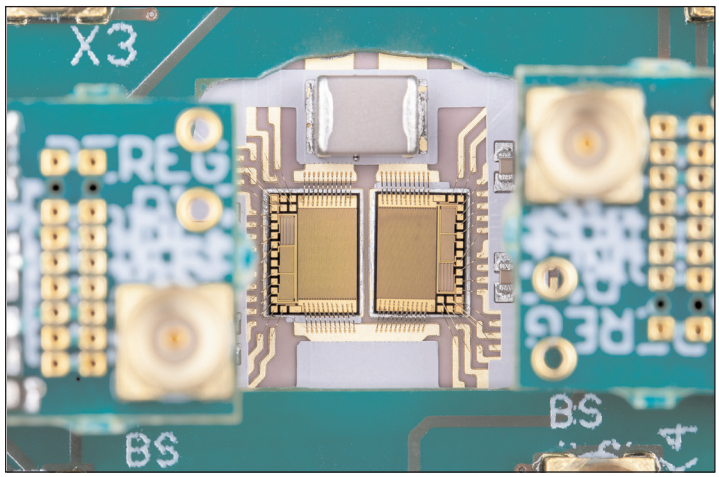
Compared with conventional voltage converters, the new circuit simultaneously not only enables higher switching frequencies and a higher power density but also provides for fast and accurate condition monitoring within the chip itself. "Although the increased switching frequency of GaN-based power electronics allows for increasingly compact designs, this results in a greater requirement for their monitoring and control," says Stefan Mönch, a researcher in the Power Electronics business unit. "This means that having sensors integrated within the same chip is a considerable advantage."

Previously, current and temperature sensors were implemented externally to the GaN chip. The integrated current sensor now enables feedback-free measurement of the transistor current for closed-loop control and short-circuit protection, and saves space compared to the customary external current sensors. The integrated temperature sensor enables direct measurement of the temperature of the power transistor, mapping this thermally critical point considerably faster and more accurately than previous external sensors, as the distance and resulting temperature difference between the sensor and the point of measurement is eliminated by the monolithic integration.

"The monolithic integration of the GaN power electronics with sensors and control circuit saves space on the chip surface, reduces the outlay on assembly and improves reliability," says Mönch, who designed the integrated circuit for the GaN chip. "For applications that require lots of very small, efficient systems to be installed in limited space, such as in electromobility, this is crucial," he adds. Measuring just 4mm x 3mm, the GaN chip is the basis for the further development of more compact on-board chargers.

Exploiting GaN's unique characteristic

For the monolithic integration, the research team utilized the gallium nitride deposited on a silicon substrate. The unique characteristic of GaN-on-Si power electronics is the lateral nature of the material: the current flows parallel to the surface of the chip, so all connections are located on the top of the chip and connected via conductor paths. This lateral structure of the GaN components allows for the monolithic integration of several components, such as transistors, drivers, diodes and sensors, on a single chip.



GaN power ICs with integrated transistors, gate drivers, diodes and current and temperature sensors for condition monitoring.

"Gallium nitride has a further crucial market advantage compared to other wide-bandgap semiconductors, such as silicon carbide: GaN can be deposited on cost-efficient, large-area silicon substrates, making it suitable for industrial applications," says Mönch.

Presentation at PCIM Europe

Project partner Finepower GmbH displayed the new GaN power module at PCIM (Power Conversion Intelligent Motion) Europe 2019 in Nuremberg, Germany (7–9 May). Researchers from Fraunhofer IAF are unveiling their latest research results and developments in power electronics at the accompanying conference. ■

www.mesago.de/en/PCIM/main.htm
www.iaf.fraunhofer.de/en/researchers/electronic-circuits/power-electronics/Ganial.html

Power Electronics 2020+ project to grow lattice-matched ScAlN on GaN for transistors with very high voltages and current-carrying capacity

Freiburg-based research shows how combining GaN and ScAlN can double output power while reducing energy demand.

As the demand for increasingly compact and efficient power electronic systems grows and as incumbent electronic components based on silicon will in the foreseeable future no longer be able to meet the increasing industrial requirements, the university of Freiburg, the Sustainability Center Freiburg and the Fraunhofer-Gesellschaft have joined forces to explore a new material structure that may be better suited for future power electronics.

The recently launched project 'Research of Functional Semiconductor Structures for Energy Efficient Power Electronics' ('Power Electronics 2020+') is researching the novel semiconductor material scandium aluminum nitride (ScAlN). Professor Oliver Ambacher, director of Fraunhofer Institute for Applied Solid State Physics (IAF) in Freiburg, Germany and professor of power electronics at the Department of Sustainable Systems Engineering (INATECH) of the university of Freiburg, is coordinating the supra-regional collaboration.

Three key factors are responsible for the strong growth of the electronics market: the automation and digitalization of the industry, the increasing awareness of ecological responsibility, and sustainable processes. Power consumption can only be reduced if electronic systems become more energy- and resource-efficient while they simultaneously become more powerful.

Silicon technology reaches physical limit

With its relative low cost and an almost perfect crystal structure, silicon dominates the electronics industry, especially because its bandgap allows for both a good charge carrier concentration and velocity as well as a good dielectric strength. However, silicon electronics are gradually reaches their physical limit. Especially with regard to the required power density and compactness, silicon power electronic components are insufficient.

Innovative material composition for more power and efficiency

The limitations of silicon technology have already been overcome by the use of gallium nitride (GaN) for power electronics. Compared with silicon, GaN performs better for high voltages, high temperatures and fast switching frequencies. This is accompanied by much higher energy efficiency — with numerous energy-consuming applications, this means a significant reduction in energy consumption. Fraunhofer IAF has been researching GaN for electronic components and systems for many years. With the help of industrial partners, the results of this research work has already been put to commercial use. The project Power Electronics 2020+ will go further in order to once more enhance the energy efficiency and durability of the next generation of electronic systems. For this purpose, a different and novel material will be used: scandium aluminum nitride (ScAlN).

First components based on ScAlN

ScAlN is a piezoelectric semiconductor material with a high dielectric strength which is largely unexplored worldwide with regard to its usability in microelectronic applications. "The fact that scandium aluminum nitride is especially well suited for power electronic components, due to its physical properties, has already been proven," notes Dr Michael Mikulla, project manager for Fraunhofer IAF. The aim of the project is to grow lattice-matched ScAlN on a GaN layer and to use the resulting heterostructures to process transistors with high current-carrying capacity. "Functional semiconductor structures based on materials with a large bandgap — such as scandium aluminum nitride and gallium nitride — allow for transistors with very high voltages and currents," says professor Oliver Ambacher, director of Fraunhofer IAF. "These devices reach a higher power density per chip

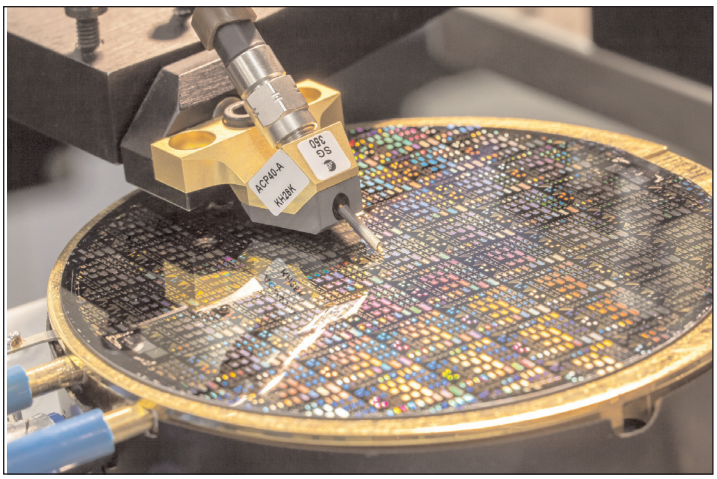
surface as well as higher switching speeds and higher operating temperatures. This is synonymous with lower switching losses, higher energy efficiency and more compact systems," he adds. "By combining both materials, GaN and ScAlN, we want to double the maximal possible output power of our devices while at the same time significantly lowering the energy demand," says Mikulla.

Pioneering work in materials research

One of the biggest challenges of the project is crystal growth, considering that there are so far neither growth recipes nor empirical values for this material. The project team needs to develop these during the coming months in order to reach reproducible results and to produce layer structures that can successfully be used for power electronic applications.

Specialist collaboration and knowledge transfer between Freiburg and Erlangen

The research project will be conducted in close cooperation between the university of Freiburg, Fraunhofer IAF, the Sustainability Center Freiburg as well as the Fraunhofer Institute for Integrated Systems and Device Technology (IISB) in Erlangen, which is a member of the High-Performance Center for Electronic Systems in Erlangen. This new form of collaboration between university research and application-oriented development will serve as a role model for future project cooperation.



Characterization of ScAlN-based high-frequency filters on a wafer. © Fraunhofer IAF

"On the one hand, this model facilitates the cooperation with companies through the prompt transfer of results from basic research to application-oriented development. On the other hand, it opens up synergies between two technically complementary Fraunhofer Centers from two different regions and thus improves both their offers for potential customers of the semiconductor industry," says Ambacher. ■

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Aluminium scandium nitride exhibits ferroelectric behavior

Researchers claim first demonstration for III–V based semiconductor material.

University of Kiel and Fraunhofer Institute for Silicon Technology (ISIT) in Germany claim the first demonstration of ferroelectric behavior in a III–V-based semiconductor [Simon Fichtner et al, J. Appl. Phys., vol125, p114103, 2019].

The researchers used aluminium scandium nitride (AlScN) alloy in their demonstration, but they also believe other group III (group 13 in more modern periodic table notation) elements such as gallium (e.g. GaScN) and group-3 Sc-relative yttrium (e.g. AlYN) could provide materials with ferroelectric behavior. Moving from group 3, the quaternary alloy aluminium magnesium niobium nitride (AlMgNbN) is another contender, they report. Magnesium is group 2 and niobium is group 5.

The team comments: "Ferroelectric switching allowed the first direct experimental observation of the switching of spontaneous polarization in an AlN based material and confirmed that, contrary to most prior theoretical publications, it can reach values larger than 100μC/cm^2."

Ferroelectric materials have a charge polarization that can be switched in direction by an applied electric field. Oxide perovskites, such as lead zirconate titanate (PZT), are commonly studied and used as ferroelectrics, but they suffer from low paraelectric transition temperatures, non-linear displacements, or limited compatibility with silicon CMOS or III–nitride manufacturing.

Classical ferroelectric applications include piezoelectric multi-layer actuator stacks and non-volatile memory cells. However, the team also sees potential for optoelectronics, multiferroic (electrical, magnetic, elastic) composites, and III–nitride electronics.

AlN has the wurtzite crystal structure, in common with other III–nitride semiconductors such as GaN. The charge polarization of the

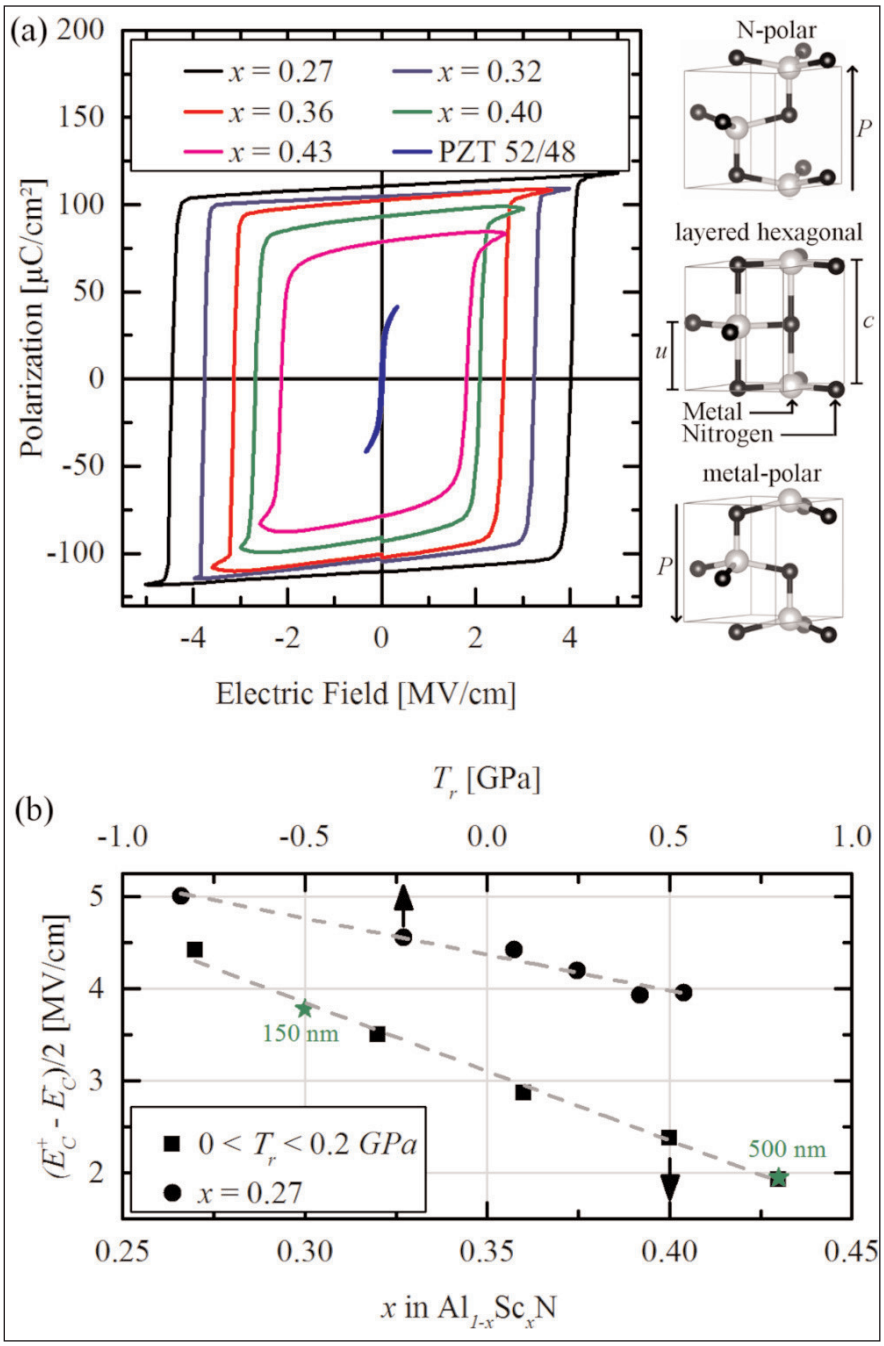

Figure 1. (a) Charge polarization-electric field (P–E) loops of ferroelectric $Al_{1-x}Sc_xN$ as well as of PZT reference. To right, structures associated with respective polarization states. (b) Dependence of mean coercive field on residual stress (T_r) and Sc content.

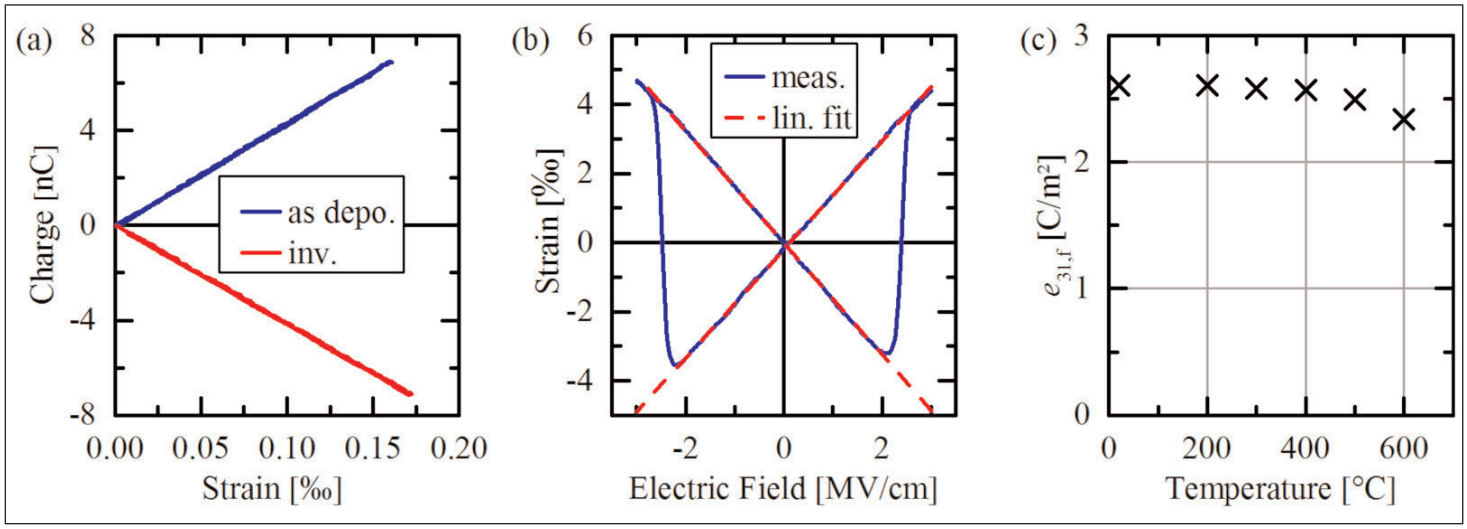

Figure 2. (a) Direct piezoelectric effect: Charge-strain curves of $Al_{0.64}Sc_{0.36}N$ as deposited and after ferroelectric polarization inversion. (b) Converse piezoelectric effect: Longitudinal strain response. (c) Transverse piezoelectric coefficient after polarization inversion and successive temperature treatments without subsequent repolarization.

unit cell is fixed by the relative positions of the component group-III and nitrogen atoms. AlN has strong spontaneous polarization and piezoelectric effects.

Introducing Sc increases the piezoelectric effect while the wurtzite structure is maintained. The researchers explain: "This can be related to a highly metastable layered-hexagonal phase (space group $P6_3/mmc$) in ScN, which in turn flattens the ionic potential energy landscape of, e.g. wurtzite-type $Al_{1-x}Sc_xN$."

The non-polar layered-hexagonal structure offers a transitional form between two polarization orientations of the wurtzite structure. The researchers see lowering the energy barrier between the two polarization states of the wurtzite structure as key to ferroelectric switching in AlScN

Poly-crystalline AlScN films were formed by sputtering onto an AlN on platinum on silicon electrode. All the samples were produced by using dual targets except $Al_{0.64}Sc_{0.36}N$, which used a single AlSc alloy target with 43% Sc content. The nitrogen was supplied as a gas at 15 standard cubic centimeters per minute, along with 7.5sccm argon. The substrate temperature was 400°C. A top electrode of platinum completed the test structures.

The material showed ferroelectric hysteresis loops (Figure 1). When the Sc content was less than 22% the material suffered dielectric breakdown before the coercive field value was reached. The coercive field for polarization reduced from ~5MV/cm in $Al_{0.73}Sc_{0.27}N$ to less than 2MV/cm in $Al0_{.57}Sc_{0.43}N$. Changes in mechanical stress could enable tuning of the coercive field of the order 1MV/cm for $Al_{0.73}Sc_{0.27}N$ films, according to measurements between −0.8GPa and +0.5GPa.

The piezoelectric effect was measured both as-deposited and after ferroelectric inversion (Figure 2). For $Al_{0.64}Sc_{0.36}N$ films the effective transverse piezoelectric coefficient charge/strain gradient was $-2.90C/m^2$ as-deposited and $+2.76C/m^2$ inverted. The researchers comment: "Both values can be considered high for an AlN-based solid solution. Repeated measurements of the piezoelectric response up to 30 weeks after polarization inversion did not show measurable degradation."

The polarization inversion was found to be stable after temperature treatments up to 600°C, placing the paraelectric transition above that value. The test structure electrodes degraded above 600°C.

The inverse piezoelectric response under electrical bias exhibited two linear regimes, giving effective longitudinal piezoelectric coefficients of +15.7pm/V and −16.2pm/V. "Compared to state of the art polycrystalline ferroelectric thin-films, both the width of the linear strain regime of 0.7% and its symmetry around the field axis are outstanding," the team writes.

The researchers used wet etching experiments to confirm that the ferroelectric-like effects were due to changes on the unit-cell level of the crystal structure, rather some more macroscopic effect of charge transfer due to the presence of p–n/Schottky junctions or electrets (charge polarization equivalent of magnets). In the experiments the inverted material was etched mainly around defects and non-switched domains. By contrast, as-deposited material etched readily with a characteristic cone-like surface morphology.

Further experiments showed expected electrical polarization retention and performance under frequency-dependent measurements. Electron microscopy and diffraction were also used in these efforts. ■

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Author:
Mike Cooke

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www.sum-ieee.org

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SEMICON West 2019
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www.semiconwest.org

10–11 July 2019
UK Semiconductors 2019 (UKS'19)
University of Sheffield, UK
E-mail: edmund.clarke@sheffield.ac.uk
www.uksemiconductors.com

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AVS 19th International Conference on Atomic Layer Deposition (ALD 2019), featuring

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the 6th International Atomic Layer Etching Workshop (ALE 2019)
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E-mail: della@avs.org
www.ald2019.avs.org

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International Congress on Advanced Materials Sciences and Engineering (AMSE-2019)
ANA Crown Plaza Osaka, Japan
E-mail: eve@istci.org
www.istci.org/icamse2019

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PowerAmerica's 2019 Wide Bandgap Summer Workshop
James B. Hunt Jr. Library, N.C. State University's Centennial Campus, Raleigh, NC, USA
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11–15 August 2019
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http://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
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www.epe2019.com

4–7 September 2019
CIOE 2019: 21st China International Optoelectronic Exposition
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www.cioe.cn/en

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SEMICON Taiwan 2019
Taipei Nangang Exhibition Centre, Taiwan
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www.semicontaiwan.org

22–25 September 2019
35th North American Conference on Molecular Beam Epitaxy (NAMBE 2019)
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E-mail: della@avs.org
www.nambe2019.avs.org

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45th European Conference on Optical Communications (ECOC 2019)
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www.ecoc2019.org

24–26 September 2019
19th International Metrology Congress (CIM 2019)
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www.cim2019.com

29 September – 3 October 2019
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New Orleans, LA, USA
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https://expo.scte.org

6–11 October 2019
22nd European Microwave Week (EuMW 2019)
Paris Expo Porte de Versailles, Paris, France
E-mail: eumwreg@itnint.com
www.eumweek.com

17–19 October 2019
LASER World of PHOTONICS INDIA 2019
Bombay Exhibition Centre (BEC), India
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www.world-of-photonics-india.com

20–22 October 2019
9th Annual World Congress of Nano Science & Technology 2019 (Nano S&T-2019) – Small World, Big Thinking, Big Pattern, and Great Development
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www.bitcongress.com/nano2019

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