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COMPOUNDS & ADVANCED SILICON

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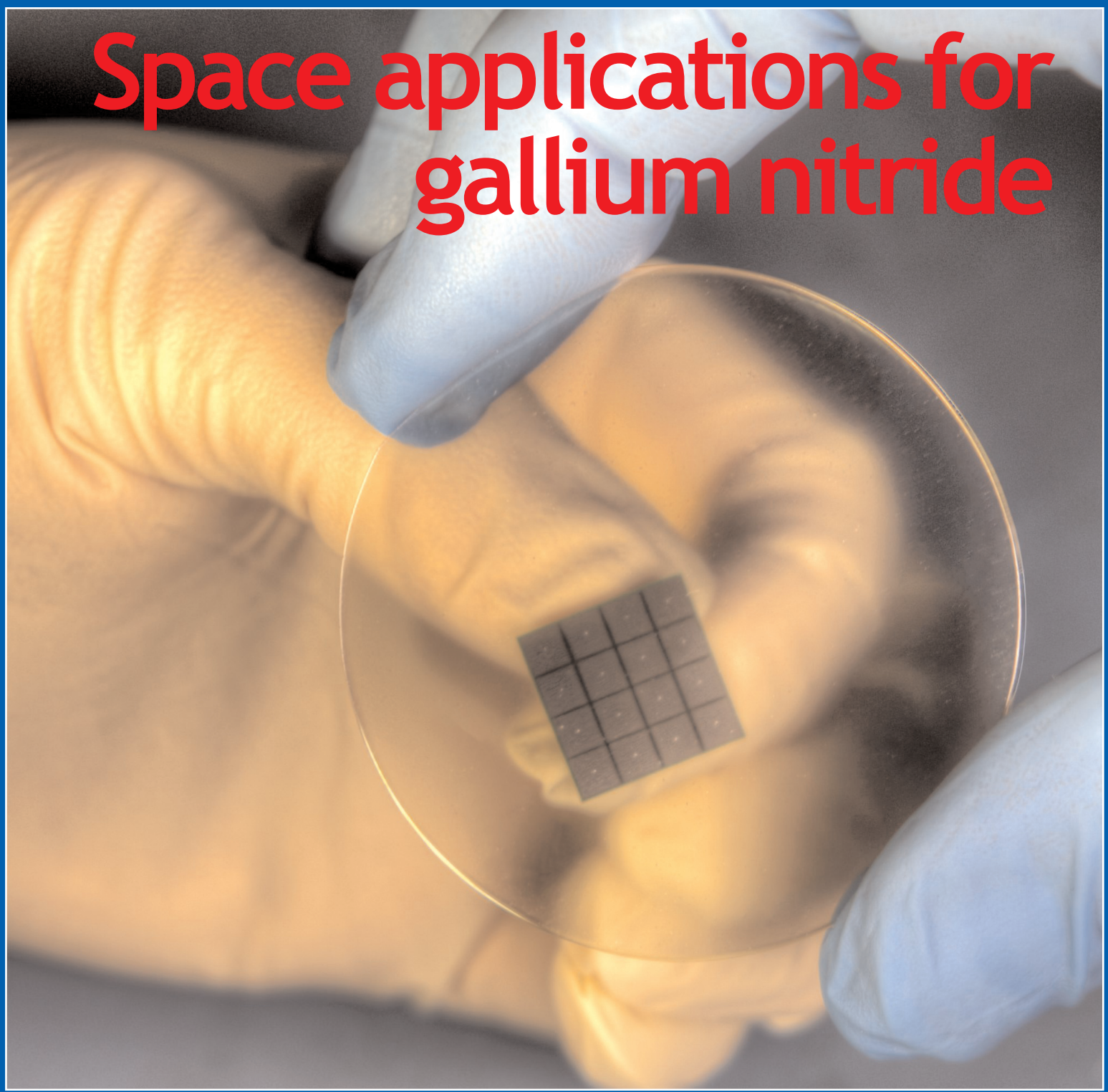
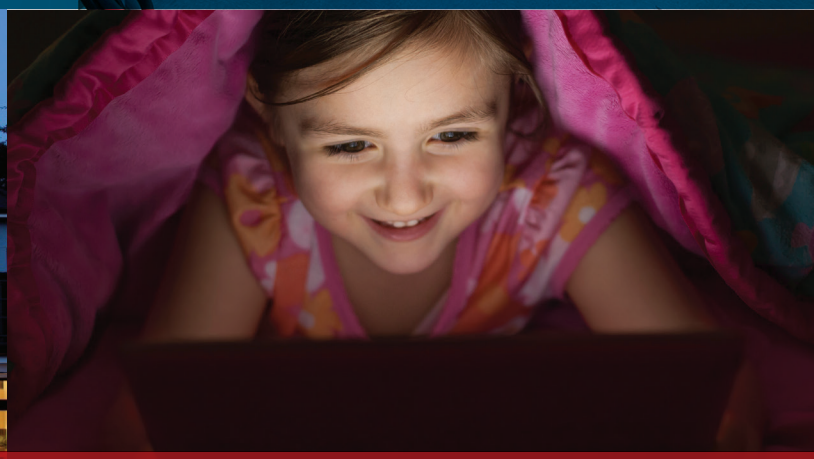


Space applications for gallium nitride

Skyworks buys Avnera • GlobalFoundries refocusing FinFET R&D
CS Applications Catapult to open Innovation Centre

Lower Cost LEDs



Faster LED Adoption

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The EPIK700 MOCVD system combines Veeco's award-winning TurboDisc reactor design with improved wafer uniformity, increased productivity and reduced operations expenses to enable a cost per wafer savings of up to 20 percent compared to previous systems.

It also features a reactor with more than twice the capacity of previous generation reactors. This increased volume coupled with productivity advancements within the EPIK700 reactor, results in an unmatched 2.5x throughput advantage over previous reactors.

Learn how Veeco's TurboDisc EPIK700 GaN MOCVD system can improve your LED manufacturing process today.

The advantage is not just big. It's EPIK.

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

Veeco's New TurboDisc EPIK700 GaN MOCVD System

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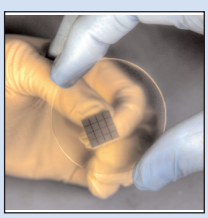


Cover: NASA is investigating the use of GaN HEMTs for studying how the Earth's magneto-sphere couples to its ionosphere, and the use of GaN on a solid-state neutron detector that is relevant to both science and homeland security. **p20**

editorial

Focus on wide-bandgap electronics

Second-quarter 2018 financial results reiterated how the established players in the LED supply chain are seeing business shifting from blue LED manufacturing towards non-lighting and even non-LED applications.

Metal-organic chemical vapor deposition (MOCVD) system maker Aixtron has seen LED applications fall from 44% of its revenue in first-half 2017 to 17% in first-half 2018 — including a shift from gallium nitride (GaN)-based blue LEDs to red-orange-yellow (ROY) LEDs. Meanwhile, non-LED opto applications have risen from just 15% to 69% of Aixtron's revenue, driven by demand for lasers such as vertical-cavity surface-emitting lasers (VCSELs) for 3D sensing (see page 32).

Similarly, Veeco has seen MOCVD systems for blue LED manufacturing in China fall further, from 39% of its total revenue in Q1/2018 to 31% in Q2/2018, as it is seeing orders delayed while recently added capacity is absorbed (see page 30). "Between 2017 and the first half of 2018, several hundred MOCVD reactors for blue LEDs were shipped into the market," it notes. Also, "with the addition of Chinese competition for MOCVD, the general lighting and backlighting market is becoming commoditized and pricing has declined," comments Veeco. Revenue from such low-margin blue LED MOCVD system sales to China are hence expected to fall further.

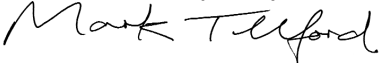
In contrast, Veeco is seeing an emergence of new, higher-margin non-LED applications such as photonics for 3D sensing, GaN power devices for electronics and electric vehicles, and GaN RF devices for 5G RF.

Most starkly, although its revenues for LED Products (chips & components) and Lighting Products both rebounded in the June quarter, formerly LED-dominated Cree still sees Lighting Products down from 43.1% of revenue a year ago to just 35.1% (see page 46). Meanwhile, the firm continues its pivot towards the Power & RF devices and silicon carbide (SiC) material business of its Wolfspeed unit, whose quarterly revenue has grown by 81%, rising from just 16.9% of Cree's total revenue to 26.9%). Cree's aim is to quadruple Wolfspeed revenue, from a little over $200m for fiscal 2017 to about $850m, by doubling its power device capacity and doubling its wafer capacity for external customers by the end of calendar 2018. "We aim to keep reducing the gap and cost compared to silicon by leveraging scale, executing engineering efforts to improve yield, and pushing the limits of material science," says CEO Gregg Lowe. "This combination of greater availability and lower cost will speed up and expand the adoption of SiC and GaN RF technologies," he reckons. Cree has hence increased its capital expenditure from $46m last quarter to $60m, targeting $220m for full-year fiscal 2019 (up from $196m for fiscal 2018 just ended).

Similarly, while RF chip maker Qorvo's return to year-on-year growth in Mobile Products revenue has been driven by strong demand from Chinese smartphone makers, growth in its Infrastructure & Defense Products (IDP) is being driven by the deployment of LTE-Advanced/Pro and 5G, the proliferation of GaN, and the Internet of Things (IoT). Likewise, Qorvo's quarterly CapEx has risen from $32.2m to $43.6m to boost manufacturing capacity for both GaN and bulk acoustic wave (BAW) filters – see page 8.

In particular, according to Strategy Analytics (page 6), 5G base-station deployment will become a primary commercial growth driver for RF GaN, with demand coming from both fixed and mobile applications, operating below 6GHz, as well as in Ka-band and higher millimeter-wave frequency bands.

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).

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

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HVM: High Volume Manufacturing

news

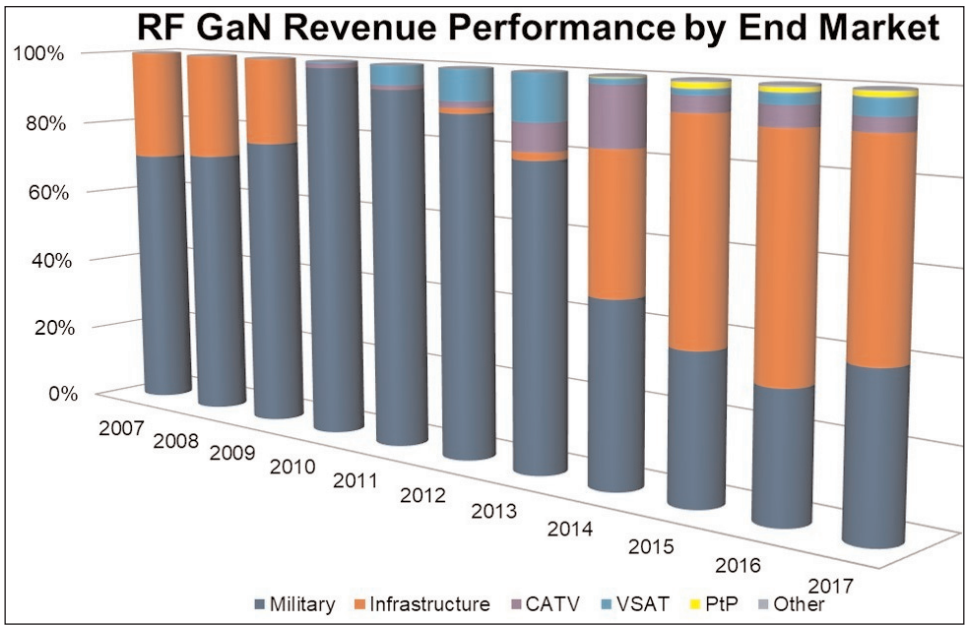
Defense and 5G to propel RF GaN market past $1bn

Increasing GaN adoption driving CAAGR of over 16% through 2022

RF gallium nitride (GaN) market growth continued to accelerate in 2017 and, with revenues growing at over 38% year-on-year, will exceed $1bn by 2022 (with defense sector demand slightly greater than commercial revenue), forecasts the Strategy Analytics Strategic Component Applications (SCA) group report 'RF GaN Market Update: 2017–2022'. GaN is seeing adoption across a range of RF applications. Growth is driven primarily by the rollout of commercial wireless infrastructure coupled with demand from military radar, electronic warfare (EW) and communications applications.

RF GaN demand from the military sector grew by 72% year-on-year in 2017, and the compound annual average growth rate (CAAGR) will be 22% through 2022. The military radar segment will remain the largest user of GaN devices in the defense sector. Substantial production activity in active electronically scanned array (AESA) radars for land-based and naval systems in particular is driving increasing demand for RF GaN, as many systems previously in development move to production.

"As well as demand from military radar, operational requirements to operate in contested and congested environments, as well as being able to counter modern agile radar and communications, will drive opportunities for RF GaN for the electronic warfare market," notes Asif Anwar, director of the Advanced Defense Systems (ADS) service. "Communicating voice, data and video simultaneously and securely over wider and higher bandwidths in an increasingly complex spectrum environment will underpin trends for military communications system design," he adds. "We expect the associated component demand will also be increasingly underpinned with RF GaN."



Wireless base stations continue to be the single largest revenue segment for RF GaN, with increasing penetration translating to year-on-year growth of more than 20%. While the big boost from Chinese LTE deployments is over, the wireless industry has done a very good job of maintaining and, in some cases, compressing the 5G deployment schedule, says the report. The resulting 5G base-station deployment will become a primary commercial growth driver for RF GaN.

"GaN improves high frequency, instantaneous bandwidth, linearity and environmental performance capabilities and this allows equipment manufacturers to develop higher-capacity, higher-power and higher-performance radios," notes Eric Higham, service director, Advanced Semiconductor Applications (ASA) service. "5G deployment will drive opportunities for GaN on multiple fronts, with demand coming from both fixed and mobile applications, operating below 6GHz, as well as in Ka-band and higher millimeter-wave frequency bands. Opportunities are also growing for RF GaN devices in wireless backhaul and VSAT, and we are seeing traction in the adjacent RF Energy market also."

5G deployment will drive opportunities for GaN on multiple fronts, with demand coming from both fixed and mobile applications

Qorvo saw good growth in its defense-related GaN revenue to maintain the market leader spot, widening the gap over rivals competing in the defense sector including captive suppliers such as Raytheon and Northrop Grumman. Sumitomo Electric Device Innovations (SEDI) continued to be the leading supplier to the overall RF GaN market in 2017, based largely on its dominant position in the base-station market, with Cree's Wolfspeed maintaining second place.

The future continues to look promising for RF GaN adoption, even as growth drivers remain in flux, concludes Strategy Analytics.

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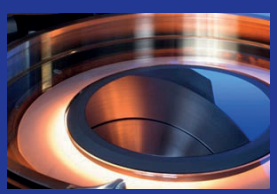

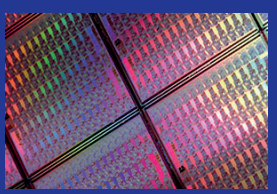

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Qorvo's growth driven by mobile demand in China

CapEx rising to boost BAW and GaN manufacturing capacity

For fiscal first-quarter 2019 (ended 30 June 2018), Qorvo Inc of Greensboro, NC, USA (which provides core technologies and RF solutions for mobile, infrastructure and defense applications) has reported revenue of $692.7m, up 4.1% on $665.4m last quarter and 8.3% on $639.9m a year ago, despite the US Department of Commerce's temporary ban on China-based ZTE (which comprises about $10m of quarterly revenue). Growth was driven by broad-based strength across markets, customers and products.

"Our June quarter exceeded guidance [$645–665m], with strong Mobile growth in China, continued broad-based growth in IDP [Infrastructure and Defense Products], and excellent cost control across the company," says chief financial officer Mark Murphy.

"The June quarter represented an excellent start to fiscal 2019 highlighted by strong smartphone unit volumes in China, design-win activity and operating discipline," comments president & CEO Robert A. Bruggeworth.

Mobile Product (MP) revenue was $486m, up 7.5% on $452m last quarter and returning to year-on-year growth (up 7%), higher than expected across multiple customers and particularly strong in China. During the quarter, Qorvo expanded shipments of quadplexers, antenna control solutions and RF Fusion Phase 6 modules in support of leading China-based smartphone makers (posting record revenue for BAW-based quadplexers in China).

Infrastructure & Defense Products (IDP) revenue was $207m, down just 2.4% on the record $212m last quarter and up 13% on a year ago (the ninth consecutive quarter of double-digit year-on-year growth), driven by record revenue in wireless connectivity and growth in base-station solutions.

"IDP is reaping the rewards of portfolio management in diversified markets including the connected home, the connected car, Wi-Fi, base stations and defense," says Bruggeworth. "These are expanding markets underpinned by positive secular trends like the deployment of LTE Advanced Pro and 5G, the proliferation of gallium nitride (GaN), and the Internet of Things (IoT)," he adds.

Revenue for IoT applications grew by more than 30% year-on-year. "In Wi-Fi, we are a leading supplier of front-end modules for tri-band distributed Wi-Fi systems," says Bruggeworth. "In these systems, our bulk acoustic wave (BAW) filters maximize spectral efficiency and our power amplifiers (PAs) increase power-added efficiency." As the IEEE governing body and the Wi-Fi Alliance work to extend spectrum for 802.11ax, Qorvo's Wi-Fi portfolio is expanding to include solutions in the 5.9–7.1GHz range for products ramping in second-half 2019.

On a non-GAAP basis, gross margin was 44%, down from 48% last quarter and 47.3% a year ago.

Operating expenses were $160.5m, up from $155.6m last quarter but cut from $165.5m a year ago (and less than the expected $165m due primarily to the timing of program development expenses).

Net income was $124m ($0.96 per diluted share), down from $138.6m ($1.07 per diluted share) last quarter but up from $113.9m ($0.87 per diluted share) a year ago (well above the $0.75 guidance).

During the quarter Qorvo expanded shipments of quadplexers, antenna control solutions and RF Fusion Phase 6 modules in support of leading China-based smartphone makers

Operating cash flow was $75.3m (down from $259m last quarter), reflecting inventory builds to support Mobile Product ramps. Capital expenditure (CapEx) was back up to $43.6m, related primarily to BAW and GaN capacity additions in the fabrication plant in Richardson, Texas. Free cash flow was hence $31.7m.

However, during the quarter cash and cash equivalents fell from $926m to $334m due to the repurchase of the remaining $429m of Qorvo's 2023 notes and from increased share repurchases (of $100m of stock).

Following quarter-end, Qorvo completed a partial tender for $300m of its 2025 notes and a $500m eight-year unsecured notes issue at a coupon of 5.5%. The firm has hence lowered its interest costs and extended its average debt maturity to 2026. "We remain well below our net leverage target and retain significant financial flexibility to grow the business and return capital to shareholders," notes Murphy.

"The team did an outstanding job supporting large customer ramps, while securing new opportunities for growth," says Bruggeworth.

During the quarter, Qorvo was selected by Qualcomm to supply a high-efficiency 5GHz front-end module for new 802.11ax carrier gateway designs. The firm also secured a design win for an ultra-high-band (UHB) front-end module for a Korea-based marquee smartphone launching this year, addressing 3.5GHz UHB requirements ahead of the coming 5G rollout. In addition, Qorvo sampled BAW-based diversity receive modules and antennaplexers to multiple smartphone makers to enable next-generation carrier aggregation and MIMO architectures.

Qorvo has expanded its 5G portfolio by adding several new products for massive MIMO and 5G macro

base stations, with highly integrated modules now supporting the full spectrum of anticipated frequency bands for 5G architectures, up to 39GHz. "Given the superior performance characteristics of gallium nitride versus legacy silicon technologies, we see GaN proliferating in multiple markets, including base stations," says Bruggeworth. Qorvo's GaN solutions support massive MIMO deployments below 6GHz. In China, demand is increasing for the firm's solutions for the 3.5GHz and 4.8GHz deployments anticipated in 2019. In millimeter wave, Qorvo's 39GHz GaN front-end modules are powering the first commercially available millimeter-wave fixed-wireless access service (deployed recently in Boston, Los Angeles and Washington DC, plus additional cities to be added later this year).

In defense applications, Qorvo has expanded its GaN-based portfolio by launching two highly integrated X-band front-end modules (combining four parts into one) optimized for next-generation mission-critical active electronically scanned array (AESA) radar systems worldwide.

"Our fiscal year is off to a strong start, and we expect our portfolio focus and operational discipline to drive stronger earnings and cash flow," says Murphy. "Qorvo's September quarter and full-year outlook reflect continued growth and margin expansion, consistent with our previous guidance."

For fiscal second-quarter 2019 (to end-September 2018), Qorvo expects growth in revenue to $850–860m, driven by new product ramps. IDP should grow, due in part to the US Department of Commerce lifting its ban on ZTE. For Mobile, Qorvo revenue should rise more than 30% sequentially due to seasonal ramps.

CapEx should increase further, due mainly to BAW and GaN investments in Richardson, the expansion of BAW capacity in the Farmers Branch plant, and the purchase of a leased facility. CapEx for the rest of the year remains tied to design opportunities

Gross margin should rise to 47.5%, reflecting expected progress on mix improvements and productivity gains partially offset by under-loaded SAW capacity. Operating expenses are forecasted to rise to $170m, driven mainly by increased design activity (although OpEx is expected to trend down in second-half 2018, totaling less than 20% of sales for the full year). Diluted earnings per share is expected to increase to $1.62.

CapEx should increase further, due mainly to BAW and GaN investments in Richardson, the expansion of BAW capacity in the Farmers Branch plant, and the purchase of a leased facility. CapEx for the rest of the year remains tied to design opportunities, tool conversions, new tool lead-times and other factors, which currently point to moderately higher CapEx for full-year fiscal 2018 driven primarily by acceleration of the build-out of Farmers Branch as Qorvo gains confidence in its BAW-based revenue outlook.

"We believe this increase is for the right reasons: value-creating investments supporting our high-growth and high-margin businesses where we hold differentiated positions," says Murphy. Due to higher revenue, stronger margins and lower working capital, operating cash flow should strengthen in fiscal second-half 2018. "As a result, our free cash flow forecast for the year is now expected to be closer to $700m," he adds.

Qorvo expects full-year revenue growth of about 10%, gross margin rising to 50% or more for the second half, and OpEx below 20% of sales.

"Qorvo's positive long-term outlook reflects our enthusiasm for the team we've built, the markets we serve, and the underlying macro-trends of LTE-Advanced/Pro, 5G, IoT and GaN," says Bruggeworth.

Qorvo closes offering of additional $130m of 5.50% senior notes due

Qorvo Inc of Greensboro, NC, USA (which provides core technologies and RF solutions for mobile, infrastructure and defense applications) has completed its offering of an additional $130m of its senior notes maturing in 2026 (upsized from the initial $100m announced on 14 July).

This brings the total to $630m, after Qorvo completed an offering of the initial $500m of the notes on 16 July (which had been upsized from the $300m originally announced on 10 July).

Issued to qualified institutional buyers and certain non-US persons, the additional notes will pay interest semi-annually at a rate of 5.50% and mature on 15 July 2026 (unless earlier redeemed in accordance with their terms).

Qorvo expects to use the net proceeds of the offering, together with cash on hand, to finance its recently announced tender offer of 7.00% senior notes due 2025.

The additional notes are senior unsecured obligations of Qorvo and are initially guaranteed, jointly and severally, by each of Qorvo's existing and future direct and indirect wholly owned US subsidiaries that guarantee Qorvo's obligations under its existing credit facility.

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

Skyworks buys analog-system-on-chip designer Avnera

Skyworks Solutions Inc of Woburn, MA, USA (which makes analog and mixed-signal semiconductors) has acquired private fabless semiconductor supplier Avnera Corp of Beaverton, OR, USA, a developer of analog system on chips (ASoCs) since 2004, following approval by the boards of directors of both firms.

Skyworks is paying $405m in cash plus up to an extra $20m if performance targets are exceeded over a 12-month post-closing period.

Excluding any non-recurring acquisition-related charges and amortization of intangibles, Skyworks expects the acquisition to be immediately accretive to diluted earnings per share.

The acquisition is expected to augment Skyworks' capabilities in wireless connectivity by adding ultra-low-power analog circuits to enable smart interfaces via acoustic signal processing, sensors and integrated software, expanding the firm's addressable market by over $5bn. Target applications include AI speakers/microphones, virtual assistants, intelligent gaming controllers and vehicle in-dash systems as well as wired/wireless headsets.

At the heart of Avnera's system solutions are market-specific ASoCs that combine audio/voice analog circuits, highly efficient power management and custom hardware accelerators for smart acoustic signal processing/AI features. The ASoCs are claimed to achieve the highest level of integration in the industry and set a new benchmark for power consumption and footprint — underpinned by over 100 issued and pending patents. Key customers include Harman, JBL, Panasonic, Philips, Pioneer, Polk, Samsung, Sennheiser, Sony, Vizio and Yamaha.

www.avnera.com
www.skyworksinc.com

Skyworks launches 5G antenna tuning solutions

Skyworks has unveiled the latest solutions from its Sky5 portfolio, the firm's unifying platform enabling 5G applications.

Skyworks' new wideband 16-state antenna aperture tuners are compact and designed to deliver improved efficiency and enhanced bandwidth coverage — from 600MHz to 6GHz for LTE Advanced Pro to emerging 5G standards — across a wide range of mobile devices.

Antenna tuning plays a critical role in maintaining smartphone power efficiency and battery life, particularly as signal processing complexity continues to rise with the onset of 5G. With smartphone makers adding new features such as 4x4 multiple-in, multiple-out (MIMO) and 5G new radio (NR) for 2019 applications, next generation architectures must embed significantly more antennas. New bezel-less smartphones integrate between four and seven antennas to support future data demand versus the two to four average antenna count within today's platforms. At the same time, the migration to full-screen infinity displays and expanded functionality limit the amount of board space available. Skyworks' antenna tuning solutions leverage proprietary design and process techniques to help drive antenna performance while meeting stringent linearity demands and size constraints.

"Skyworks is at the forefront of developing breakthrough solutions for revolutionary 5G applications," claims Carlos Bori, senior VP of sales & marketing. "With best-in-class performance, our antenna tuners are playing a pivotal role in enabling 4x4 MIMO-capable mobile devices as global demand for emerging 5G applications is set to explode."

The SKY5-9256-701LF aperture tuner features reliable linear operation and extremely low R_{on} (1.1Ω) and C_{off} (145fF) to deliver what is claimed to be superior antenna performance, allowing system designers to recover the 1.5–3dB gain degradation caused by shrinking antenna sizes. The MIPI-controlled, 16-state capability of the tuner also gives engineers the ability to combine arms for even smaller Ron and Coff. Excellent harmonics are delivered throughout the operating range, it is claimed, helping to achieve RSE requirements and passing certification.

Skyworks is leveraging its technology expertise to meet requirements for low, mid, high, and ultra-high cellular frequency bands. All Sky5 solutions support new 5G waveforms and spectrum in addition to enhanced carrier aggregation and dual connectivity (4G/5G) while delivering high levels of integration and performance. Sky5 products also offer a MIPI interface and are highly flexible, featuring customizable architectures that help deliver performance, footprint and power efficiency with 100MHz CP-OFDM modulation. The portfolio includes:

- SKY5-8250 — a 5G NR power amplifier module with integrated filtering and dual-path low-noise amplifiers (LNA) supporting n77, n78, n79 and b42, b43, b48 bands. It also uses SkyBlue technology and integrates a dual antenna output.
- SKY5-3728 — a 5G NR diversity receive module with integrated filtering and dual-path LNAs supporting n77, n78, n79 and b42, b43, b48 bands. It also integrates antenna switching functionality, enabling PCB design flexibility as well as 5G NR SRS hopping support.
- SKY5-5761 — a cellular vehicular-to-everything (C-V2X) front-end module with Class 2 power and integrated gain control.
- SKY5-5811 — an LAA receive module with integrated bypass LNA and variable gain control.

www.skyworksinc.com/Sky5

Qualcomm abandons $44bn acquisition of NXP in absence of China regulatory approval

Qualcomm pays NXP $2bn termination fee

After agreeing in October 2016 for its indirect subsidiary Qualcomm River Holdings B.V. to acquire automotive and Internet of Things (IoT) chip maker NXP Semiconductors N.V. of Eindhoven, The Netherlands for $44bn, telecom chip and mobile processor manufacturer Qualcomm Inc of San Diego, CA, USA has now terminated the deal.

In January, Qualcomm said that the acquisition had received eight of the nine approvals required around the world under anti-monopoly provisions — most recently from the European Union and the Korea Fair Trade Commission (KFTC). However, in the absence of regulatory clearance by the China Ministry of Commerce's State Administration for Market Regulation (SAMR) and other closing conditions (including the tender of at least 70% of the issued and outstanding common shares of NXP in the offer) by the deal's agreed 'end date' of 25 July, Qualcomm River Holdings has now been obliged to pay NXP a termination fee of $2bn (using existing cash and cash equivalents).

As promised to shareholders if the NXP deal fell through, Qualcomm has announced a stock buyback program of up to $30bn. Likewise, NXP has announced a $5bn stock buyback program "based on the significant strength of the NXP capital structure, and its confidence in the company's ability to drive long-term growth and strong cash flow".

"Our core strategy of driving Qualcomm technologies into higher-growth industries remains unchanged," says Qualcomm's CEO Steve Mollenkopf. The firm continues to achieve strong growth, accelerated by its expansion and momentum in the areas of IoT, Automotive, RFFE, Compute, and Networking. "We will continue to focus on our strong momentum in these growth industries with projected revenues of approximately $5bn for fiscal year 2018, up greater than 70% from fiscal year 2016," he adds.

"While it is unfortunate that the semiconductor powerhouse that would have resulted from the transaction with Qualcomm could not close after 21 months of diligent efforts by the team, we are confident in our future as an independent market leader and will continue to focus our efforts to drive our long-term strategy in our leadership markets of automotive and secure IoT solutions," says NXP's president & CEO Richard Clemmer.

www.nxp.com
www.qualcomm.com

JUMP program to fund 24 new research projects

Semiconductor Research Corporation (SRC) has released $26m in added research funding for the Joint University Microelectronics Program (JUMP), a consortium of 11 industrial participants and the US Defense Advanced Research Projects Agency (DARPA) that is one of two complementary research programs for the New Science Team (NST) project — a five-year, greater-than-$300m SRC initiative launched in January. JUMP and its six thematic centers aim to advance a new wave of fundamental research focused on high-performance, energy-efficient microelectronics for communications, computing and storage needs for 2025 and beyond.

JUMP will fund 24 additional research projects spanning 14 US universities. The new projects will be integrated into JUMP's six existing research centers. NST will continue to distribute funds over its five-year plan, and industrial sponsors are welcome to join to further accentuate those plans.

The awards have been given to 27 faculty and will enhance the program's expertise in technical areas such as atomic layer deposition (ALD), novel ferroelectric and spintronic materials and devices, 3D and heterogeneous integration, thermal management solutions, architectures for machine learning and statistical computing, memory abstractions, reconfigurable RF front-ends, and mmWave to THz arrays and systems for communications and sensing.

"The goal of the NST project is not only to extend the viability of Moore's Law economics through 2030, but to also change the research paradigm to one of co-optimization across the design hierarchy stack through multi-disciplinary teams," says SRC's president & CEO Ken Hansen. "Our strategic partnerships with industry, academia and government agencies foster the environment needed to realize the next wave of semiconductor technology innovations," he adds.

"A new wave of fundamental research is required to unlock the ultimate potential of autonomous vehicles, smart cities, and artificial intelligence (AI)," says Dr Michael Mayberry, senior VP & chief technology officer of Intel and the elected chairman of the NST Governing Council. "Such advances will be fueled by novel and far-reaching improvements in the materials, devices, circuits, architectures and systems used for computing and communications."

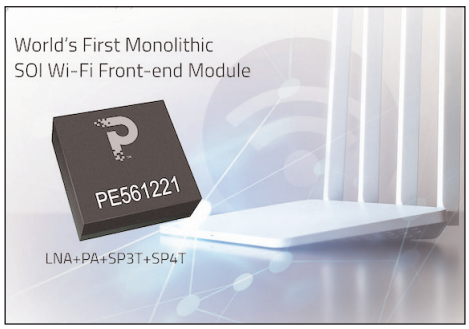
www.src.org/about/nst

pSemi launches first monolithic silicon-on-insulator Wi-Fi front-end module

Murata company pSemi Corp of San Diego, CA, USA (formerly Peregrine Semiconductor Corp) — a fabless provider of radio-frequency integrated circuits (RFICs) based on silicon-on-insulator (SOI) — has introduced what it claims is the first monolithic silicon-on-insulator (SOI) Wi-Fi front-end module (FEM).

Suitable for Wi-Fi home gateways, routers and set-top boxes, the PE561221 uses a smart bias circuit to deliver a high-linearity signal and excellent long-packet error vector magnitude (EVM) performance. Combining the intelligent integration capabilities of pSemi's SOI technology and Murata's expertise in Wi-Fi connectivity solutions and advanced packaging, the 2.4GHz Wi-Fi FEM integrates a low-noise amplifier (LNA), a power amplifier (PA) and two RF switches (SP4T, SP3T). The monolithic die uses a compact 16-pin, 2mm x 2mm LGA package suitable for either stand-alone use or in 4x4 MIMO and 8x8 MIMO modules.

"The new IEEE 802.11ax standard is utilizing high-order modulation schemes (1024 QAM) with demanding EVM requirements," says VP of worldwide sales Colin Hunt. "Traditional process technologies



struggle to keep up with both performance and integration requirements, and only SOI can offer the ideal combination of integration and high performance," he adds. "This new monolithic Wi-Fi module is a great example of the types of technology and product advancements pSemi and Murata can accomplish together."

The 2.4GHz Wi-Fi FEM is based on pSemi's UltraCMOS technology platform — a patented form of SOI. Due to its RF and microwave properties, SOI is said to be an optimal substrate for integration. When paired with high-volume CMOS manufacturing, the result is a reliable, repeatable technology platform that offers what is reckoned to be superior performance compared with other mixed-signal processes. UltraCMOS technology also enables intelligent integration — the unique design ability to integrate RF, digital and analog components on a single die.

The PE561221 leverages the intelligent integration capabilities of UltraCMOS technology to deliver what is claimed to be exceptional performance, low power consumption and high reliability with 2kV HBM ESD rating. Through advanced analog and digital design techniques, the Wi-Fi FEM delivers long-packet EVM performance with less than 0.1dB of gain droop while operating across the entire –40°C to 85°C temperature range. At –40dB EVM (MCS9), the output power is +19dBm with less than 0.05dBm droop in power output after a 4ms packet. The IC delivers what is claimed to be best-in-class dynamic error vector magnitude (DEVM) and current consumption without requiring digital pre-distortion (DPD), as well as excellent MCS11 performance for 802.11ax applications.

Volume-production parts and samples of the PE561221 are available now.

The PE561221 is the first product in pSemi's Wi-Fi front-end module portfolio; the product roadmap also includes 5GHz Wi-Fi FEM solutions.

www.psemi.com

Analog Devices reinstates share repurchase program, and increases authorization by $2bn

Analog Devices Inc of Norwood, MA, USA (which provides mixed-signal ICs for cable access) says that it has reinstated its share repurchase program, and that its board of directors has authorized the firm to repurchase an additional $2bn of its common stock.

Analog Devices commenced its common stock repurchase program in fiscal year 2004. Since then, it has repurchased about $5.4bn of its common stock.

The announcement "reflects our confidence in ADI's strong performance and the successful execution of our strategy," says president & CEO Vincent Roche. "We have achieved our 2x leverage ratio goal ahead of plan, allowing us to enhance our capital returns to shareholders through both our quarterly dividend and share repurchases," he adds. "Our goal is to continue delivering broad revenue growth and generate strong cash flow to enable us to invest in the business, grow our capital returns, and deliver shareholder value for years to come."

Under the reinstated share repurchase program, the firm may repurchase outstanding shares of its common stock from time to time on the open market or through privately negotiated transactions. ADI's management will determine the timing and amount of shares repurchased.

www.analog.com

GlobalFoundries refocusing FinFET development from 7nm to 14/12nm to target high-growth markets, including RF SOI and SiGe

ASIC business established as independent custom design subsidiary, with access to alternative foundries

In line with the strategic direction launched following the appointment of Tom Caulfield as CEO in March, GlobalFoundries of Santa Clara, CA, USA (one of the world's largest semiconductor foundries, with operations in Singapore, Germany and the USA) is reshaping its technology portfolio to intensify its focus on delivering differentiated offerings for clients in high-growth markets.

The firm is realigning its leading-edge FinFET roadmap to serve the next wave of clients that will adopt the technology in the coming years. It will shift development resources to make its 14/12nm FinFET platform more relevant to these clients, delivering a range of IP and features including RF, embedded memory, and low power. To support this transition, GlobalFoundries is putting its 7nm FinFET program on hold indefinitely and restructuring its R&D teams to support its enhanced portfolio initiatives. This will require a workforce reduction, but a significant number of top technologists will be redeployed on 14/12nm FinFET derivatives and other differentiated offerings.

"The vast majority of today's fabless customers are looking to get more value out of each technology generation to leverage the substantial investments required to design into each technology node," notes Caulfield. "Essentially, these nodes are transitioning to design platforms serving multiple waves of applications, giving each node greater longevity. This industry dynamic has resulted in fewer fabless clients designing into the outer limits of Moore's Law," he adds. "We are shifting our resources and focus by doubling down on our investments in differentiated technologies across our entire portfolio that are most relevant to our clients in growing market segments."

In addition, to better leverage its heritage and investments in ASIC design and IP, GlobalFoundries is establishing its ASIC business as a wholly owned subsidiary, independent from the foundry business. Since a relevant ASIC business requires continued access to leading-edge technology, the independent ASIC entity will provide clients with access to alternative foundry options at 7nm and beyond, while allowing the ASIC business to engage with a broader set of clients, especially the growing number of systems companies that need ASIC capabilities and more manufacturing scale than GlobalFoundries can provide alone.

GlobalFoundries says that it is intensifying investment in areas where it has clear differentiation and adds true value for clients, with an emphasis on delivering feature-rich offerings across its portfolio. This includes continued focus on its FDX platform, leading RF offerings (including RF SOI and high-performance SiGe), analog/mixed signal, and other technologies designed for a growing number of applications that require low power, real-time connectivity, and on-board intelligence. GlobalFoundries reckons that it is uniquely positioned to serve this burgeoning market for 'connected intelligence', with strong demand in new areas such as autonomous driving, Internet of Things (IoT) and the global transition to 5G.

"Lifting the burden of investing at the leading edge will allow GlobalFoundries to make more targeted investments in technologies that really matter to the majority of chip designers in fast-growing markets such as RF, IoT, 5G, industrial and automotive," comments Samuel Wang, research vice president at market analyst firm Gartner. "Fewer customers can afford the transition to 7nm and finer geometries," he adds. "14nm and above technologies will continue to be the important demand driver for the foundry business for many years to come. There is significant room for innovation on these nodes to fuel the next wave of technology."

www.globalfoundries.com

SUNY Poly professor awarded $2m US ARL grant to make ultra-high-voltage power electronics chips for next-generation military and commercial applications

Device fabrication to use the SUNY Poly-led New York Power Electronics Manufacturing Consortium's tools and support graduate students' research

State University of New York (SUNY) Polytechnic Institute says that associate professor of nanoengineering Dr Woongje Sung has been selected to receive $2,078,000 in total federal funding over three years from the US Army Research Laboratory (ARL) for advancing 'MUSiC' (the Manufacturing of Ultra-high-voltage Silicon Carbide devices).

By developing higher voltages compared with traditional silicon-based devices and enabling more reliable and robust switching devices in SiC, the research aims to establish a leading-edge process for the creation of power electronics chips with a range of military and commercial applications, from solar energy and electric vehicles to the electrical grid, for example.

Sung's research will help to establish a baseline process for MUSiC. The proposed SiC high-voltage devices will be fabricated at the SUNY Poly-led New York Power Electronics Manufacturing Consortium (NY-PEMC) facility, located at the Albany NanoTech Complex and one of only two foundry service providers for 6-inch SiC device fabrications in the USA.

The power electronics-focused research will also support SUNY Poly graduate students who will gain first-hand experience optimizing the device structure, designing the process flow, and characterizing the electrical performances of the fabricated devices as they work closely with the NY-PEMC process team. More specifically, the students will be designing and optimizing the 10–15kV metal-oxide-silicon-field-effect-transistors (MOSFETs) — the switch components of the power electronics chips — using 2D device simulations. After fabrication, the students will provide feedback to improve the device design and the process.

Woongje Sung.

"This latest award showcases the importance of SUNY Poly's faculty research and how our institution and New York State have been able to push new boundaries to power innovative, high-tech advances," says SUNY Poly interim president Dr Grace Wang.

"This award will drive hands-on research opportunities for a number of graduate students to provide them with an even stronger background in the technologies that are shaping our future," comments interim provost Dr Steven Schneider.

The ARL has recognized the importance of developing a US base for MUSiC, says Sung. "As this project develops, I look forward to the numerous opportunities that may result, for the establishment of the 'MUSiC' will provide a foundation for further R&D," he adds. "It will also serve as an invaluable hands-on educational vehicle for SUNY Poly students."

The ARL award also follows another recent announcement of $375,000 in funding for Sung's research from the US Department of Energy (DOE) for the development of next-generation power electronics chips that are smaller and more efficient than existing power electronics chips. As an emerging power semiconductor material with properties that make it the prime candidate for next-generation high-voltage switching devices for military and commercial applications, SiC-based power devices have been demonstrated to provide greater than twice the power density of the ubiquitous silicon power devices and at greater efficiency.

www.sunypoly.edu
www.ny-pemc.org

PowerAmerica funds new projects to advance wide-bandgap technology in USA

$20m for six new member projects and 20 existing member projects

The PowerAmerica institute — a member of Manufacturing USA — has awarded funding to six new member projects that aim to enhance wide-bandgap (WBG) technologies in the USA. In addition, PowerAmerica awarded funding for 20 projects to be led by existing members for a total of $20m in project funding for this cycle.

PowerAmerica aims to save energy and create US manufacturing jobs by accelerating the development and large-scale adoption of wide-bandgap semiconductor technology made with silicon carbide (SiC) and gallium nitride (GaN) in power electronics systems. Located at North Carolina State University (NCSU) in Raleigh, NC, the institute is funded by the Department of Energy, industry partners and the state of North Carolina, and has a member portfolio representing over 45 leading companies in the wide-bandgap semiconductor field.

"These projects are instrumental in fulfilling PowerAmerica's mission of accelerating the adoption of wide-bandgap technologies into power electronics systems," says PowerAmerica's deputy executive director & chief technology officer Victor Veliadis. "To date, the institute has funded scores of projects that have contributed to the development of more efficient power electronics, which will benefit a range of applications — from electric vehicles to data centers."

The new member projects receiving funding are:

- Module Development and Manufacturing
- Design and Manufacture of Advanced Reliable WBG Power Modules
- GE Aviation Systems and National Renewable Energy Laboratory (NREL) will work together to design and produce advanced wide-bandgap power modules made with silicon carbide and gallium nitride. The goal is to enable true engine coolant temperature-grade equipment which is required to support next-generation defense systems as well as commercial transportation, wind and solar, while reducing overall system costs.

Commercialization Applications

- *Dual-Inductor Hybrid Converter for Direct 48V to sub-1V PoL DC–DC Module*

A team at University of Colorado, Boulder will design and implement a GaN-based, novel converter with an increased density of 10 times of converters currently on the market, with up to three times lower power loss. The converter will have fewer components, simpler implementation and lower cost. It can be used for power delivery to data centers, cellular base stations, portable applications, and defense systems.

- *Introduction of WBG devices for Solid-State Circuit Breaking at the Medium Voltage Level*

A team at University of North Carolina, Charlotte (UNCC) will test a functioning prototype of a medium-voltage (3.3kV) SiC solid-state circuit breaker. The use of silicon carbide will enable fast turn-off capability in the microsecond range or better, and superior efficiency compared to silicon. Market segments to be targeted include utility operators of the electricity distribution network.

These projects are instrumental in fulfilling PowerAmerica's mission of accelerating the adoption of wide-bandgap technologies into power electronics systems. The institute has funded scores of projects that have contributed to the development of more efficient power electronics, which will benefit a range of applications

- *600V GaN Dual-gate Bi-directional Switch*

Infineon will develop a low-cost, 600V bi-directional 70mΩ switch based on the firm's CoolGaN high-electron-mobility transistor (HEMT) technology, capitalizing on the unique bi-directional nature of the GaN HEMT. The project will validate both the dual-gate concept and a solution for substrate voltage stabilization, and will make the GaN switch more economically attractive compared to the standard silicon devices commonly used today.

Education and Workforce Development

- *Graduate Wide Bandgap Semiconductor Power Device Lab*

A team at North Carolina State University (NCSU) will establish a graduate laboratory course focused entirely on the design, fabrication, and characterization of wide-bandgap power devices, and disseminate the curriculum to PowerAmerica members to accelerate the education of new engineers.

- *Power Electronics Teaching Lab Incorporating WBG Semiconductor Switches and Circuits*

Researchers at University of North Carolina, Charlotte (UNCC) will develop a modular, multi-function, educational high-frequency power electronics board with plug-&-play capability. The new board will give students the flexibility to perform different power electronics lab sessions and train undergraduate students as wide-bandgap power electronics engineers through hands-on experience and practical knowledge of WBG semiconductors in power electronics applications.

https://poweramericainstitute.org/member-projects
www.manufacturingusa.com

Wolfspeed's E-Series first family of SiC MOSFETs and diodes to meet automotive AEC-Q101 standards

Wolfspeed of Durham, NC, USA — a Cree Company that makes silicon carbide (SiC) power products and GaN-on-SiC high-electron-mobility transistors (HEMTs) and monolithic microwave integrated circuits (MMICs) — has launched the E-Series, a new family of robust SiC semiconductor devices for the electric vehicle (EV) and renewable energy markets that delivers what is claimed to be the highest available power density and durability for on-board automotive power conversion systems, off-board charging, solar inverters and other outdoor applications.

The E-Series family is the first commercial family of SiC MOSFETs and diodes to be automotive AEC-Q101 qualified and PPAP (production part approval process) capable. The designation makes it the only commercially available family of SiC MOSFETs and diodes that meets high-humidity and automotive qualifications to deliver reliable and corrosion-resistant components in the power market.

"The new E-Series family provides automotive manufacturers with robust, automotive-qualified MOSFETs and diodes for on-board and off-board charging circuits, which are crucial to the evolution of EV technology," says Wolfspeed's senior VP & general manager Cengiz Balkas. "The commercial rollout of the E-Series family establishes Wolfspeed as the first in the industry to launch a full suite of MOSFETs and diodes that are capable of withstanding high-humidity environments while offering the reliability and system-level value needed to drive widespread adoption of silicon carbide among automakers for their next generation of EVs."

Wolfspeed says that, with the new automotive-qualified SiC MOSFET, it becomes the first silicon carbide semiconductor maker to offer a complete family of qualified parts to the EV market. The portfolio expansion also enables it to supply power conversion components within an EV for an end-to-end solution. Specifically:

- The E-Series SiC MOSFET is the only automotive AEC-Q101-qualified, PPAP-capable and humidity-resistant MOSFET available. It features Wolfspeed's third-generation rugged planar technology, which has more than 10 billion field hours. Offering what are claimed to be the lowest switching losses and highest figure of merit, the E-Series 900V MOSFET is optimized for use in EV battery chargers and high-voltage DC/DC converters and is featured in Wolfspeed's 6.6kW B-Directional On-Board Charger reference design.
- The E-Series Merged-PIN Schottky Diodes (MPS) deliver high reliability for on-board power conversion systems and solar inverters, complementing Wolfspeed's existing AEC-Q101-qualified 650V SiC diode portfolio. The diodes deliver a 1200V blocking capability with a current rating up to 20A at a $T_{J,Max}$ = 175ºC. Reference designs for the E-Series diodes are available, including Wolfspeed's 20kW Two-Level AFE and DC/DC Converter for Off-Board Chargers, which delivers more than 30% reduction in power loss compared with existing three-level Vienna rectifiers.

The E-Series family also addresses the key challenge in designing and maintaining solar power systems: finding products that can withstand extremely harsh environmental conditions while maintaining peak performance. Since corrosion caused by humidity is a major consideration when designing outdoor power systems, the key qualification for harsh environments is the HV-H3TRB rating (also known as HVDC THB or THB80). The HV-H3TRB qualification testing was performed at 80% of the rated blocking voltage in an environmental chamber at a constant 85ºC ambient with 85% relative humidity. Both the E-Series MOSFETs and diodes are HV-H3TRB rated, so they are optimized for use in solar inverters and other outdoor systems as well as EVs.

www.wolfspeed.com/e-series

Advantech receives million-dollar order for GaN-based SatCom BUCs

Toronto-based Baylin Technologies Inc says its subsidiary Advantech WirelessTechnologies Inc of Montreal, Canada (which makes satellite, RF equipment and microwave broadband communications systems) has received an order for more than 1 million dollars from a military customer for its satellite communication (SatCom) GaN-based block up converters (BUCs).

"Our customers appreciate the exceptional linearity and operating efficiency our products offer," says Baylin's president & CEO Randy Dewey. "The GaN X-band line of solid-state power amplifiers (SSPAs) is extremely versatile and provides small-form-factor units for mobile applications, medium power for maritime use and high power for large teleport applications," he adds.

Advantech's latest generation of X-band GaN-based SSPAs/BUCs are extremely versatile and suitable harsh environments, Satcom on the Move (SOTM) and man-pack terminal deployments. The X-band GaN-based BUCs are weatherproof and constructed in a compact cooling enclosure suitable for outdoor operation. With ruggedized designs, the smaller BUCs are fully integrated units that enable new terminal designs for both mobile and on-the-halt tactical communication systems.

www.advantechwireless.com

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or contact us: x-fea-fuji-dc@fujielectric.com

PowerSphyr and GaN Systems collaborate on wireless charging systems

Firms to co-develop high-powered consumer, industrial and automotive applications

PowerSphyr Inc of Danville, CA, USA — which delivers end-to-end wireless power charging solutions — and GaN Systems Inc of Ottawa, Ontario, Canada (a fabless developer of gallium nitride-based power switching semiconductors for power conversion and control applications) have announced a strategic agreement to bring GaN-based wireless power systems to market for high-powered applications spanning consumer, industrial and automotive sectors worldwide.

Working together to develop hardware and firmware solutions, the firms aim to deliver solutions that adhere to wireless charging standards, while developing next-generation power and functional capabilities that exceed anything offered in the market currently. PowerSphyr supports the three key industry standards for wireless power charging: magnetic induction; magnetic resonance; and RF energy harvesting.

GaN Systems says that gallium nitride transistors are the best means for higher-power-level applications from 30W up to several kilowatts — much greater than achieved with traditional silicon solutions and providing the building block to achieve higher power, higher efficiency and lower cost in wireless power transmitters. GaN-based wireless power solutions have enabled faster charging, higher power transfer and new system designs that are removing the limitations of distance and power, and moving charging beyond phones into applications including power tools, robots, drones and ebikes.

"We selected GaN Systems on the basis of our strategic vision for delivering fast, flexible and complete wireless charging solutions, and their ability to rapidly deliver a complete family of robust, reliable, best-in-class semiconductors," says PowerSphyr's CEO & chairman Neil Ganz.

"Cutting the cord began with the telephone then ethernet LAN and now the power cord," comments GaN Systems' CEO Jim Witham. "A world without cords is becoming a realization because of collaboration with visionary companies like PowerSphyr, whose technology, approach and expertise is uniquely positioned to accelerate the wireless power transfer and charging marketplace."

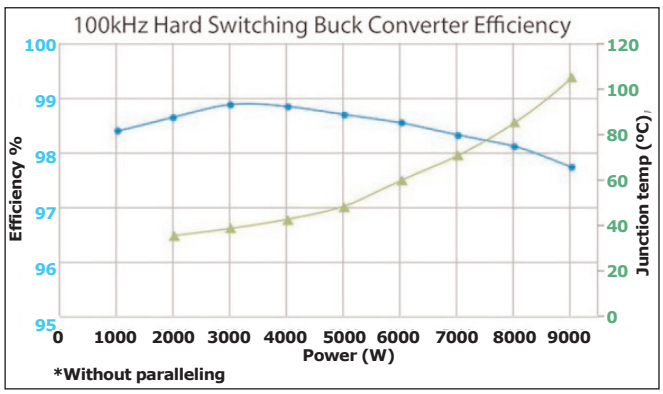
www.powersphyr.com
www.gansystems.com

VisIC announces 9kW GaN half bridge without paralleling

VisIC Technologies Ltd of Nes Ziona, Israel — a fabless developer of power conversion devices based on gallium nitride (GaN) metal-insulator-semiconductor high-electron-mobility transistors (MISHEMTs) — has announced a new water-cooled V22N65A-HBEVB half-bridge evaluation board to demonstrate the high-power performance achievable using its GaN All-Switches (advanced low-loss switches).

The V22N65A-HBEVB evaluation platform consists of:

- a half Bridge power stage using 22mΩ GaN All-Switches;
- an isolated half-bridge driver from Silicon Labs (Si82394);
- two isolated auxiliary power supplies from Murata (NXE251212MC);
- dead time control from 75ns to 200ns; and
- high-current (85A) connectors from Wurth Electronics (74655095R).



The evaluation platform can be operated in any half-bridge topology and was tested in buck and boost topologies up to 9kW, using only single V22N65A transistors. This is said to be the first GaN-based solution on the market that can deliver up to 9kW of power, without the need for paralleling, making it suitable for high-density on-board chargers (OBC) in hybrid and electric vehicles.

The V22N65A All-Switch SMD discrete top-cooled devices feature ultra-low conduction and switching losses coupled with an advanced isolated package design, allowing maximum performance and power out of each GaN device, the firm says.

A low parasitic inductance power and gate loop design, combined with a high threshold voltage (5V), allows designers to safely employ VisIC GaN switches in high-power applications in the multi-kW range.

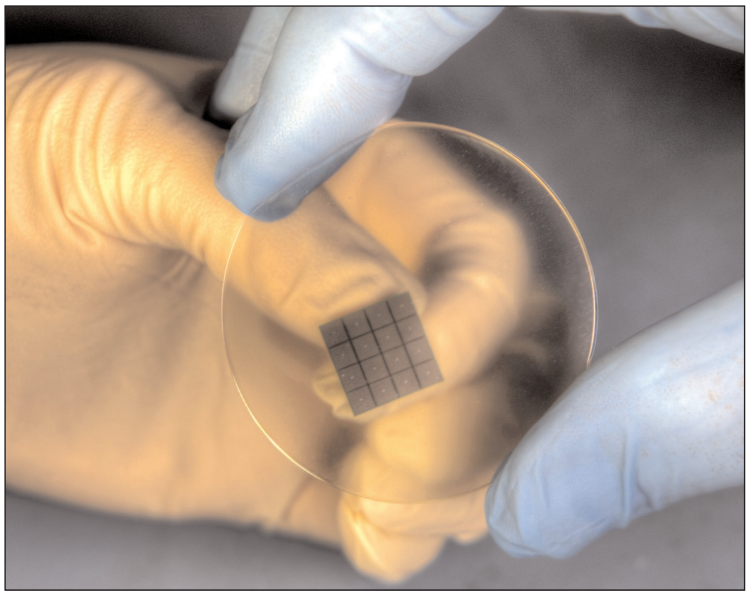
The All-In-One water-cooled V22N65A-HBEVB is available at a cost of $600. An air-cooled version is available for $500.

www.visic-tech.com

NASA studies space applications for GaN crystals

Two teams at the US National Aeronautics and Space Administration (NASA) Goddard Space Flight Center in Greenbelt, MD, USA are being funded to investigate the use of gallium nitride (GaN) to enhance space exploration.

Engineer Jean-Marie Lauenstein and scientist Elizabeth MacDonald are investigating GaN high-electron-mobility transistors (HEMTs) for use in studying how Earth's magnetosphere couples to its ionosphere — a key question in the field of heliophysics which, among other things, studies the forces that drive change in our space environment. Stanley Hunter and Georgia de Nolfo are investigating GaN's use on a solid-state neutron detector that is relevant to both science and homeland security.



The GaN disk and photomultiplier array offer a potential solution for building a detector and imaging short-lived neutrons, which stream off the Sun and are produced from the bombardment of cosmic rays in Earth's protective magnetosphere. Credit: NASA/W. Hrybyk.

GaN transistors

GaN transistors became available commercially in 2010, but they have not yet found their way into space scientists' instruments, despite their potential to reduce their size, weight and power consumption. Even though GaN is predicted to be resistant to many types of radiation damage encountered in space, neither NASA nor the US military has established standards characterizing the performance of these transistor-enabled devices when exposed to the extreme radiation in space.

When struck by galactic cosmic rays or other energetic particles, electronic equipment can experience catastrophic or transient single-event upsets. "We have standards for silicon," says Lauenstein. "We don't know if the methods for silicon transistors would apply to gallium nitride transistors," she adds. "With silicon, we can assess the threshold for failure."

With the funding, Lauenstein and MacDonald are teaming with the Los Alamos National Laboratory in New Mexico, a parts manufacturer, and the NASA Electronic Parts and Packaging to establish criteria assuring that a GaN-type device could withstand the effects of potentially harmful particles produced by galactic cosmic rays and other sources.

The material could be useful in electron-beam accelerators — consisting of GaN transistors — built to map specific magnetic lines in the protective magnetosphere to their footprints in the ionosphere where aurora occur, helping to show how the two regions of near-Earth space connect.

"The team's research on radiation tolerance helps us understand how to fly these accelerators in the harsh space environment over the mission's lifetime," MacDonald says.

According to Lauenstein, these standards will also benefit other scientific disciplines. "We need a path forward for this technology. This opens the door for others to incorporate this technology into their own missions."

Potentially game changing

For de Nolfo and Hunter, GaN offers a potential solution for building a detector and imaging neutrons, which are short-lived and typically expire after about 15 minutes. Neutrons can be generated by energetic events in the Sun as well as cosmic-ray interactions with the Earth's upper atmosphere. The neutrons generated by cosmic rays in the atmosphere can add to the Earth's radiation belt (a swatch of radiation surrounding Earth that, among other things, can interfere with onboard satellite electronics) when they decay. Researchers have discovered that GaN can form the basis of a highly sensitive neutron detector.

In their concept, Hunter and de Nolfo would position a GaN crystal inside an instrument. As neutrons entered the crystal, they scatter off gallium and nitrogen atoms and, in the process, excite other atoms, which then produce a flash of light, revealing the position of the neutron that initiated the reaction. Silicon photomultipliers attached to the crystal convert the flash of light into an electrical pulse to be analyzed by the sensor electronics.

"Gallium nitride is reasonably well understood in the photo-electronics industry, but I think we're pushing the envelope a little on this application," says Hunter, adding that the beauty of the concept is that it would contain no moving parts, use little power, and operate in a vacuum. If it works, the instrument would benefit different space science disciplines and the military in detecting nuclear material, he adds.

www.nasa.gov/centers/goddard

Northrop Grumman delivers first GaN G/ATOR system to US Marine Corps

Northrop Grumman Corp of Redondo Beach, CA, USA has delivered the first AN/TPS-80 Ground/Air Task-Oriented Radar (G/ATOR) that incorporates high-power and high-efficiency gallium nitride (GaN) antenna technology, further improving the system's operational capabilities. The system was delivered to the US Marine Corps ahead of schedule and is the seventh G/ATOR delivered in the low-rate initial production (LRIP) phase of the program.

Four G/ATOR systems preparing for fielding located at Northrop Grumman's Stoney Run test range in Baltimore.

All subsequent G/ATOR LRIP and full-rate production systems will now incorporate GaN technology, which provides cost savings and performance benefits including enhanced system sensitivity and increased reliability.

Delivery of the first GaN G/ATOR system follows the delivery of six LRIP systems to the Marines that began in early 2017. Using two of those six systems, the Marine Corps achieved G/ATOR Initial Operational Capability (IOC) of the air surveillance mission in February. The remaining four systems will establish IOC for the counter-battery mission later this year. As a result, G/ATOR systems, trained Marines and associated logistics support are now in operational service with Marines.

The AN/TPS-80 G/ATOR is an active electronically scanned array (AESA) multi-mission radar that provides comprehensive real-time, 360-degree situational awareness against a broad array of threats including fixed-wing aircraft, helicopters, cruise missiles, unmanned autonomous systems (UAS), and rockets, artillery and mortar. It is rapidly deployable worldwide to meet US Marine Corps needs and includes the latest cyber and digital beam forming technology that enables the radar to perform multi-mission tasks at significantly lower operation and maintenance costs compared to existing USMC radar systems.

"The Marine Corps are the first to take delivery of a production ground-based multi-mission AESA radar that incorporates this advanced GaN technology," says Roshan Roeder, VP, land & avionics C4ISR division, Northrop Grumman. "The incorporation of this advanced technology in production radars is unique to the Marine Corps and enables G/ATOR to provide additional mission capability to the warfighter at an affordable cost."

Both the Marine Corps and Northrop Grumman continue to make detailed preparations to execute the full-rate production program, which is scheduled to begin in early 2019.

Additionally, given the AN/TPS-80's open architecture design, Northrop Grumman was awarded a contract via the Office of Secretary of Defense Strategic Capabilities Office in 2016 to support the addition of a fire control mission.

www.northropgrumman.com

Compound Semiconductor Applications Catapult to receive £51m from UK Catapult network

Innovation Centre to open in South East Wales in early 2019

Secretary of State for Wales Alun Cairns has announced that the Compound Semiconductor Applications Catapult — Wales' first and the UK's newest Catapult — will open its Innovation Centre, based in South East Wales, in early 2019.

He also confirmed that the Catapult will receive £51m of grant funding from the £780m investment in the UK's Catapult network, announced by UK Chancellor Philip Hammond as part of the Government's industrial strategy. This builds on the £180m announced in July by Prime Minister Theresa May for centers in the North East, taking the total of additional funding to almost £1bn.

The Compound Semiconductor Applications Catapult is a not-for-profit organization focused on accelerating the adoption of compound semiconductors and on bringing applications to life. It aims to help the UK economy grow and works across the UK within a range of industry sectors from automotive to medical, and from digital communications to aerospace.

The Catapult has already employed 23 people and is set to create around 100 new jobs internally. By 2023 it aims to have helped to create 1000 new jobs within the businesses it has supported around the whole of the UK.

With analysts predicting that the world market for compound semiconductors will increase from $66bn today to over $300bn by 2030, the UK intends the Catapult to play a substantial part in tapping that growth.

"This investment in the Compound Semiconductor Applications Catapult cements Wales' reputation as a leader in advanced electronics," comments Cairns. "Bringing together academics and businesses to develop new technologies will support areas of our daily lives from the next-generation 5G mobile network to improving scanning at airport security. Our investment in this technology will help Welsh businesses exploit a hugely lucrative global market," he adds.

Artist's impression of Cardiff University's Innovation Campus.

"Our Catapult is a UK-wide center, based in Wales. With immediate effect, this grant funding will allow the Catapult to create a critical mass of industry-leading expertise at the heart of the world's first compound semiconductor cluster in South Wales," says Compound Semiconductor Applications Catapult CEO Stephen Doran. "The transformative potential for compound semiconductors to meet the challenges of the future has never been higher, and our new Innovation Centre will make sure that Wales is at the forefront of this revolution."

The Catapult Innovation Centre will house a design studio, laboratories and test facilities, supported by simulation and modeling tools and advanced capabilities. It will help companies to accelerate the development of new products using compound semiconductors.

The Compound Semiconductor Applications Catapult has also set out its strategy with the publication of its brochure 'Launching the Compound Semiconductor Applications Catapult', which was developed in collaboration and with input from over 150 companies in the sector.

The strategy focuses around three areas:

- the Catapult's new Innovation Centre;
- designing and manufacturing a series of Evaluation Modules to help companies prototype systems; and
- running a series of Challenge Programmes to identify how compound semiconductors can best address global challenges.

"So far we have had contact with more than 150 businesses from around the UK and that has allowed us to develop an in-depth understanding of the compound semiconductor market and create a strategy that will help us to support and collaborate with industry," says Doran. "We are open for business and looking for great people to help us make these innovations happen."

The Catapult is actively looking to fill positions across all levels of the organization and in particular its three technology areas: Power Electronics, Photonics, and Microwave and RF. Working with the Catapult can provide the opportunity to contribute and shape a business in its early stages with the stability of secured funding within which to operate. The Catapult aims to have a collaborative, supportive and inclusive culture, which will be reflected in its Innovation Centre with agile workspaces and settings for different types of working behaviour. The Catapult also claims a fast-moving entrepreneurial culture and a strong financial footing.

https://csa.catapult.org.uk

StratEdge receives ISO 9001:2015 QMS certification

StratEdge of San Diego, CA, USA (which designs and manufactures packages and provides chip assembly & test services for microwave, millimeter-wave and high-speed digital devices) says that DNV GL - Business Assurance has found it to conform to the quality management system standard ISO 9001:2015. The certificate is valid for the design and manufacture of semiconductor packages, filters and electronic component assembly.

"ISO 9001:2015 reflects the changes in the industry since the 2008 version of the certification," notes president Tim Going. "As a company that manufactures and assembles very high-precision, high-frequency packages, we have always had to be ahead of the curve in our manufacturing capabilities, practices, and procedures," he adds. "Quality must be a given for our packages to function as intended or the high-reliability products that depend on our packages will not work. This new certification validates procedures that we abide by on a regular basis."

www.stratedge.com

NI AWR releases V14 of Design Environment software platform

RF/microwave electronic design automation (EDA) software provider NI (formerly AWR Corp) of El Segundo, CA, USA says that V14 of its Design Environment platform has been released and is available to download for current customers and evaluators.

The latest release includes new features, add-on modules and enhancements to the NI AWR Design Environment software suite of products, including Microwave Office/Analog Office circuit design software, Visual System Simulator (VSS) system design software and AXIEM planar and Analyst 3D finite-element method (FEM) electromagnetic (EM) simulators.

In particular, the V14 release focuses on streamlining and expediting all stages of design — from initial starts using powerful network synthesis to circuit, system and EM simulation technology improvements for performance analysis, optimization and verification. Along with enhancements to design flow automation, the release can accelerate RF/microwave designs from concept to product.

Highlights include:

Design Environment, Layout and Automation

- advanced report/measurement management
- improved report generation for power amplifiers (PAs)
- expanded PCB import wizard automates layout edit/capture
- enhanced iNet intelligent net routing and layout manager

System Simulation and Models/Libraries

- phased-array generation wizard (add-on module)
- new spatial channel models
- system bus support

Circuit Simulation and Models/Libraries

- new network synthesis for impedance matching (add-on module)
- new tuner interface for large-scale parametric design
- loop gain stability analysis

EM Simulation and Modeling

- port points for component/EM integration
- 3D internal wave ports
- support for conformal structures such as antennas.

V14 can be downloaded by via the customer portal download site.

www.awrcorp.com/products

Silanna to set up advanced manufacturing research facility at University of Adelaide

picoFAB to drive compound semiconductor research program using new $6.5m Veeco MBE system

Silanna Group of Brisbane, Australia (which was founded in 2006 to develop and productize advanced technologies) is partnering with the University of Adelaide to establish an advanced manufacturing research facility on its campus, developing products through the engineering of innovative semiconductor technology.

The first stage of the partnership is the establishment of the 'picoFAB' facility in the Faculty of Engineering, Computer and Mathematical Sciences. The first of its kind in South Australia, the facility aims to engineer new semiconductor materials at the atomic level, using novel materials and unique techniques.

The new facility will drive Silanna's compound semiconductor research program, centered around a new US$6.5m molecular beam epitaxy (MBE) system that has been purpose-built by Veeco Instruments Inc of Plainview, NY, USA.

As an ISO 9001-certified firm with operations and design centers in Sydney, San Diego, Raleigh, Toronto and Singapore, Silanna has a track record in demonstrating new semiconductor technologies and commercialization. The establishment of picoFAB will add to the university's diverse materials research programs, as well as the state's growing advanced manufacturing industry.

Silanna's chief scientist Dr Petar Atanackovic in the picFAB facility at the University of Adelaide.

Silanna's products are used in the communications, defence, medical and space industries, including new types of solar cells, antennas for mobile phones, power switches and light-emitting diodes.

Chief scientist Dr Petar Atanackovic is a University of Adelaide graduate. After graduation he went to California's Silicon Valley and Stanford University. He founded materials start-up Translucent Inc in Palo Alto, CA, USA. Upon returning to Australia, he developed commercial-scale aluminium gallium nitride.

"I wanted to help create the same opportunities I had in Silicon Valley at the University of Adelaide," says Atanackovic. "The university has some unique capabilities on campus with research and training programs that are complementary to our operations, and access to a whole generation of potential young 'quantum mechanics' as future employees," he adds.

"Together with the new high-tech ecosystem that's developing in Adelaide, and Adelaide's lifestyle and culture as a centre of learning, there are clear drawcards to overseas professions and businesses wanting to establish themselves and take advantage of the opportunities that are here. Adelaide is very similar to Santa Barbara about 30 years ago," he reckons.

"The new partnership between the University of Adelaide and Silanna Group is a great example of industry and researchers working together to develop new commercial solutions and drive innovation," says South Australian Minister for Industry and Skills the Hon. David Pisoni. "Silanna's new facility adds advanced manufacturing capabilities in South Australia that will attract further investment into our state. Importantly, it will provide STEM students with access to world-class infrastructure that will give them practical experience and further their employment opportunities in their home state," he adds.

"Having Silanna in our faculty means our students will be interacting with industry researchers and global leaders in materials engineering for a great educational experience," comments professor Anton Middelberg, executive dean of the Faculty of Engineering, Computer and Mathematical Sciences.

www.silanna.com

5N Plus doubles production capacity

Electronic Materials division addressing growing demand in sensing and imaging technologies

Specialty metal and chemical products firm 5N Plus Inc of Montreal, Québec, Canada is doubling the capacity of its ultra-high-purity Semiconductor plant to enable its Electronic Materials division to satisfy the growing demand for its specialty semiconductor materials for advanced sensing and imaging technologies in a new generation of medical devices, and in security and defense applications.

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

Launched in 2016, the company's strategic plan 5N21 identified the specialty semiconductor sector as a key growth area, aiming to grow the revenue contribution from this sector to 15% of total revenue by 2021. This investment should be completed by mid-2019 and is included in the overall investment envelope envisioned under 5N21 which aims to deliver adjusted EBITDA of US$45m along with 17% return on capital employed by 2021.

The portfolio of ultra-pure semiconductor engineered materials produced by 5N Plus reaches purity levels of more than 99.99999% (7N) and are increasingly being used in sensing, imaging and optoelectronic applications across growing industries.

In the medical industry, these materials are critical for detectors in dental x-ray imaging systems, bone mineral density measurements and advanced single-photon emission computed tomography (SPECT) molecular imaging systems. Recently, the firm has developed ultra-pure semiconductor products targeting the next generation of x-ray computed tomography (CT) medical imaging systems. These materials enable multi-color imaging capabilities and reduction in radiation dosage, all of which are expected to improve safety and reliability of diagnostics.

In the security industry, the firm is seeing increased demand for materials related to advanced detectors in gamma-ray, x-ray and neutron radiation, with an emphasis on enhanced resolution and expanded capabilities across applications including baggage screening, civil nuclear safety, hazardous material detection, liquid detection and other safety- and security-related applications.

In the defense industry, demand comes from applications related to high-performance infrared imagery, early-detection systems and surveillance applications for which high-purity semiconductor engineered materials play a crucial role in improving system sensitivity and device imagery.

"Over the last two decades, 5N Plus has developed a wide spectrum of precursors which are recognized worldwide as the reference materials for the fabrication of advanced solid-state semiconductor detectors," says Nicholas Audet, executive VP, Electronic Materials. "Given the emergence of more stringent requirements within healthcare, security and defense industries, 5N Plus is uniquely positioned to address these opportunities," he reckons. "This investment will not only support the growing market demand but will also reinforce 5N Plus' global leadership position in this field."

www.5nplus.com

AXT's revenue grows 11% in Q2/2018

Increased raw materials pricing yields first contribution to profitability from seven part-owned JVs in ten quarters

For second-quarter 2018, AXT Inc of Fremont, CA, USA — which makes gallium arsenide (GaAs), indium phosphide (InP) and germanium (Ge) substrates and raw materials in Beijing, China — has reported revenue of $27.1m, up 11.1% on $24.4m last quarter and up 15% on $23.6m a year ago (and exceeding the $25.5–26.5m guidance), reflecting "solid demand in each of our primary product categories," says CEO Morris Young.

Of total revenue, raw material joint ventures (namely the three companies consolidated into AXT's results) contributed $5.5m, up 7.8% on $5.1m last quarter. "We have seen an uptick in the price of raw materials," notes Young. For example, gallium has risen from last year's all-time low of $110–120/kg to about $200/kg (although still down on 2011's $800–900/kg). "This has enabled a financial improvement in some of the [seven] raw material companies in which we have partial ownership [non-consolidated, accounted for using the equity method, and hence contributing to improved profitability]," he adds. "Q2 was the first time that these seven companies have previously presented a collective gain to our financial statement in ten quarters. Each provides strategic advantage for our business."

Substrate sales contributed $21.6m, up 11.3% on $19.4m last quarter.

"Broadly, the demand environment for our wafers remains strong, and we continue to focus on producing high-quality products that meet rigorous application requirements, as well as achieving greater efficiency in our manufacturing process," says Young.

In particular, revenue from both semi-insulating and semiconducting GaAs grew, due mainly to a wide variety of applications showing incremental growth. "Gallium arsenide appears to be experiencing a resurgence of demand with new applications and advancement in existing applications driving its use," notes Young. "The largest contributor to all revenue continued to be power amplifiers and Wi-Fi chips for wireless devices, LED lighting, signage and display and infrared applications. But we have seen smaller but meaningful demand from many other applications including solar panels, surveillance cameras, biometric centers, horticultural lighting and more," he adds.

Germanium substrate revenue was again strong (growing by more than 70% since Q1/2017) as the satellite industry continue its positive trend.

InP revenue was a record. "Demand was particularly strong in China, driven by increasing number of broadband subscribers," says Young. "The passive optical network (PON) market was really strong in the first quarter and second quarter, but towards the end of the second quarter the PON market started to turn south, since customers have built some inventory," he adds.

Gallium has risen from last year's all-time low of $110–120/kg to about $200/kg (although still down on 2011's $800–900/kg). "This has enabled a financial improvement in some of the [seven] raw material companies in which we have partial ownership"

Of total revenue, 67% came from Asia Pacific, 8% from North America and 25% from Europe. No customer reached 10% of revenue, and the top five generated about 33% (down from 38%), showing that growth is "diversified in both products and customers," says AXT.

Gross margin has risen further, from 30.8% a year ago and 39.2% last quarter to 40.6%. This is due to (1) a favorable product mix; (2) the increase in raw materials pricing that positively impacted margins at the three consolidated raw material joint ventures; and (3) no longer writing down gallium at one of the three JVs (boosting total company gross margin by about 1%).

Operating expenses have risen from $5m a year ago and $5.6m last quarter to $6.5m, due largely to an extra $0.56m from: (i) a one-time bonus payout at one of the subsidiaries of about $0.35m; (ii) site consulting fees of $0.12m regarding the relocation of GaAs and Ge manufacturing from Beijing to the new facility about 90 miles south in Dingxing, China; and (iii) $0.01m in filing fees for business licenses and registrations as a result of the relocation. For first-half 2018, operating expenses are $12.1m (about $6m per quarter, in-line with the expected run rate for the year).

Net income has risen further, from $1.9m ($0.05 per diluted share) a year ago and $2.9m ($0.07 per diluted share) last quarter to $3.9m ($0.10 per diluted share, exceeding the $0.07–0.09 per share guidance).

Depreciation and amortization was again steady at $1.2m. Capital expenditure (CapEx) was $8.7m.

During the quarter, cash, cash equivalents and investments fell from $67m to $54m, due mainly to spending on the new facility and equipment as well as an increase in inventory from $51.1m to $57m, of which 52% was in raw materials, 44% in work in progress (WiP) and

only 4% in finished goods.

"The increase in inventory was a deliberate decision based on two primary factors," remarks VP & chief financial officer Gary Fischer. "First, with the ramp of our new manufacturing facilities [in Dingxing], we are carrying inventory in multiple locations. Second, the prices of both raw gallium and raw germanium have been increasing meaningfully and our supply-chain investments allow us to be a first responder to such changes. As such, we have taken certain opportunities to purchase ahead in order to achieve a better cost structure for our substrate business. It is important to note also that 80% of our total inventory consists of raw materials and ingot WiP. At this stage, there is no customization and no shelf-life concerns. This makes the possibility of obsolescence of no real concern. The additional 16% is wafer WiP, which can contain some customization but a huge percentage is for existing high-volume customers," he adds. "Looking ahead, we expect to be able to turn the total inventory number down over time."

For third-quarter 2018, AXT expects revenue to grow to $27.5–28.5m, with earnings per share of $0.08–0.10.

"The ongoing need for faster networks and increasing fiber-to-the-home (FTTH) requirements will continue to fuel InP-based applications, although it may be somewhat lumpy in the second half," notes Young. "We are beginning to see an improvement in demand for InP for data-center connectivity that recurred in Q1 and Q2," says Young. "The continued adoption of silicon photonics technology in hyperscale and enterprise data centers, as well as the transition over time to 100G and 400G technologies, will drive the need for indium phosphide for many years to come," he believes.

Emerging application such as 3D sensing, LiDAR for autonomous cars and wireless-based Internet connectivity are expected to provide an opportunity for growth over the next 18 months. The timing of these opportunities coincides nicely with our capacity expansion

For germanium, positive market conditions are likely to provide an opportunity for sustained growth over the coming quarters, reckons the firm.

For GaAs, emerging application such as 3D sensing, LiDAR for autonomous cars and wireless-based Internet connectivity are expected to provide an opportunity for growth over the next 18 months. "The timing of these opportunities coincides nicely with our relocation and capacity expansion," notes Young. "We will continue to make solid progress in bringing up new product production lines, hiring and training personnel, and working with customers to fulfill their qualification requirements. Our internal qualification results to-date demonstrate consistent specifications across our sites. In addition, we have completed a number of customer qualifications and are in the process with many more including all of our major customers," he adds. "Our strategy is to execute the move in a measured and incremental way. This enables us to mitigate risks and provide a seamless transition for our customers while ramping up to meet our increasing demand. By the end of the year, we expect to have relocated approximately 60% of our wafer production, and we expect to complete the process by mid-2019."

www.axt.com

QuantumClean and ChemTrace demonstrating how to reduce wafer fab CoO in Tech Talks at SEMICON Taiwan

In a series of Tech Talks in booth J2734 at the SEMICON Taiwan 2018 show in Nangang Exhibition Center, Taipei, Taiwan (5–7 September), QuantumClean and ChemTrace (divisions of Quantum Global Technologies LLC of Quakertown, PA USA) are demonstrating how their ultra-high-purity cleaning, proprietary coatings and micro-contamination analytical testing can help to reduce wafer fabrication cost-of-ownership (CoO).

QuantumClean and ChemTrace will give short presentations on atomic layer deposition (ALD), chemical vapour deposition (CVD), diffusion, etch, ion implantation and physical vapour deposition (PVD) ultra-high-purity cleaning and Parts Quality Monitoring customer solutions to educate original equipment manufacturers (OEMs), integrated device manufacturers (IDMs), original product manufacturers (OPMs) and foundries on how they can reduce CoO. The presentations discuss how: cleaner chambers start-up more quickly; faster part turnaround times reduce inventory; longer Mean Time Between Cleans improves productivity and reduces PM (preventative maintenance) costs; and less aggressive cleaning methods and recoating extend part life.

"SEMICON Taiwan 2018 visitors can attend Tech Talks at our booth J2734 to learn how our differentiated service offerings can bring improvement to your operation by solving critical semiconductor process chamber part-related manufacturing challenges," says Quantum Global Technologies' president & CEO Scott Nicholas.

www.quantumclean.com

Riber's first-half revenue grows 36% year-on-year as MBE system sales quadruple

Orders more than double, boosted by purchases of evaporators for photovoltaic industry

Riber S.A. of Bezons, France — which manufactures molecular beam epitaxy (MBE) systems as well as evaporation sources and effusion cells — has reported year-on-year revenue growth of 36% from €12.5m in first-half 2017 to €17m in first-half 2018. Asia contributed 74% of revenue (down from 84.2%), Europe 20% (up from 12.2%) and the USA 6% (up from 3.4%).

System revenue more than quadrupled from just €0.9m to €4.1m, reflecting the delivery of four machines (including three research units) compared with just one research machine in first-half 2017.

Services & Accessories revenue fell by 10% from €2.8m to €2.5m.

Evaporator revenue (cells and sources) grew by 18% from €8.8m to €10.4m, due to the high level of deliveries for the screen industry (from which most of the orders were delivered during the first half of the year).

The order book at end-June has doubled, from €16.8m to €34.1m.

Specifically, Systems orders more than doubled, rising by 128% from €10.5m to €24m (nine production machines versus four, and four research machines versus three). This excludes the order from China for a production machine, announced on 12 July.

Services & Accessories orders rose by 23% from €5.1m to €6.3m, reflecting the positive trend for production and research MBE activities.

Evaporator orders more than tripled, rising by 214% from €1.2m to €3.8m, driven by purchases for the photovoltaic industry.

Riber expects revenue in second-half 2018 to be up on second-half 2017. For full-year 2018, the firm is targeting year-on-year revenue growth of at least 15%, in view of the planned delivery timetable (which extends until 2019).

Earnings figures for first-half 2018 will be released on 27 September.

www.riber.com

Veeco's GEN10 automated MBE cluster system wins Max Planck Institute tender to support research on oxide–nitride layer structures

Veeco Instruments Inc of Plainview, NY, USA says that its dual-chamber GEN10 automated molecular beam epitaxy (MBE) cluster system has won the tender offer by the Max Planck Institute of Microstructure Physics (MPI-MSP) of Halle (Saale), Germany to support research on complex oxides.

Demand for oxide-nitride layer structures has increased due to their potential in enabling next-generation energy-efficient nano-devices and advanced data storage. The department of Nano-systems from Ions, Spins and Electrons (NISE) at MPI-MSP aims to use Veeco's MBE technology to expand research and develop innovative applications.

"Our team is highly interested in exploring the properties of atomically engineered oxide-nitride layer structures especially because of their extraordinary properties but also for their potential in paving the way to novel energy-efficient nano-devices," says Stuart Parkin, director of the NISE at MPI-MSP and Alexander von Humboldt Professor at Martin Luther University Halle-Wittenberg. "Veeco's reputation and expertise in MBE combined with the GEN10's high reliability, throughput, customization and automation capabilities will help support our research into novel materials."

Veeco says that the win at MPI marks the first time that it has provided a fully integrated solution for a concentrated ozone source. The GEN10 allows for up to three configurable material-specific growth modules, enabling high system utilization and allowing multiple researchers use the system at the same time to perform unattended growth. By expanding its reach in the R&D sector worldwide, Veeco is aiding the growth of complex oxide structures.

Veeco's MBE systems continue to expand their footprint in the global R&D space, says Gerry Blumenstock, VP & general manager of MBE and ALD products. "We are pleased with the confidence Dr Parkin and his team placed in our MBE expertise and we look forward to supporting the MPI-MSP as it continues to lead R&D exploration and applications for complex oxides," he adds.

www.mpi-halle.mpg.de/NISE
www.veeco.com/technologies-and-products/mbe-systems

Veeco reports higher-than-expected Q2 profits, despite falling revenue from sales of blue LED MOCVD systems to China

Gross margin to surpass 40% by year-end, driven by growth in higher-margin, non-LED applications

For second-quarter 2018, epitaxial deposition and process equipment maker Veeco Instruments Inc of Plainview, NY, USA has reported revenue of $157.8m, down slightly on $158.6m last quarter but up 40.6% on $112.2m a year ago.

Geographically, the USA has risen from 15% to 21% and Europe, Middle East & Africa (EMEA) from 10% to 16%, while China has fallen from 47% of total revenue to 45% (including sales of metal-organic chemical vapor deposition systems for blue LEDs falling from 39% to 31%) and the rest of the world has fallen from 28% to 18%.

Of total revenue, the Lighting, Display & Compound Semiconductor segment fell slightly from $90m to $88m (from 57% of total revenue to 55%, including the 31% for blue LED MOCVD systems for China).

The Advanced Packaging, MEMS & RF Filter segment — including lithography and Precision Surface Processing (PSP) systems — fell back slightly from $27m to $25m (from 17% of total revenue to 16%).

The Scientific & Industrial segment (including shipments for data storage as well as optical coding applications) fell from $32m to $27m (from 20% of total revenue to 17%).

The Front-End Semiconductor segment (formerly part of the Scientific & Industrial segment, before the May 2017 acquisition of lithography, laser-processing and inspection system maker Ultratech of San Jose, CA, USA) rebounded from $9m to $18m (doubling from 6% of total revenue to 12%), which included revenue from ion beam etch systems for STT-MRAM manufacturing as well as laser spike annealing (LSA) systems.

Ultratech product lines have performed below the projections made at the time of the acquisition, due to lower-than-expected unit volumes of certain vendors' smartphones that incorporate fan-out wafer-level packaging as well as a delay in the adoption of fan-out wafer-level packaging by other electronics manufacturers. In addition, there has been a delay in the build-out of 28nm fabs in China that were expected to buy LSA systems. Veeco has hence had to assess the carrying value of intangible assets on the books and has recorded an impairment charge of $252m for GAAP results (a non-cash charge, so it does not affect liquidity, day-to-day operations or non-GAAP results). "Relative to the current run rates, we are confident about the growth of this business in future in both the Front-End Semi as well as Advanced Packaging markets," comments chief financial officer Sam Maheshwari.

"Veeco had solid Q2 performance with non-GAAP gross margin, operating income, net income and EPS at the high end of our guided ranges," notes chairman & CEO John R. Peeler.

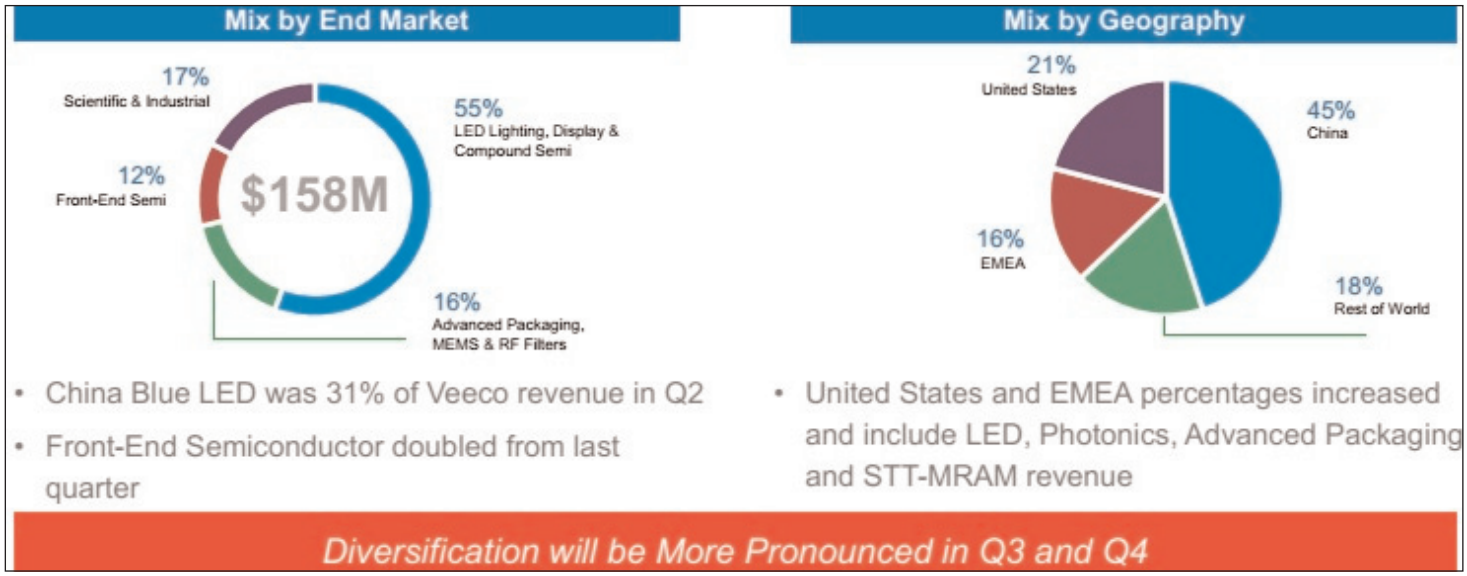
Although gross margin has fallen from 39.1% a year ago and 36.5% last quarter to 35.8%, this exceeds the 33-35% guidance due to better product mix as well as favorable cost structure in warranty and manufacturing areas. Collective first-half gross margin of 36% was also higher than expected.

Operating expenditure (OpEx) has been cut slightly from $46.5m last quarter to $45.7m, better than the guidance of $46–48m. "We continue to make progress towards generating synergies through the integration of Ultratech," says Peeler. "After unifying our enterprise resource planning (ERP) systems, we're now eliminating redundant manufacturing operations by closing one of the Singapore manufacturing sites," he adds. "We expect to complete this initiative by the end of Q1/2019 and anticipate approximately $2m in annualized savings."

Operating income was $10.8m, down from $11.3m last quarter but up from $6.7m a year ago. Likewise, net income was $7.2m ($0.15 per diluted share), down from $9.2m ($0.20 per diluted share) last quarter but up from $4m ($0.09 per diluted share) a year ago, and towards the high end of the guidance of $1–10m ($0.01–0.20 per diluted share).

However, cash and short-term investments fell during the quarter from $310.6m to $261m, driven by working capital investments. Accounts receivable rose from $108m to $134m due to shipments being backend-loaded in the quarter. Inventory rose from $131m to $146m (from 61 days to 76 days) as Veeco invests to get ready to launch new products in second-half 2018. Lastly, customer deposits fell due to a reduction in orders from China-based MOCVD customers.

Order bookings in Q2 were $132m, down 14.8% on $155m last quarter. This was mainly due to the weakness in the LED Lighting, Display & Compound Semiconductor segment, where Veeco is beginning to see LED makers delay orders as they absorb recently added capacity. Specifically, blue LED MOCVD orders from China for general lighting and backlighting applications fell quarter-over-quarter. "Between 2017 and the first half of 2018, several hundred MOCVD reactors for blue LEDs were shipped into the market and we expect an absorption



period," notes Peeler. In contrast, in Scientific & Industrial markets, Veeco saw a sharp increase in orders from data storage customers, particularly for ion beam deposition tools.

Order backlog fell during Q2 from $331m to $305m. However, about two-thirds of this is scheduled to ship in 2018. The other third includes longer-lead-time ion beam systems that are scheduled to ship in first-half 2019.

"Currently, there are two market dynamics happening at the same time," notes Peeler. "First, with the addition of Chinese competition for MOCVD, the general lighting and backlighting market is becoming commoditized and pricing has declined. We began to see this towards the end of 2017 with orders at very low gross margins. Second, there is an emergence of new applications such as photonics for 3D sensing, GaN power devices for electronics and electric vehicles, GaN RF devices for 5G RF, and micro-LED displays. Our strategy in this market has been to focus on delivering value through differentiated technology, and our R&D has been aligned with this strategy for some time, resulting in a broad MOCVD product portfolio to address these emerging applications," he adds.

"We had several announcements throughout the quarter that highlighted the traction we are receiving as a result of our innovation. They highlighted customer wins in our exciting growth markets of Photonics, Display, Advanced Packaging for Memory and Power Electronics," says Peeler.

"In 3D sensing, we were pleased to see additional phone manufacturers adopt VCSEL-based facial recognition in their devices. We will be shipping systems in the second half of this year to address this demand. We are engaged with several VCSEL manufacturers for their epi process and are getting ready to invest for volume production. We also had recent traction with wet etch and clean products for metal lift-off and photoresist strip for VCSEL manufacturing, and we believe 3D sensing growth is just beginning," Peeler says. "In GaN RF and GaN Power markets, we are engaged with several large IDMs with our single-wafer Propel platform. Our Propel installed base is expanding and we are well positioned to capitalize when mass production ramps. Recently, we shipped multiple wet etch and clean products to Taiwanese foundries for production of RF amplifiers and other compound semiconductor applications," he adds. "We expect photonics and RF devices to continue to provide growth potential for us."

"The overall distribution of bookings across our markets was more balanced, notwithstanding the very strong bookings for Scientific & Industrial," notes Peeler. Advanced Packaging, MEMS & RF Filters comprised 19% of total bookings, Lighting, Display & Compound Semi 14%, Front-End Semi 21%, and Scientific & Industrial orders 46%. Diversification should be more pronounced in Q3 and Q4/2018.

For Q3/2018, Veeco expects revenue to fall to $130–140m, due to the softness in China MOCVD shipments, partially offset by strength in ion beam systems. Gross margin should rise to 36–38%. Despite operating expenses being cut further to $43–45m, the firm expects drops in operating income to $4–9m and net income to $1–6m ($0.03–0.13 per diluted share).

Q4/2018 revenue is seen tracking flat with Q3, but with higher gross margin. While revenue is expected to continue to see growth in all four market segments in 2018, low-margin blue LED MOCVD system sales in China in particular are expected to decline. "As sales from the rest of our businesses grow and increase as a proportion of our overall business, we expect gross margin for the company to pick up," says Peeler. "We remain committed to a target of exiting the year at 40% gross margin [with second-half gross margin improving on first-half 2018's 36%]."

Beyond Q4, gross margin for calendar 2019 is expected to be higher than 40% as a result of sustainable better product mix and completing cost-reduction initiatives.

www.veeco.com

Aixtron's orders rise 20% year-on-year in first-half 2018, driven by MOCVD systems for lasers and red-orange-yellow LEDs

Full-year order intake guidance raised from €230–260m to €260–290m

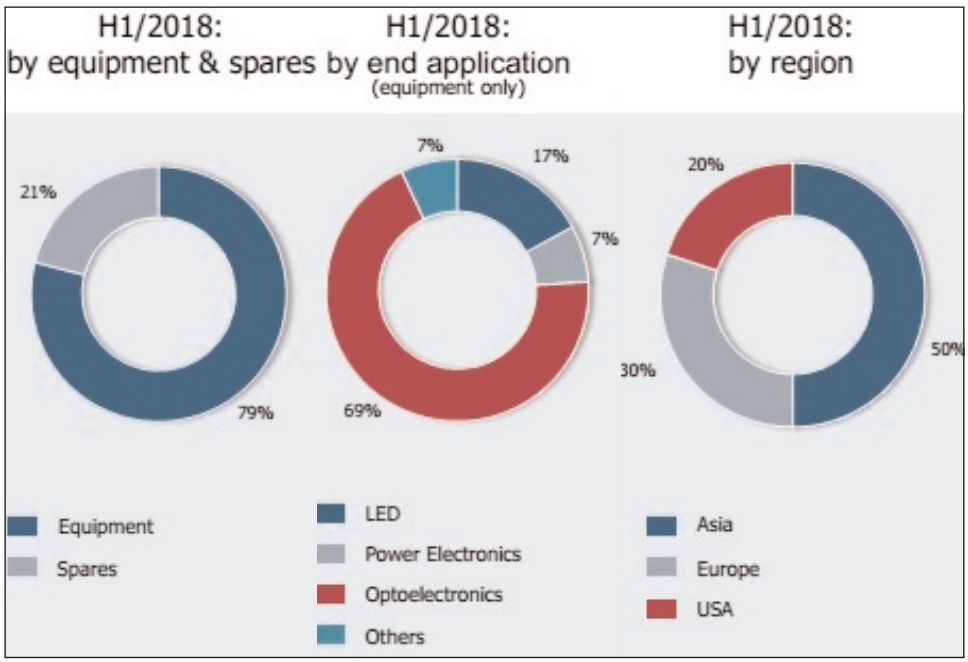
For first-half 2018, deposition equipment maker Aixtron SE of Herzogenrath, near Aachen, Germany has reported revenue of €117.6m, up 3% on first-half 2017's €114.1m, although Q2's €55.2m was down 12% on Q1's €62.4m due solely to the scheduling of shipments in accordance with customers' target delivery dates.

Revenue and order intake in first-half 2018 were driven by continued demand for AIX 2800G4 metal-organic chemical vapor deposition (MOCVD) systems for the production of red-orange-yellow (ROY) LEDs (e.g. for displays) as well as lasers such as vertical-cavity surface-emitting lasers (VCSELs) or edge-emitting lasers (EELs) for applications in 3D sensing and optical data transmission.

Correspondingly, on a regional basis, just 50% of revenue came from Asia (falling from 82% in first-half 2017), while Europe has leapt from just 8% to 30% and the USA from 10% to 20%.

Due to the favorable product and regional mix (aided by a positive $/€ exchange rate during Q2), gross margin has recovered from 25% in first-half 2017 (when inventories were being cleared) to 43% in first-half 2018.

Operating expenses (OpEx) in first-half 2018 were €38.7m (33% of revenue), down 26% on first-half 2017's €52.4m (46% of revenue) which included €12.1m in write-downs related to frozen product lines as well as atomic layer deposition/chemical vapor deposition (ALD/CVD) activities for memory chip production (based at US subsidiary Aixtron Inc in Sunnyvale, CA, USA) that were divested to Eugene Technology Inc last November.



Most significantly, R&D costs have been slashed by 32% from €39.5m in first-half 2017 to €27m in first-half 2018. However, this was due mainly to the sale of the memory business and the freezing of development activities in III-V-on-silicon (TFOS) for microprocessor logic. Excluding this, R&D costs were cut organically by 6% from €28.8m (from 25% of revenue to 23%).

Compared with a loss of –€24m in first-half 2017, operating result (EBIT) improved to a profit of €12m in first-half 2018 (margin of 10% of revenue).

Compared with +€43.3m in first-half 2017, operating cash flow was –€8.5m in first-half 2018, as the +€12.5m in Q2 could not fully offset the –€21.1m from Q1, which resulted primarily from scheduled payments in connection with the sale of the ALD/CVD product line in Q4/2017. Capital expenditure (CapEx) was €4.5m (up from €3.6m in first-half 2017). Total cash flow was –€11.8m (compared with +€37m in first-half 2017).

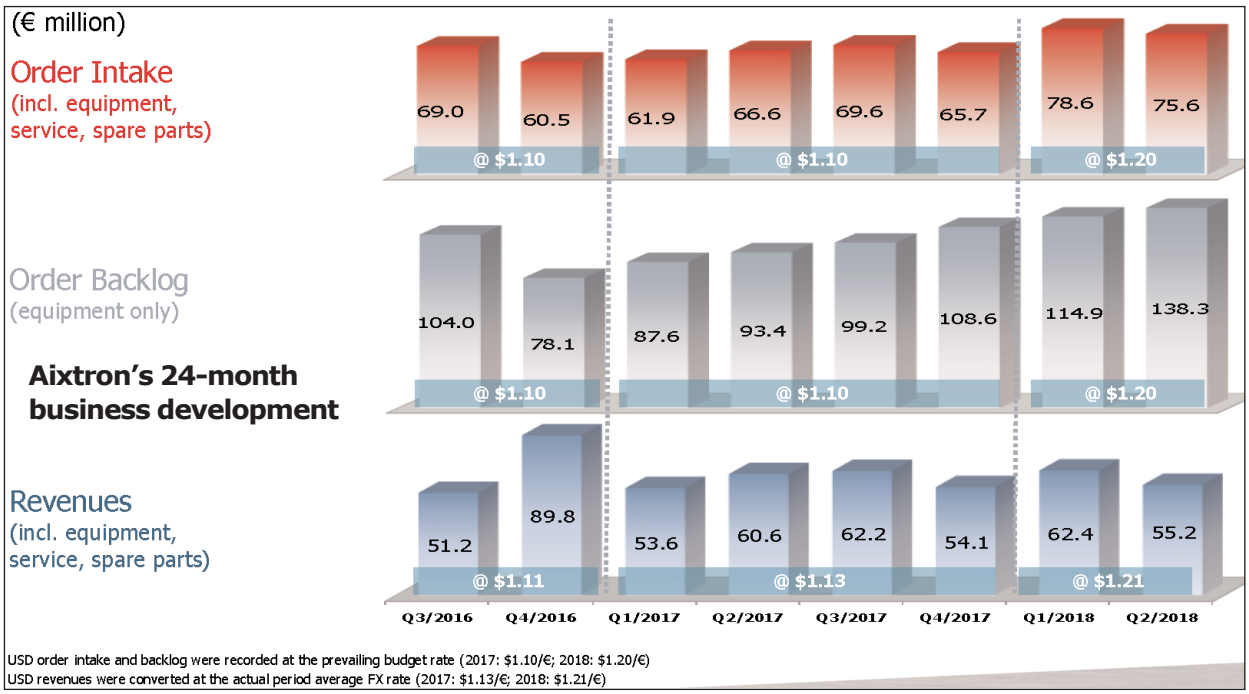
Cash and cash equivalents at the end of June of €234.7m were hence down from €246.5m at the end of 2017 but up from €223.2m at the end of March, reflecting the operating performance including orders received in Q2.

Total order intake (including spare parts and service) has risen by 20% from first-half 2017's €128.5m to €154.3m in first-half 2018 (with Q2's €75.6m down 4% on Q1's €78.6m but up 30% on €66.6m a year ago).

Equipment order backlog at the end of June was €138.3m, up 20% on €114.9m at the end of March and up 48% on €93.4m a year previously (and the highest backlog since 2011). Of this backlog, 35–45% is for laser applications.

"We continue to benefit from the stable global demand for MOCVD systems for laser applications such as VCSEL or EEL, which are particularly in demand in the field of 3D sensors or optical data transmission," says president & executive board

member Dr Felix Grawert. "Our MOCVD systems for the production of red, orange and yellow (ROY) LEDs are also in high demand, as they are indispensable for the market penetration of display technologies based on fine-pitch LEDs, mini-LEDs and in the future also micro-LEDs," he adds. "The power electronics area could become a growing driver for Aixtron in the upcoming quarters," believes fellow president & executive board member Dr Bernd Schulte.



Based on the results for first-half 2018 (with most order backlog due for shipment in 2018) and internal assessment of the development of demand, Aixtron expects higher revenue in second-half 2018. The firm has hence refined its full-year 2018 guidance (given in February) for revenue from €230–260m to €260m, gross margin from 35–40% to 40% and EBIT margin from 5–10% to 10%. "The positive development in order intake continued in the second quarter of this year, so we have decided to raise our order intake guidance for fiscal year 2018 [from €230–260m to €260–290m]," says Schulte. Operating cash flow is expected to be positive.

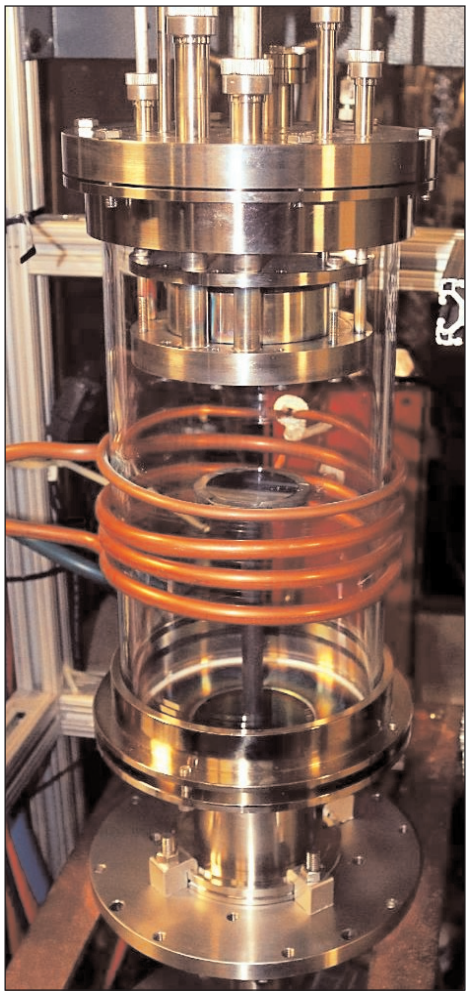
www.aixtron.com

SMI optimizes NanoV CVD reactor for SiGeSn growth

Structured Materials Industries Inc (SMI) of Piscataway, NJ, USA — which provides chemical vapor deposition (CVD) systems, components, materials, and process development services — has optimized a design version of its NanoV CVD research reactor for exploring growing thin films of silicon germanium tin (SiGeSn) materials.

The NanoV CVD research system is configured for growth on single 2" wafers, but a 3" platter is also available. Advantages of the 2" substrate reactor include its optional height-adjustable water-cooled showerhead, the substrate susceptor rotation, an upgradeable option to include a double wall for very high-temperature operation, and plasma enhancement.

"The height-adjustable showerhead is an important feature for some researchers since it changes the distance between gas injection and substrate and, thus, gas-phase pre-reaction pathways," notes research scientist Dr Arul Arjunan. "SMI designed a height-adjustable modular showerhead to allow exploration of these effects (along with rotation) with different chemistries," he adds. "The showerhead modification allows the showerhead-to-susceptor distance to be adjusted to determine the best position for a given set of process parameters as well as tune the pre-reactions, efficiency, and uniformity." The NanoV CVD system for SiGeSn growth also optionally features substrate rotation through the SMI SpinCVD rotation assembly. Substrate rotation helps to improve uniformity and efficiency as well as to minimize pre-reactions. At high speed (several hundred rpm), rotation generates forced convection, which can be used to enhance laminar flow and thus uniformity and efficiency.



SMI's in-house NanoV CVD reactor with a 2" wafer platter in place — the system can also run a 3" size wafer.

The plasma-enhancement option can catalyze low-temperature cracking of the precursors, provide radicals to enhance reaction pathways, and enhance surface atom mobility, all of which are important for the growth of SiGeSn. SMI offers a low-cost unregulated 180–250kHz output frequency 1kW power scale plasma option (that can generally operate through several tens of Torr) or a high-end 13.56MHz 300W plasma source option (that operates in the range from mTorr to a few Torr).

These tool developments have been supported in part by the US Department of Energy (contract no. DE-SC0015164), wherein SMI is funded to develop SiGeSn-based IR photodiode sensors and waveguides on silicon chips. That work is supported by a subcontract with professor Hongbin Yu of Arizona State University.

The NanoV CVD tool is a vertical reactor system designed to provide the researcher with the most complete and versatile low-cost CVD platform on the market to investigate of the widest range of materials and amorphous films and structures such as epitaxy, polycrystalline, or nanowires and nanotubes. This one platform is conveniently configurable for either oxidizing or reducing environments. Simple exchangeable components in a small footprint at an economical price allow the researcher great process variability — allowing great flexibility in adapting to changing research needs or supporting multiple material research needs on one simple platform with low-cost, modular, easily reconfigured components.

www.smicvd.com
https://ecee.engineering.asu.edu/project/hongbin-yu yuhb@asu.edu

SMI offering compact Closed Space Sublimation System for CdTe/II-VI material growth

Structured Materials Industries is providing a packaged solution for CdTe/II-VI material growth, among other materials, with the manual or automatic Close Space Sublimation System. The fast linear slide loading/unloading and the sublimation/deposition assembly enables efficient growth.

With a small footprint, the system is suitable for researchers facing both budget constraints as well as facility limitations. Further, with space left in the frame for additional gases and precursors, the system is designed to grow with the researcher as their needs evolve.

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Sanan IC extends III-V foundry from Greater China to North American, European and APAC markets

High-volume 6-inch epiwafer capability targeted at RF, millimeter-wave, power electronics and opto markets

Sanan Integrated Circuit Co Ltd (Sanan IC) of Xiamen City, Fujian province (China's first 6-inch pure-play compound semiconductor wafer foundry) has announced its entry into the North American, European and Asia Pacific (APAC) markets with its III–V technology platform, which spans a wide range of applications for the microelectronics and photonics markets via its broad portfolio of gallium arsenide (GaAs) HBT, pHEMT, BiHEMT, integrated passive device (IPD), filters, gallium nitride (GaN) power HEMT, silicon carbide (SiC), and indium phosphide (InP) DHBT process technologies.

Founded in 2014 and focused on high-performance, large-scale III–V semiconductor manufacturing and on serving the RF, millimeter-wave, power electronics, and optical markets, Sanan IC is a subsidiary of LED chip maker Sanan Optoelectronics Co Ltd (China's largest LED epiwafer and chip maker, based on GaN and GaAs technologies). Leveraging high-volume production and years of investment by its parent company in epiwafer reactors for the LED lighting and solar photovoltaic markets, Sanan IC is expanding its go-to-market strategy beyond the Greater China region as its process technologies and patent portfolio mature, aiming to fulfill the needs of integrated devide manufacturers (IDMs) and fabless design houses for high-volume compound semiconductor fabrication.

"We see tremendous opportunity in serving the worldwide demand for large-scale production of 6-inch III–V epitaxial wafers, driven by continual growth of the RF, millimeter-wave, power electronics and optical markets," says Sanan IC's CEO Raymond Cai. "Our vertically integrated manufacturing services over our broad compound semiconductor technology platform, with in-house epitaxy and substrate capabilities, make us an ideal foundry partner," he reckons. "Given the capital investments made on state-of-the art equipment and facilities, with full support from our parent company Sanan Optoelectronics combined with strategic partnerships and a world-class team of scientists and technologists, Sanan IC is well positioned for success in this active compound semiconductor market."

As cellular mobility and wireless connectivity proliferates in the Internet-of-Things (IoT) and as 5G sub-6GHz evolves into the millimeter-wave range, III–V technologies is becoming even more critical for supporting the infrastructure and clients' device deployments by carriers worldwide, says Sanan. According to market research firm Yole Développement, the GaAs wafer market (RF, photonics, photovoltaics and LEDs) will grow to over 4 million units in 2023, with photonics having the highest compound annual growth rate (CAGR) of 37%. GaN and SiC for power electronics — such as for data centers, electric vehicles (EVs), battery chargers, power supplies, light detection and ranging (LiDAR) and audio — are predicted to ramp up, with GaN shipments growing at a CAGR of 79% to $460m in 2022 and SiC growing at a CAGR of 29% to $1.4bn in 2023. Optical components continue to be in high demand for datacom, telecom, consumer, automotive and industrial markets, leading to increased revenue for photodectors, laser diodes and especially vertical-cavity surface-emitting lasers (VCSELs), with expected shipments of $3.5bn in 2023.

www.sanan-ic.com

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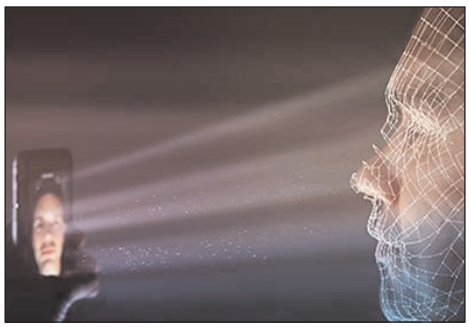
Oxford Instruments supplies Sino-semic, China's first mass-production VCSEL fab

UK-based plasma etch and deposition processing system maker Oxford Instruments Plasma Technology (OIPT) says that Sino-semic — the first all-Chinese developer and manufacturer of vertical-cavity surface-emitting lasers (VCSELs) for face recognition — has selected its Cobra plasma etch systems for its manufacturing facilities in Taizhou City.

Sino-semic notes that process capability and local support were key factors in its decision to adopt the inductively coupled plasma (ICP) etch Cobra systems. "We



chose Oxford Instruments to supply our ICP etch equipment because they offer cutting-edge plasma processing systems and unrivalled process support, which will be invaluable to us during our production scheme," comments Sino-semic's vice general manager Li Jun.

Cobra process solutions are designed to support device applications such as lasers, RF, power and advanced LEDs.

"VCSEL-based devices are entering another exciting phase of growth," says OIPT's managing director Richard Pollard. "We are thrilled to be providing our VCSEL processing solutions to a pioneering production manufacturer such as Sino-semic," he adds.

www.oxford-instruments.com/plasma

ClassOne's Solstice CopperMax electroplating system chosen by China's largest GaAs device maker

ClassOne Technology of Kalispell, MT, USA (which manufactures electroplating and wet-chemical process systems for ≤200mm wafers) has announced a multi-tool sale of its flagship Solstice CopperMax electroplating system to China's premier compound semiconductor manufacturer.

As the largest such supplier in China — among the largest gallium arsenide (GaAs) fabs in the world — ClassOne's new client will use CopperMax to anchor the production of highly advanced power chips with designs suitable for a variety of leading-edge semiconductor markets.

"ClassOne has presence in each of the leading compound semiconductor fabs around the world, now including a global leader in the development and manufacture of semiconductors based on GaAs substrates," says ClassOne CEO Byron Exarcos.

ClassOne says that it expects multiple similar sales in the coming months, as semiconductor manufacturing facilities throughout Asia expand their processing capabilities for advanced applications such as 3D sensing, autonomous vehicles, and 4G/5G communications.

www.classone.com/products

Rudolph appoints David B. Miller as chairman

Rudolph Technologies Inc of Wilmington, MA, USA (which makes defect inspection, lithography, process control metrology and process control software for semiconductor and advanced packaging device makers) has appointed David B. Miller as chairman of the board of directors (effective from 5 August) following the resignation of Thomas G. Greig, who served as lead director and chairman

"Dave Miller brings the right skills and industry background to the chairmanship role in order to continue to drive Rudolph's success," comments Greig. "I look forward to supporting him as I continue to serve on our board of directors," he adds.

"We greatly appreciate Tom Greig's leadership over the past six years and his ongoing service," says CEO Michael Plisinski. "We are pleased to have Dave Miller's leadership as chairman while the company continues to focus on the strategy to build a well-balanced and sustainable growth company."

Rudolph says that Miller, who has been an independent member of the board for three years, brings leadership and practical experience to the chairmanship role. This experience includes over 40 years within the electronics industry, including six years as president of DuPont Electronics & Communications, as well as prior service on the board of SEMI International. He has a broad international perspective and understanding of global semiconductor and display markets, cultivated not only from his global work experience but also as a result of residing in Asia for three years.

www.rudolphtech.com

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MRSI launches MRSI-HVM3P die bonder for new photonics applications

MRSI Systems of North Billerica, MA, USA (which manufactures fully automated, high-precision eutectic and epoxy die bonding systems) is expanding its high-speed MRSI-HVM3 die bonder platform with the launch of the MRSI-HVM3P to offer configurations for active optical cable (AOC), gold-box packaging, and other applications in addition to chip-on-carrier (CoC).

The expansion is in response to customers' requests to take advantage of the field-proven performance of the flexible high-speed MRSI-HVM3 platform for their other essential packaging applications in photonics manufacturing which are high volume and high mix by nature.

The new MRSI-HVM3P is the first major extension to the HVM3 family, equipped with an inline conveyor for single fixture or multiple cassette inputs that can automatically transport large forms of carriers of the dies. This configuration is targeted at AOC or similar die-to-printed circuit board (PCB) applications, gold-box packaging, and CoC in fixture. The processes include eutectic, epoxy stamping, UV epoxy dispensing, and in-situ UV curing.

"MRSI Systems is now able to offer flexible high-volume die bonding solutions, not just for CoC, but also for PCB and box levels of packaging to our customers in photonics, sensors and other advanced technology fields," says VP of product management Dr Yi Qian. "This is another demonstration of MRSI's commitment to provide critical solutions promptly in response to our customers' needs," adds president Michael Chalsen.

Both the MRSI-HVM3 and MRSI-HVM3P now carry the following options inherited from the long-proven MRSI-M3 family: localized heating, flip-chip bonding, and co-planarity bonding. These options are increasingly critical for new applications such as 400G transceivers and silicon photonics.

The MRSI-HVM3 product family delivers speed, future-proof high precision (<3mm) and flexibility for multi-process, multi-chip, high-volume production.

The launch of the MRSI-HVM3P builds on the firm's first configuration launched last year — the MRSI-HVM3 for CoC, chip-on-submount (CoS), and chip-on-baseplate (CoB) assembly using eutectic and/or epoxy stamping die bonding — which, it is claimed, has proved to be the best-in-class die bonder with the leading speed, zero-time tool change between dies, and <3mm accuracy. The performance was enabled by a dual-head, dual-stage, integrated 'on-the-fly' tool changer, ultrafast eutectic stage, and multi-levels of parallel processing optimizations.

MRSI Systems is exhibiting at the 20th China International Optoelectronic Expo (CIOE 2018) with its partner CYCAD Century Science and Technology (booth #1C66) in Shenzhen (5–8 September) and booth #577 at the 44th European Conference on Optical Communications (ECOC 2018) in Rome, Italy (24–26 September).

www.cioe.cn/en
www.ecocexhibition.com

KLA-Tencor appoints Ana G. Pinczuk to board

Process control and yield management solutions provider KLA-Tencor Corp of Milpitas, CA, USA has appointed Ana G. Pinczuk to its board of directors.

Pinczuk was most recently president & general manager for HPE Pointnext, HPE's $7bn+ services organization, where she led a global organization of 25,000 IT experts delivering professional and operational services to HPE customers worldwide.

"Ana is an accomplished technology executive with demonstrated success leading industry transformation, enabled through world-class technology and business model execution for large-scale global enterprises," comments chairman Edward W. (Ned) Barnholt. "She has broad experience across a number of technology industries, including mobile, IP networking, software, data storage and security."

Prior to HPE Pointnext, Pinczuk was executive VP & chief product officer of Veritas Technologies LLC, where she led its multi-billion-dollar product portfolio. During her 15-year tenure at Cisco Systems Inc, she drove the transformation of Cisco's services business and grew the cloud, software, IoE and professional services sectors, ultimately serving as senior VP of sales.

"Ana's expertise and guidance will be a tremendous resource to KLA-Tencor's growing services business," believes Barnholt.

Pinczuk serves on the board of Carnegie Mellon University's College of Engineering, is a member of the Cornell University Computer and Information Sciences advisory board, and was also named a 2016 Woman of Influence by the Silicon Valley Business Journal. She holds a Bachelor of Science and a Master of Engineering in mechanical engineering from Cornell University, a Master of Technology Management from the University of Pennsylvania Wharton School, and a Master of Science in software management from Carnegie Mellon University.

www.kla-tencor.com

Inseto to represent SUSS MicroTec in Finland, Norway and Sweden

Inseto (UK) Ltd of Andover, UK, a distributor of equipment and materials to the semiconductor, microelectronic & advanced technology sectors (as well as adhesives for electronics, automotive and industrial manufacturing), has been appointed to represent SUSS MicroTec AG of Garching, near Munich, Germany (which makes photomask aligners, laser processing systems and wafer bonders) in Finland, Norway and Sweden.

Inseto's Equipment Division will be responsible for the regional sales of mask and wafer aligners, spin coaters, wafer bonders and other equipment from SUSS MicroTec's product range.

"Inseto has been representing our product lines in the UK and Ireland for a little over a year and we are extremely impressed with their knowledge of the semiconductor industry," comments Virginie Quet, who is SUSS MicroTec's director of sales & marketing in Europe, the Middle East and Africa.

Inseto's experts have received formal training from SUSS MicroTec on the use of its equipment. Combined with Inseto's complementary equipment portfolio and ability to supply wafers and other materials, the company can hence provide a comprehensive sales service supporting customers' overall program goals.

"We know the territories extremely well as we've been representing other OEMs and their product lines in Finland, Norway and Sweden for almost 10 years now, and we have well-established relationships with customers already using, or who could benefit from using, SUSS MicroTec's semiconductor manufacturing equipment," says Jim Rhodes, technical sales – Nordic for Inseto.

"In Inseto, we feel there's potential for an enduring partnership that will benefit our highly valued customers in Finland, Norway and Sweden," comments Quet.

www.inseto.co.uk
www.suss.com

Xcerra's MT9510 XP pick & place handler proven for tri-temperature testing of LED devices in volume production

Test equipment maker Xcerra of Norwood, MA, USA says that its MT9510 XP pick-and-place handler has passed the onsite buy-off for an automotive LED test application at a leading lighting manufacturer, enabling it to test high volumes of LED devices with best temperature performance.

Xcerra says that the system leverages the temperature accuracy of the established MT9510 test handler to ensure full temperature control during test, while the LEDs are turned on and producing heat. In addition, the MT9510 configuration allows for the sensitive surface areas of the LEDs, which must not be touched while handling the device.

All dedicated hardware is integrated in the conversion kit and does not change the base handler, maintaining full flexibility and not impacting any loading, soaking, sorting or unloading core functions.

"Our solutions replace the previously applied hand test method, with obvious advantages in production volume and reliability," says product manager Syariffuddin A.Kamarudin. "Reliability has been of highest importance for the customer, as the LEDs are used in the automotive industry."

https://xcerra.com/mt9510

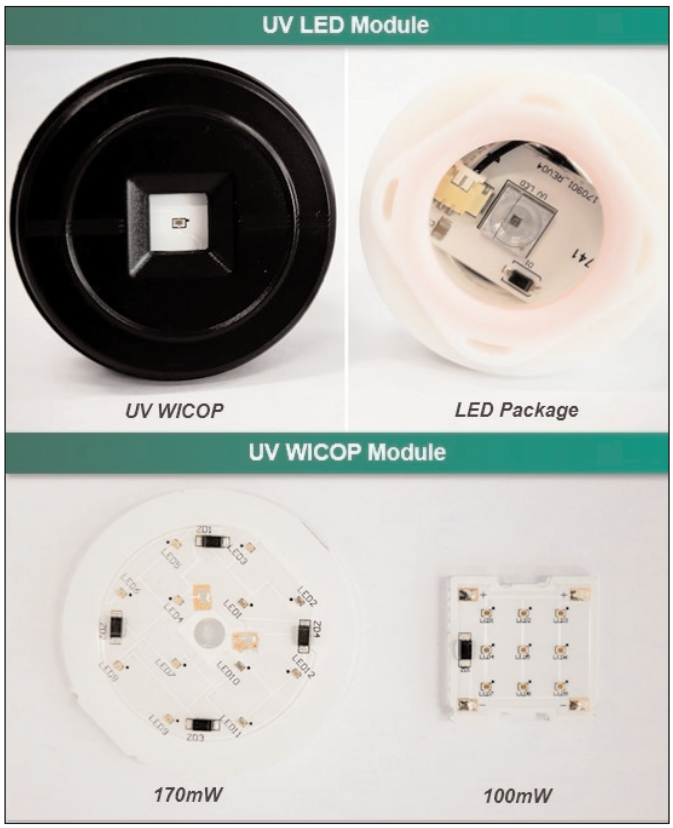
Seoul Viosys launches UV WICOP LED module

South Korean UV LED maker Seoul Viosys Co Ltd has launched the UV WICOP module, which combines Seoul Semiconductor's WICOP LEDs with compact and high-efficiency technology.

Designed using a single chip and phosphor only (without any components such as lead frame and gold wire), Seoul Semiconductor's patented WICOP (Wafer Level Integrated Chip on PCB) is said to be the first product that does not require a packaging process. Seoul Viosys has applied the technology to its UV LEDs and has been granted a patent for the combined technology.

Conventional UV LEDs have high manufacturing costs due to the additional components, and performance is also degraded by the overload of heat emitted from each component. However, UV WICOP cuts cost by incorporating just a single chip without additional components, and it is effective for heat dissipation. The design can be changed easily, depending on the application or customer requirements.

Seoul Viosys has tested performance by applying UV WICOP technology to various applications for water and air purification as well as surface disinfection. As a result, the new UV WICOP has improved performance by more than 600%, with a lighting duration time of 45,000h compared with 2000–7000h for conventional high-powered LED packages. The price is reckoned to be 80% less than for competitors offering equivalent performance.



Seoul Viosys's UV WICOP module, which combines Seoul Semiconductor's WICOP LED technology.

"Conventional UV LEDs have difficulty in expanding applications, with low light power, short duration time and high price," says Jong Man Kim, UV development executive vice president.

"Seoul Viosys has the patent for vertical high-powered package (patent no. USP 8,242,484) based on UV WICOP technology," he adds. "We will initiate mass production for new UV WICOP with cost competitiveness in the near future."

www.seoulviosys.com
www.SeoulSemicon.com

AquiSense cuts price of UV-C LED-based PearlAqua product lines

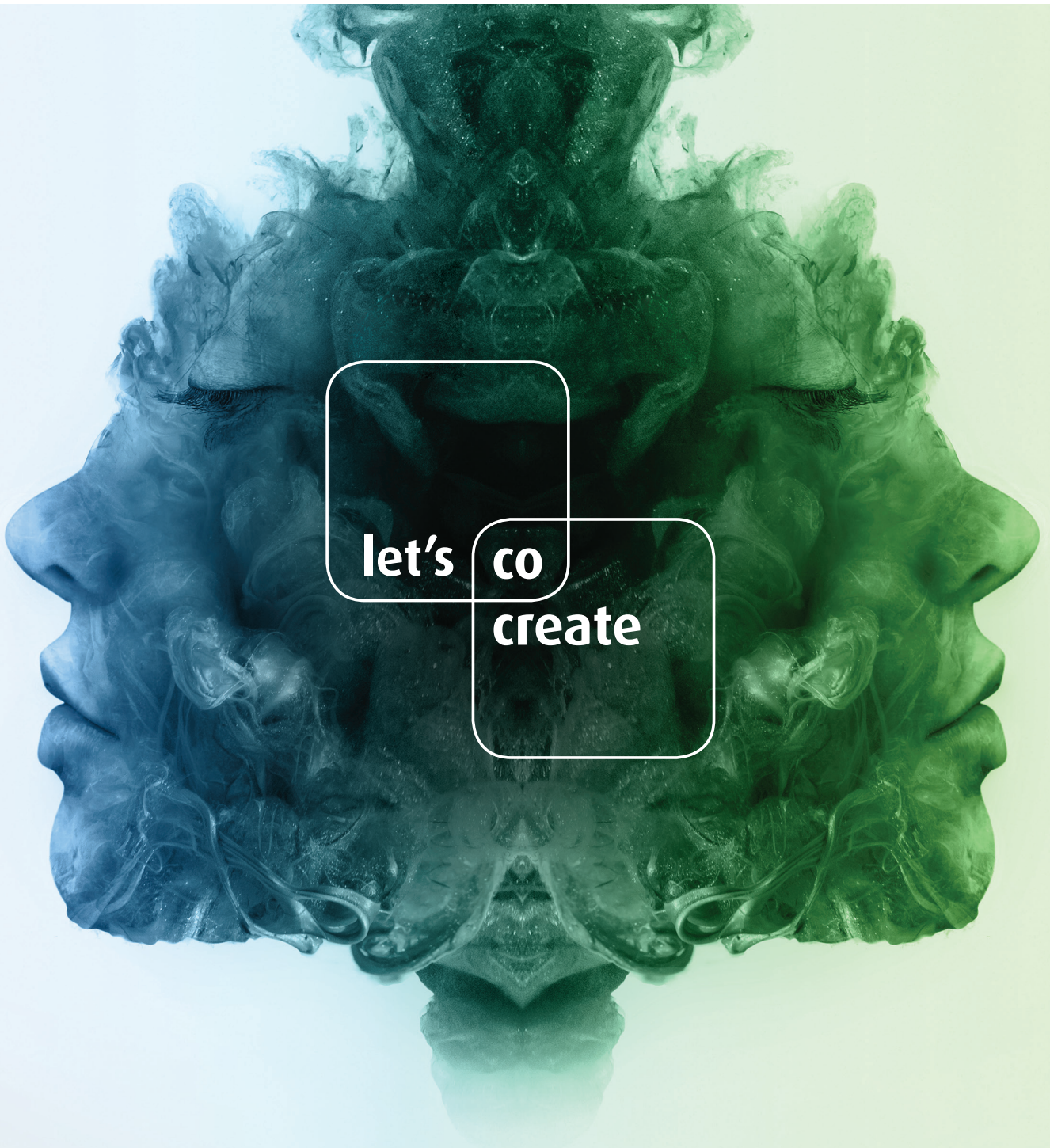
Nikkiso Group company AquiSense Technologies LLC of Erlanger, KY, USA (which designs and manufactures water, air and surface disinfection systems based on UV-C LEDs) has announced a price reduction to its PearlAqua and PearlAqua OEM models.

Since its introduction in 2012, the PearlAqua has been AquiSense's flagship product, using UV-C LEDs to reduce pathogens by up to 99.99%. It is claimed that the PearlAqua was a first-to-market product in this sector and has been the benchmark for price/performance evaluations of all other products since. Also, its patent-pending replaceable UVinaire lamp module provides true plug-and-play operation.

AquiSense says that the price reduction makes its systems more cost effective, bringing pricing in line with conventional mercury-based UV systems. "Early adopters of our systems were attracted by the unique benefits of UV-C LEDs and the slick design, meaning they were deployed in places where traditional mercury-based systems could not be utilized," says CEO Oliver Lawal. "A price reduction further enhances an already compelling value proposition and will lead to further market penetration of UV-C LED technologies," he reckons.

The price reduction was made possible by a variety of factors including increasing purchasing power with suppliers and the establishment of new automation in AquiSense's manufacturing facilities. Since launching the PearlAqua, both the UV-C LED device market and the PearlAqua design have progressed. "We have benefited from our first-mover status in developing product refinements and greater production volumes," reckons Wes Morin, vice president of operations.

www.aquisense.com



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Lumileds awarded $66m damages in IP theft lawsuit against Elec-Tech International

US Superior Court of the State of California imposes $66m in damages

On 10 August, a jury of six men and six women rendered a verdict in favor of LED maker Lumileds LLC of San Jose, CA, USA, finding that a Chinese competitor stole trade secrets related to Lumileds core technology for making high-power LEDs used in flash phones, automotive headlights and general illumination.

The case — Lumileds LLC versus Elec-Tech International Co Ltd (ETI), Donglei 'Tony' Wang and Gangyi Chen — in the Superior Court of the State of California, County of Santa Clara, found the defendants liable for damages in intellectual property theft. The jury awarded Lumileds $66m.

The jury concluded that ETI, Wang and Chen misappropriated Lumileds trade secrets, took them to China, and used them to develop ETI's LED technology. The award of $66m is the amount of R&D costs that the jury concluded ETI saved by using Lumileds trade secrets rather than engaging in its own development.

"At Lumileds, we invest heavily in innovation," says Lumileds' CEO Mark Adams. "We will continue to work with the judiciary, law enforcement and appropriate government agencies to defend and protect our valuable intellectual property rights."

Lumileds says that the circumstances of the trade secret theft involved Wang (ETI's CEO) and Chen (a former scientist employed by Lumileds). Wang authorized a substantial payment to be made to Chen four months before he left Lumileds to go to work for ETI in China, effectively putting him on the payroll of ETI while he was working daily with Lumileds' most confidential trade secret technology.

ETI, Wang and Chen misappropriated Lumileds trade secrets, took them to China, and used them to develop ETI's LED technology

Lumileds was represented in the matter by senior VP, general counsel, Cheree McAlpine and outside lead counsel Brian Roche, a partner at Reed Smith LLP.

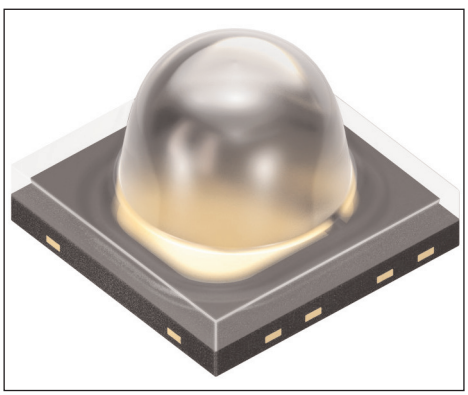
"The precedent set by today's verdict sends a clear message to the industry that intellectual property will be guarded and enforced to safeguard the health of our business," says McAlpine.

www.lumileds.com

Osram adds narrower-beam-angle SFH 4718A IRED to cut size and cost of CCTV illumination units

Osram Opto Semiconductors GmbH of Regensburg, Germany is expanding its Oslon Black portfolio for infrared illumination by adding an infrared LED in the low-output range a new version with a narrower beam angle of ±25°. Particularly for camera systems with a medium capture range, the illumination unit can now be designed without additional secondary optics, making the overall system more compact and cost-effective. At the same time, the SFH 4718A provides a radiant intensity of 730W/sr. At a current of 1A, the IRED offers an optical output of 0.8W. The 850nm wavelength is barely discernible by humans, but lies firmly within the sensitivity range of the camera sensors.

The Oslon Black family now offers a wide selection for the most varied of infrared-based applications, taking in four power classes, three wavelengths and three beam angles. With the addition of the SFH 4718A, the Oslon Black portfolio now comprises three wavelengths (810nm, 850nm and 940nm) and three beam angles (±25°, ±45° and ±75°). These are flanked by four different power levels, with optical outputs ranging from 0.3W right through to 2W. "Since all the products are based on the same package, the emitters are easy to combine," says Jörg Heerlein, marketing Emitter Laser Sensor at Osram Opto. "Since the footprint remains identical, an existing design can also be easily upgraded with a new variant," he adds.



Osram Opto's new Oslon Black SFH 4718A infrared LED.

Spanning all types of infrared illumination, key applications of the Oslon Black series include the illumination of areas monitored by closed-circuit television (CCTV) systems using infrared light. CCTV is used to monitor public spaces, parking lots and company premises, as well as museums and bank foyers etc. Adding infrared illumination ensures that the camera delivers high-quality images regardless of the prevailing light conditions. The IRED can also be used for automatic license plate recognition systems.

www.osram.com

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FerroTec

Cree's quarterly revenue grows 15%, driven by 40% organic year-on-year growth from Wolfspeed

For full-year fiscal 2018 (to 24 June), Cree Inc of Durham, NC, USA reported revenue of $1.494bn, up 1% on $1.473bn for fiscal 2017.

Revenue for Lighting Products (LED lighting systems and lamps) fell 19% from $701.5m to $568.8m (from 47.6% to 38.1% of total revenue), due to softness in the North America commercial lighting market, the impact of product quality issues, the legal settlement with Feit Electric Company Inc leading to patent license revenue in fiscal 2017 that did not reoccur in fiscal 2018, and lower consumer product sales as Cree shifted emphasis to the premium lamp category.

Revenue for LED Products (chips and components) grew 8% from $550.3m to $596.3m (from 37.4% to 39.9% of total revenue), due to strong demand in high-power general lighting, video screen and specialty lighting applications, plus the addition of mid-power joint venture (JV) product sales. "The business is performing well against the objective of driving value through greater focus," comments CEO Gregg Lowe.

Revenue for the Wolfspeed business (Power & RF devices and SiC material) grew 49% from $221.2m to $328.6m (from 15% to 22% of total revenue). However, this included the first full quarter of results from the Infineon RF Power business (acquired on 6 March). Even without this, organic growth was 35% year-on-year, with strong growth in both materials and devices.

For fiscal fourth-quarter 2018, revenue was $409.5m, up 15% on $356m last quarter and 14% on $359m a year ago, and at the upper end of the targeted range of $390–410m.

Revenue for Lighting Products was $143.7m (35.1% of total revenue), down 7% on $154.7m (43.1% of total revenue) a year ago but up 10% on $130.8m last quarter, as the business continues its recovery. "Q4 represented another step forward towards the objective of fixing the business," reckons Lowe.

Revenue for LED Products was $155.8m (38% of total revenue) — the highest in almost four years — up 9% on $143.3m last quarter and $143.4m a year ago

Revenue for Wolfspeed was $110m (26.9% of total revenue), up 34% (more than the expected 27%) on $81.9m (23% of total revenue) last quarter and up 81% on $60.8m (16.9% of total revenue) a year ago. Even without the full quarter of results from the Infineon RF Power business, organic growth was still a strong 40% year-on-year.

"Wolfspeed, which is our primary growth driver, continued to deliver on its objective of achieving high growth and strong gross margins," comments chief financial officer Mike McDevitt. "We completed the successful integration of the Infineon RF Power business and delivered accretive non-GAAP results for the quarter," adds Lowe. "That was less than three months after closing the acquisition — a remarkable timeline for such a large integration that comprised 12 sites and roughly 260 employees around the world."

On a non-GAAP basis, full-year company gross margin has fallen from 30.2% in fiscal 2017 to 28.1% for fiscal 2018. However, fiscal Q4 gross margin was 30% (above the targeted 29.7%), up from 27.8% last quarter and 28% a year ago.

Wolfspeed gross margin rose from 45.5% a year ago to an above-target 47.9% (only slightly down on last quarter's 48%) even while Cree managed the challenges of ramping new capacity and integrating the acquired Infineon RF business (which exceeded targets). This helped full-year Wolfspeed gross margin to rise from 46.8% in fiscal 2017 to 48.2% for fiscal 2018, due primarily to changes in product mix and successfully managing factory execution.

Full-year LED Products gross margin has fallen from 27.6% for fiscal 2017 to 26.5% in fiscal 2018, due mainly to a shift in product mix, including the mid-power JV product sales (which have lower gross margin). However, quarterly LED Products gross margin has recovered further, from 25.9% a year ago and 26.4% last quarter to an above-target 27.4%, due primarily to strong product demand, improved factory execution, and a more favorable product mix.

Full-year Lighting Products gross margin has fallen from 28% in fiscal 2017 to 19.2% for fiscal 2018, due mainly to non-recurrence of the Feit legal settlement, higher warranty-related costs, and lower sales reducing factory utilization. However, although still down on 23.8% a year ago, quarterly Lighting Products gross margin has recovered further, from 19.1% last quarter to 20.3% (the second consecutive quarter of more than 100 basis points improvement), due mainly to lower warranty-related cost, better process controls and incremental improvement in factory operation.

Operating expenditure (OpEx) has risen from $97m last quarter to $108m (26.4% of revenue), but this is slightly lower than forecasted (27.5% of revenue) due to early realization on some of the targeted Lighting right-sizing savings and lower IT litigation spending. "Over time, we target reinvesting these Lighting savings back into our Wolfspeed business to support its long-range targeted growth," says McDevitt.

Full-year net income has fallen from $49.7m ($0.50 per diluted share) in fiscal 2017 to $18.8m ($0.19 per diluted share) for fiscal 2018. However, quarterly net income has continued to recover, from $3.8m ($0.04 per diluted share) last quarter to $11.5m ($0.11 per diluted share), exceeding the targeted $5–9m ($0.05–0.09 per diluted share).

"Fiscal year 2018 finished with good momentum, with fourth quarter non-GAAP earnings per share that exceeded the top end of our range driven by Wolfspeed growth and gross margin improvement," notes Lowe.

Cash flow from operations has rebounded from $19.6m last quarter to $41.9m. Spending on property, plant & equipment (PP&E) has been increased further, from $43.2m to $57.3m, while patent spending has dropped from $3m to $2.2m. So, total capital expenditure (CapEx) has risen from $46m to $59.5m (taking full-year CapEx to $195.8m). Free cash flow rose from –$26.5m to –$17.5m. Overall, cash and investments fell from $401m to $387.1m.

"Capital allocation priorities remain focused on expanding our capacity on Wolfspeed business," says McDevitt.

"Demand for silicon carbide and gallium nitride technologies continues to grow, as evidenced by the excellent results of our Wolfspeed business," says Lowe. "We aim to keep reducing the gap and cost compared to silicon by leveraging scale, executing engineering efforts to improve yield, and pushing the limits of material science to achieve the next breakthrough. This combination of greater availability and lower cost will speed up and expand the adoption of SiC and GaN RF technologies across a wide range of markets," he adds. "We are expanding our manufacturing footprint and broadening our product portfolio to extend our leadership position in this market and drive growth."

In June, Wolfspeed launched its C3M third-generation 1200V silicon carbide MOSFET family, targeted at helping to foster the adoption of electric vehicles (EVs) by delivering higher efficiency and hence increasing driving range and reducing system costs. In August, the firm launched the E-Series, the first commercial family of SiC MOSFETs and diodes to be automotive AEC-Q101 and PPAP (production part approval process)-capable. Cree reckons that the rollout establishes Wolfspeed as first in the industry to launch a full suite of MOSFETs and diodes that are capable of withstanding high-humidity environments while offering the reliability and system-level value needed to drive widespread adoption of silicon carbide among auto makers for the next generation of EVs.

For fiscal first-quarter 2019 (ending 23 September 2018), Cree targets revenue of $395–415m, including Lighting Products revenue down 6% sequentially (as Cree focuses on increasing gross margins by improving the mix in its business); LED Products revenue down 6% (due to shifting some of the fungible capacity to Wolfspeed, normal European market seasonality, and order delays from certain customers as the industry evaluates how best to navigate the US and China tariffs); but Wolfspeed revenue up 13% (based on solid growth across all product lines). With the additional growth targeted for Q1, Wolfspeed's annual revenue run rate is now $0.5bn. "While we are encouraged that the restriction on selling to [China's] ZTE was lifted in July, we target just a small amount of revenue from them in Q1 as they rebuild their supply chain," says McDevitt. "The business could ramp steadily beyond Q1, but it's too soon to say when it would be back to prior levels."

Gross margin is expected to rise to 30.6%. This is mainly because more of the revenue mix will come from Wolfspeed (despite Wolfspeed's margin falling slightly due to its product mix). Also, Lighting Products margin should improve. "As a result of new product introductions, improved relationships with our channel partners and continued progress on quality, we see continued gross margin improvement," says Lowe. This will be offset partially by an impact of 50 basis points from the 6 July tariffs, mainly affecting LED Product margin (which would otherwise remain level). "Momentum is building in our focused areas like automotive lighting and application-optimized solutions that are stickier and have an opportunity for us to create more value," says Lowe. "The results should be a business that generates strong free cash flow through modest revenue growth, gross margin expansion and lower CapEx."

Operating expenses should be similar to fiscal Q4/2018, including incremental spend related to semiconductor R&D projects, higher IP litigation costs and CFO transition costs (with Neil Reynolds replacing McDevitt on 27 August), offset by the targeted Lighting right-size initiative savings.

Net income is targeted at $10–14m ($0.10–0.14 per diluted share, reflecting the negative impact of $0.02 per diluted share from the China-related tariffs that went into effect on 6 July).

The impact of the China-related tariffs is expected to be $0.03 per diluted share per quarter starting in fiscal Q2. "If the upcoming 23 August tariffs are applied the same way as the 6 July tariffs, we would anticipate the impact to be nominal," says McDevitt.

For full-year fiscal 2019, Cree still targets a 40/20/20 business model (40% gross margin, 20% OpEx and 20% operating margin). Targeted capital spending is $220m, driven primarily by expanding Wolfspeed's production capacity to support forecasted long-term customer demand. Free cash flow is expected to be –$10m, due to the timing of the Wolfspeed's capacity investments to alleviate current constraints and support the substantial growth opportunity forecasted over the next several years. "We are slightly ahead of our target to double wafer capacity for external material customers and double our power device capacity by the end of calendar 2018 from where we exited fiscal 2017," notes McDevitt. "As we continue to ramp this new capacity, we could have some variability in our initial production yields and factory utilization that may reduce our near-term Wolfspeed gross margins," he adds.

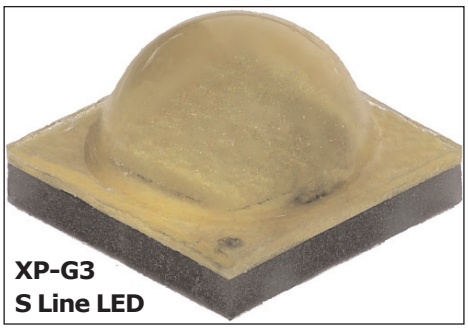
"Our target is to quadruple the size of the Wolfspeed business from fiscal 2017, which was a little north of $200m, to about $850m," says Lowe.

www.cree.com

Cree launches XLamp XP-G3 S Line LED for connected lighting systems

LED chip, lamp and lighting fixture maker Cree Inc of Durham, NC, USA has launched the XLamp XP-G3 S Line LED, an extension of the XLamp XP-G3 range that delivers high-power LED technology optimized for long-lifetime, high-power general lighting applications where sensors and the Internet of Things (IoT) are becoming common, such as commercial indoor, parking, industrial and roadway.

Connected lighting systems use information from occupancy sensors and other sources to continuously react to the target environment, dimming or switching off unneeded lights to conserve energy. On average, a connected lighting system will dim or switch off lights up to 10 times more often than with a standard lighting system. These additional dimming and switching cycles put more stress on the LED system and can limit the luminaire's lifetime. Through innovations in component architecture, the new XLamp XP-G3 S Line LED can withstand double the number of switching cycles compared with competing LEDs in its class, it is claimed.



XP-G3 S Line LED

The new XP-G3 S Line LED further improves the standard XP-G3 with better reliability through switching and dimming cycles, improved resistance to sulfur exposure, and higher light output and efficacy. This more robust version of the XP-G3 LED delivers LED system reliability in all lighting applications, including those with harsher environments.

Cree's new S Line LEDs employ a unique chip and package architecture that delivers the reliability and performance to withstand harsh environments, repeated dimming and on/off cycles

"The lighting market will require LEDs designed to withstand the rigors of connected intelligent lighting," says Cree LEDs executive VP & general manager Dave Emerson. "Cree's new S Line LEDs employ a unique chip and package architecture that delivers the reliability and performance to withstand harsh environments, repeated dimming and on/off cycles."

The XP-G3 S Line LED provides an easy upgrade path for existing XP-based LED systems, allowing manufacturers to quickly implement these LED innovations into their designs.

Product samples are available now and production quantities are available with standard lead times. The XP-G3 S Line LED has LM-80 data available to enable luminaires to immediately meet the requirements for DesignLights Consortium qualification.

www.cree.com/xlamp/xpg3

Cree prices offering of $500m convertible senior notes

Cree Inc of Durham, NC, USA (which makes lighting-class LEDs, LED lighting and power semiconductors) has announced the pricing of $500m of its 0.875% convertible senior notes due 2023 in a private offering to qualified institutional buyers. In addition, it has granted the initial purchasers an option to purchase (for settlement within a 13-day period from, and including, the date on which the notes are first issued) up to a further $75m of the notes.

Sale of the notes to the initial purchasers is expected to settle on 24 August (subject to the satisfaction of customary closing conditions) and is expected to result in about $488m in net proceeds (or $561m if the initial purchasers exercise their option to purchase additional notes in full) after deducting the initial purchasers' discount and estimated offering expenses payable by Cree.

The notes will be unsecured, senior obligations of Cree, bearing interest at a rate of 0.875% per year. Interest will be payable semi-annually in arrears on 1 March and 1 September of each year, beginning on 1 March 2019. The notes will mature on 1 September 2023, unless earlier repurchased, redeemed or converted.

Cree intends to use part of the net proceeds to repay its borrowings under its revolving credit facility and the remainder to fund capacity expansion of Wolfspeed (its Power & RF device and silicon carbide materials business), working capital needs and for general corporate purposes.

The initial conversion rate for the notes is 16.6745 shares of common stock per $1000 of notes (equivalent to an initial conversion price of about $59.97 per share). Conversions of the notes will be settled in cash, shares of Cree's common stock or a combination thereof, at Cree's election. The initial conversion price represents a conversion premium of about 31% over the last reported sale price of $45.78 per share of Cree's common stock on the Nasdaq Global Select Market on 21 August.

OSI Optoelectronics buys Luna's OPTO business

Photodiode and optical sensor maker OSI expanding portfolio as Luna focuses on fiber-optic-based test & measurement

Luna Innovations Inc of Roanoke, VA, USA (which makes high-speed fiber-optic test products for the telecoms industry and distributed fiber-optic sensing for the aerospace & defense and automotive industries) has sold its Optoelectronic Solutions (OPTO) business for up to $18.5m to photodiode & optical sensor maker OSI Optoelectronics Inc, a subsidiary of OSI Systems Inc of Hawthorne, CA, USA (a vertically integrated designer and manufacturer of specialized electronic systems and components for the homeland security, healthcare, defense, and aerospace industries).

"The transaction demonstrates strong execution of our strategy to focus our business on our core fiber-optic-based test & measurement technology platform," says Luna's president & CEO Scott Graeff. "This divestiture is another important step in ensuring we have a robust and flexible balance sheet and a portfolio of complementary, scalable businesses," he adds.

"The addition of Luna's Optoelectronic Solutions business is well aligned with our focus on expanding and enhancing our product portfolios," says OSI Optoelectronics' president Manoocher Mansouri. "This acquisition is expected to be a complementary addition with its highly regarded, customized solutions."

Originally acquired in 2015 as part of its merger with Advanced Photonix Inc (API), Luna's OPTO division designs and manufactures fully integrated photonic solutions for a wide range of industries. Revenue for 2017 was $13.1m.

OPTO division staff in Camarillo, CA, USA and Montreal, Quebec, Canada are expected to transfer to OSI. Luna plans to use the proceeds to invest in its core fiber-optic-based test & measurement platform, consistent with the key focus of its long term strategy.

www.lunainc.com

CST Global's new automatic visual inspection machine processes 500,000 laser chips per month

III–V optoelectronic foundry Compound Semiconductor Technologies Global Ltd (CST Global) of Hamilton International Technology Park, Blantyre, near Glasgow, Scotland, UK has installed and commissioned an Opto Systems VVSP4000 automatic pick & place visual inspection machine in its fabrication facility.

The machine performs a visual inspection of both the top side and facets of laser diode chips.

"The automatic pick & place visual inspection machine increases our inspection capacity in line with other production processes and is fed from our recently commissioned automatic bar stacker and automatic scribe and break machines," says operations manager Graeme Masterton.

"The automatic VI machine picks the singulated laser bars from tape, sorting out the working distributed feedback (DFB) laser chips on each bar, before placing them back on either tape or gel pack," he adds. "The current Takt time (process time) is 4.5 seconds per laser chip, meaning our automatic inspection capability increases our test capacity by over 500,000 laser chips per month."

"The automatic VI machine will recognize the laser ID number, with an option to record an image of each laser for reference," continues Masterton. "The process is repeatable and totally consistent, with a full audit trail. We can also track wafer batch quality, working with our key suppliers to help increase yield if required."

www.CSTGlobal.uk

Emcore's inventory correction from main CATV customer offset by revenue growth from other customers in Q2/2018

Gross margin to rebound as chip capacity increases and L-EML based transmitters transition to production

For fiscal third-quarter 2018 (to end June), 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 $17.7m, down 4.9% on $18.6n last quarter and 43% on $31m a year ago.

Of total revenue, cable TV comprised 66%. Of the 34% in non-CATV revenue, Chips comprised 14%, Satcom video & wireless 11% and Navigation 9%.

"Over the past two quarters, revenue from our cable TV products has been impacted [more than expected] by inventory correction with our largest cable TV customer. This particular customer chose to consolidate their outsourced EMS [electronics manufacturing services] into their own captive facility," says chief financial officer Jikun Kim. "Strong [better-than-expected] demand from our other cable TV customers offset this decline, such that overall cable TV revenues remained flat in Q3 quarter-over-quarter," he adds. "Our other major customers in cable TV continue to meet or exceed their forecast, demonstrating that overall MSO spending levels remain on a solid footing." In particular, sales for L-EML (linear externally modulated laser) transmitters grew by over 75% quarter-on-quarter.

Of other (non-CATV) broadband products, revenue for Satcom video & wireless products also remained flat quarter-over-quarter, with near-term strength in the Satcom product line offsetting lumpiness in the Sat sampling activity of DAS (distributed antenna system) wireless products (for which project engagement remains robust, so Emcore continues to expect a material revenue contribution in 2019–2020, when 5G deployments move beyond trial phases).

Revenue for Chips and Navigation products were both nominally down due to the timing of shipments during the quarter.

"In the chip market, we continue to see strong demand for 2.5G PON [passive optical network] product within China. However, we were unable to service all the demand in the third quarter due to limitation in external supply chain," comments president & CEO Jeffrey Rittichier. "Beyond GPON, the uncertainty around ZTE in China continued to create headwinds for our customers' customers in the third quarter [who are more exposed to ZTE in higher-margin, higher-ASP chips], which in turn impacted our overall chip revenue as expected. However, we believe this is more of a timing issue and would expect to see this demand return in subsequent quarters," he adds.

"In the navigation market, the production level for our products remains on plan, with a growing backlog of programs," Rittichier says. "We were selected as the winner of two new programs for our flagship product that we are expected to formally announce in the coming quarter. Both wins were achieved against strong competition from incumbent suppliers."

On a non-GAAP basis, gross margin has fallen further, from 35.4% a year ago and 27.3% last quarter to just 7.3%. However, this was driven by several unique challenges including the timing of wafer fab period expenses, inventory write-downs for CATV-related DFB [distributed fiber Bragg] lasers and long inventory, under-absorption by wafer fabs driven by lower shipments, new L-EML transmitter introduction cost, lower chip yields and higher chip testing costs as Emcore ramped up new suppliers to add on new chip delivery capacity. Without these expenses (totalling $2.6m or 15% of sales) which are not expected to recur in fiscal Q4, gross margin would have been 22%.

"The trough in CATV orders hurt us on the top line, while a poor product mix exerted additional pressure on margins," notes Rittichier.

Operating expenses rose from $8.9m last quarter to $9.1m. A rise in R&D expenses from $3.3m to $3.9m (due to the acceleration of product development on the fiber-optic gyro side) offset a cut in sales, general & administrative (SG&A) expenses from $5.6m to $5.2m. Also, the latter included a $520,000 G&A expense due to a reserve taken as an allowance for bad debt related to Satcom and Chip customers.

"When coupled with higher factory costs due to weak absorption and higher E&O [excess and obsolete] charges, our net income fell well below expectations," says Rittichier.

Compared with pre-tax income of $3.6m ($0.13 per diluted share) a year ago, pre-tax loss from has worsened from –$2.1m (–$0.08 per diluted share) last quarter to –$6.7m (–$0.26 per diluted share).

Capital expenditure (CapEx) was $1m, and depreciation was $1.5m. Despite the challenges during the quarter, cash and cash equivalents fell only slightly from $65.5m to $65.3m.

"We continue to experience a headwind due to the inventory overhang [at our main cable TV customer," says Rittichier. "Looking beyond the specific customer

dynamics, we have seen an overall strengthening in demand for our cable TV product, notably for our L-EML based solutions," he remarks. "We shipped a record number of L-EML transmitters in the quarter and notched two more design wins for our L-EML mini transmitter at the ANGACOM show [Exhibition & Congress for Broadband, Cable and Satellite in Cologne, Germany] in June. The increased adoption of L-EML products provides solid evidence that this technology provides a distinct competitive advantage in the markets that enables substantially higher transmission efficiency versus legacy DSP-based products," he adds.

For fiscal-fourth quarter 2018 (to end-September), given the relatively limited demand visibility inherent in the cable TV business, Emcore expects revenue to grow to $21–23m. "We expect to see growth across all three of our product areas, namely Cable TV, Chips and Navigation," says Rittichier.

"ZTE coming back means a richer margin picture for us at the expense of possibly damping down some amount of demand on the GPON side," he adds. "We expect gross margin to be in the low to mid 20s in the fourth quarter, as we continue to increase chip capacity and transition L-EML based transmitters to production," says Kim. "Next year by far the majority of the [CATV] product shipments will be linear EML," forecasts Rittichier.

www.emcore.com

POET's revenue grows 11.7% in Q2/2018

Optical Interposer-based product revenue on track for early 2019

For second-quarter 2018, POET Technologies Inc of Toronto, Canada and San Jose, CA, USA — a designer and manufacturer of optoelectronic devices, including light sources, passive waveguides and photonic integrated circuits (PIC) for the sensing and datacom markets — has reported revenue of US$752,198, up 11.7% on US$673,229 last quarter and up 16% on US$648,382 a year ago. Revenue primarily comprises sales of DenseLight photonic sensors for test & measurement applications.

Gross margin was 57.5%, down from 60.2% last quarter but up from 50.5% a year ago.

Net loss before taxes has grown further, from US$2,901,259 ($0.01 per share) a year ago and US$3,249,292 ($0.01 per share) last quarter to US$4,687,492 ($0.02 per share). However, Q2's net loss included non-cash stock-based compensation of US$1,063,773 and depreciation and amortization of US$659,820, compared with $792,122 and $596,015, respectively, last quarter and US$159,783 and US$558,919, respectively, a year ago.

Capital investment in plant, equipment and patents has risen further, from US$195,281 a year ago and $1,036,193 last quarter to US$1,139,259.

Overall, during the quarter, POET's cash and short-term investments have fallen from US$13.2m to US$10m.

During Q2, POET announced a master collaboration with SilTerra Malaysia Sdn Bhd (a wafer foundry offering fabrication and design support services in CMOS logic, high-voltage, mixed-signal, RF, BCD, power and MEMS technologies) for the co-development of fabrication processes and the manufacturing of its Optical Interposer Platform.

The firm also executed an agreement to co-develop transmit device solutions for POET's Optical Interposer Platform with photonic product maker Almae Technologies SAS of Marcoussis, France, a spin-off from III–V Lab (the joint Nokia, Thales and CEA-Leti industrial research laboratory). Almae is majority-owned by an affiliate of Accelink Technologies Co Ltd of Wuhan, China (a manufacturer of optical components and subsystems for the datacom, telecom and network access markets), which in March entered into a memorandum of understanding (MOU) with POET for the co-development of transceivers for 100/400G markets as well as low-cost single-channel (10/25G) products for telecom applications.

"Co-packaging of optics and electronics and chip-scale packaging for photonics components have emerged as the most actively discussed topics in the industry, with major data-center operators demanding integrated solutions from module manufacturers. The POET Optical Interposer promises to fulfill this need by providing a more versatile and less costly solution than currently available," believes CEO Dr Suresh Venkatesan. "We continue to focus on the development and commercialization of multiple highly differentiated products leveraging our Optical Interposer platform. We anticipate demonstrating the superiority of our solutions with the shipment of prototypes to customers later this year," he adds. "Moreover, the development of our interposer-compatible lasers, detectors and packaging processes are all on track, and we remain on target for initial revenues from these products in early 2019."

Venkatesan is delivering a presentation 'Integrated Photonics Using the POET Optical Interposer Platform' at the China International Optoelectronic Exposition (CIOE 2018) in Shenzhen, China on 5 September.

Also on 5 September, the firm is participating at the H.C. Wainwright 20th Annual Global Investment Conference at the St. Regis Hotel in New York, where executive VP & chief financial officer Thomas R. Mika is scheduled to present.

www.poet-technologies.com

Lumentum's annual revenue grows 25% to record $1.25bn, yielding record profit

Capacity constraints for diode lasers and ROADMs being alleviated by Thailand factory ramp-up

For full-year fiscal 2018 (to 30 June), optical and photonic optical component and subsystem maker Lumentum Holdings Inc of Milpitas, CA, USA has reported revenue up by 24.6%, from $1001.6m for 2017 to $1247.7m for 2018.
By segment, Commercial Lasers grew by 31.1% from $143.8m to $188.5m (driven by micro and macro materials processing). Optical Communications grew by 23.5% from $857.8m to $1059.2m, driven by 848% growth in the Industrial & Consumer segment (due to the adoption of 3D sensing in mobile devices) outweighing falls in both Telecom and Datacom revenues.

Fiscal fourth-quarter 2018 revenue was $301.1m, up slightly on $298.8m last quarter and by 35.2% on $222.7m a year ago, driven by record revenues in TrueFlex ROADMs (reconfigurable optical add/drop multiplexers), commercial lasers, and industrial pump lasers.

Commercial Lasers reached a record $56.2m (18.7% of total revenue), up 7% on $52.5m last quarter and 56.5% on $35.9m a year ago, driven by record revenue from 1kW-class fiber lasers. "We continue to ramp our newest fiber-laser products to meet strong customer demand and are benefiting from investments in capacity expansion made earlier in the year," says president & CEO Alan Lowe.

Optical Communications revenue was $244.9m (81.3% of total revenue), down only slightly on $246.3m last quarter but up 31.1% on $186.8m a year ago. Of this, Datacom revenue was $34.5m, down 5% on $36.3m last quarter and 31% on $50.1m a year ago. However, Telecom revenue was $133.1m, up 9% on $122.6m last quarter and 11% on $120.2m a year ago (with telecom transport products contributing significantly, including record sales for TrueFlex ROADMs, including strong demand from multiple customers in China). Telecom pump laser sales continue to be strong, but remain capacity-limited (exacerbated by Lumentum's increased internal need for pumps for its ROADMs). Industrial & Consumer revenue was $77.3m, down 12% on $87.4m last quarter (due to 3D sensing seasonality) but up 368% on just $16.5m a year ago (due mainly to the introduction of 3D sensing into consumer mobile applications).

"Industrial diode laser product lines, which is primarily driven by customers building their own fiber lasers, also delivered record revenues," notes Lowe. "Growth was enabled by newly expanded capacity and efficiency improvements. However, even with these, the combination of external customer demand and internal demand for use in our own fiber lasers out-stripped our ability to supply in the fourth quarter," he adds. "Part of these capacity additions is in our own factory in Thailand, which started shipping qualified industrial diode products in the fourth quarter."

On a non-GAAP basis, gross margin has risen further, from 32.9% a year ago and 36.3% last quarter to 37.2%. Despite the degradation in revenue mix (with more Telecom and less Industrial & Consumer revenue), Optical Communications gross margin rose from 31.1% to 34.8%, driven by improvements in Telecom margins associated with the higher mix of higher-margin transport products and lower average manufacturing costs due to higher volumes. Commercial Lasers gross margin rose from 42.1% to 47.9% due to the relative increase in fiber lasers in the revenue mix. Full-year gross margin has risen from 34.7% to 38.9%, driven by more higher-margin Industrial & Consumer and Laser products in the revenue mix as well as overall increased leverage over fixed manufacturing costs.

Operating expenses (OpEx) have been cut from $59.1m (19.8% of revenue) last quarter to $58.5m (19.4% of revenue). Despite growing by 7% from $222.9m to $238.9m, full-year operating expenses were cut from 22.3% of revenue for 2017 to 19.1% for 2018.

Operating income has risen from $20.4m (operating margin of 9.2%) a year ago and $49.4m (16.5% margin) last quarter to $53.6m (17.8% margin). Full-year operating margin has risen from $124.3m (12.4% margin) to $246.2m (19.7% operating margin, a larger increase than for gross margin due to strong leverage over operating expense).

Net income was $61.6m ($0.95 per diluted share), up from $50.6m ($0.78 per diluted share) last quarter and $25m ($0.39 per diluted share) a year ago. Full-year net income more than doubled from $122.4m ($1.94 per diluted share) for 2017 to $247.8m ($3.82 per diluted share) for 2018.

Due to strong free cash flow, cash and short-term investments have risen further, from $555.3m a year ago and $692.8m at the end of last quarter to $711.5m, despite higher capital investment throughout the year related to manufacturing capacity expansion, new products, and expenses related to bringing up the new factory in Thailand.

"Our strategy of investing in differentiated products addressing multiple growing end-markets critically dependent on photonics

drove our strong fiscal 2018 results and positions us well for the future," reckons Lowe.

For fiscal first-quarter 2019, Lumentum expects revenue to grow to $340–360m. Operating margin should rise to 19–21%, while diluted earnings per share is expected to be $0.90–1.10.

ROADM modules and line-card systems continue to be limited by production capacity, so Lumentum is adding more new capacity to meet the increasing customer demand.

"Later this calendar year, we will be introducing a full turnkey fiber-laser system to broaden our customer base. We expect this, along with other new laser products to be introduced in the future, will even further accelerate growth," says Lowe. "We are also expanding pump laser capacity to meet customer demand, which we expect to remain strong," he adds.

"Early in the fourth quarter, we started shipping VCSEL products that we believe will be used in next-generation product cycles. We expect this volume ramp to continue through the first quarter and into the fiscal second quarter of 2019," he adds. "This earlier ramp [than expected] will result in 3D sensing volumes being spread across more quarters compared to last year's peak profile. In the fourth quarter we had modest revenue contributions from multiple Android customers who have or will be announcing new high-end devices. We've numerous additional products in design with our lead customer. We are also engaged with new customers on multiple new products and have received production purchase orders from several of these customers," he adds. "We expect to broaden our customer base and product mix over the time that 3D sensing proliferates from high-end mobile devices to a broader range of products and price points. We also continue to work on 3D sensing and LiDAR for automobile applications, and expect this to be a growth driver in 2021 and beyond. With our proven manufacturing scalability, proven field reliability and new product pipeline, we believe we are well positioned to be the partner of choice for 3D sensing customers around the world in fiscal 2019 and over the long run."

"Later this calendar year, we're planning to introduce a significantly cost-reduced 100G transceiver targeting the hyper-scale data-center market to increase our competitiveness and margins in this rapidly growing end market," continues Lowe. "We also continue to make good progress on our 400G datacom transceiver programs, which are receiving a lot of interest from a broad range of customers. Moving from 100G to 400G, significant technology leads are required and Lumentum's core technologies positions us well," he reckons.

In July, the stockholders of Oclaro Inc of San Jose, CA, USA (which provides optical components and modules for the long-haul, metro and data-center markets) approved its acquisition by Lumentum (agreed on 12 March). Although the merger has received approval under the US Hart–Scott–Rodino (HSR) Antitrust Improvements Act of 1976, it is subject to other closing conditions including anti-trust regulatory approval in China. "We entered Phase 1 of this approval process in mid-July," notes interim chief financial officer & senior VP of strategy and corporate development Chris Coldren. "We continue to work with Oclaro on completing this pending transaction."

www.lumentum.com

MACOM showcasing optical & semiconductor components for cloud data-center, FTTx and 5G applications at CIOE

In booth #1A32 at the China International Optoelectronic Exposition (CIOE 2018) in Shenzhen Convention & Exhibition Center, China (5–8 September), MACOM Technology Solutions Holdings Inc of Lowell, MA, USA (which makes semiconductors, components and subassemblies for RF, microwave, millimeter-wave and lightwave applications) is showcasing its product portfolio for 10 and 25Gbps passive optical network (PON), 5G optical networks, metro/long-haul and 100/200/400Gbps cloud data-center applications.

MACOM is highlighting how its broad portfolio is enabling high bandwidth and low latency, addressing the high-performance analog interfaces between electrical and optical domains and providing solutions aimed at meeting the demanding size, power and signal integrity requirements of high-speed next-generation PON, 5G and cloud data-center networks.

Highlights at the CIOE show include:

- 10/25Gbps-PON ONU/OLT: total integrated circuit and optical solutions;
- 5G wireless connectivity solutions: featuring MACOM's 50Gbps PAM-4 chipset;
- data-center solutions: featuring 100Gb/s CWDM4, 1 DR1/FR1/LR1, and 100/200/400Gb/s PAM-4; and
- long-haul and metro solutions: featuring MACOM's 64 GBaud driver and TIA.

MACOM's complete portfolio includes high-performance modulator drivers, transimpedance amplifiers (TIAs), clock/data recovery circuits (CDR), crosspoints, APD, PIN photodiodes, FP and DFB lasers, silicon photonics, mixed-signal PHYs and PAM-4 for enterprise and telecom optical systems operating up to 100/200/400Gbps and beyond.

www.cioe.cn/en
www.macom.com

Oclaro's quarterly revenue falls 5%, but 100G CFP2-ACO sales again breaks record

Americas rebounds to 34% of sales, as ZTE ban cuts China shipments

For full-year fiscal 2018 (to 30 June), Oclaro Inc of San Jose, CA, USA (which provides components, modules and subsystems for optical communications) has reported revenue of $543.2m, down 9.6% from $601m in fiscal 2017.

Fiscal fourth-quarter 2018 revenue was $120.9m (split 40%:60% between client-side/datacoms and line-side/telecoms, compared with 49%:51% a year ago). This is down 5% on $127.3m last quarter and 19% on $149.4m a year ago.

Although down by 20.4% on $120.6m a year ago, sales of 100G-and-above products rebounded slightly from $95.7m last quarter (75% of total revenue) to $96m (79% of total revenue).

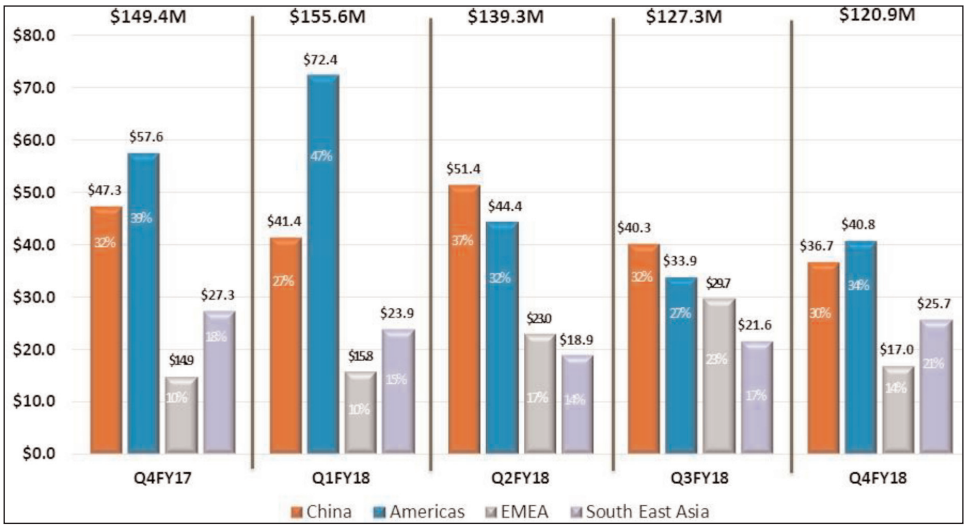
"We once again had a record revenue quarter for our ACO [100G CFP2 analog coherent optics] product families and our high-speed, data-center laser chips," says CEO Greg Dougherty.

Sales of 40G-and-below products fell further to $24.9m (21% of total revenue), down 21% on $31.6m (25% of total revenue) last quarter.

China has fallen further from 32% of total revenue last quarter ($40.3m) to 30% ($36.7m) and Europe, the Middle East & Africa (EMEA) from 23% ($29.7m) to 14% ($17m), while the Americas have rebounded from 27% ($33.9m) to 34% ($40.8m) and Southeast Asia has risen further from 17% ($21.6m) to 21% ($25.7m).

"Despite the negative revenue impact of US Department of Commerce sanctions that prevented us from shipping to ZTE [in China] during Q4, we had another strong quarter," says Dougherty.

Although full-year gross margin has fallen from 39.5% in fiscal 2017 to 38.6% for fiscal 2018, quarterly gross margin has rebounded from 37.2% last quarter to 37.7%.



Operating expenses have risen further, from $31.3m a year ago and $32.4m last quarter to $33m (and from $115.6m for fiscal 2017 to $129m for fiscal 2018).

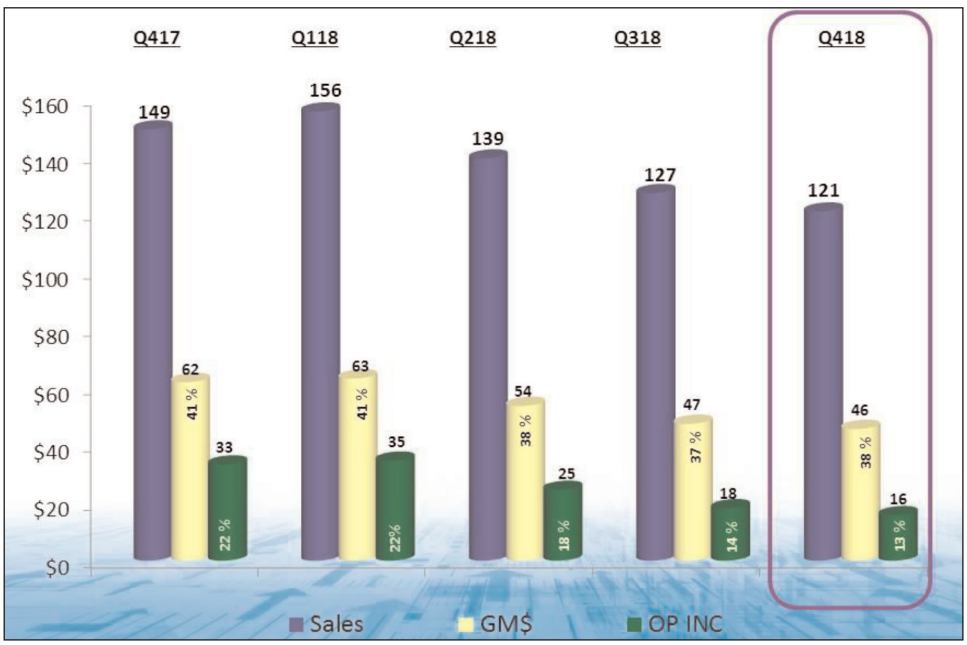
Operating income has fallen further, from $33.3m (operating margin of 22.3%) a year ago and $18.1m (14.2% margin) last quarter to $15.7m (13% margin). Full-year operating income was hence $92.9m (17.1% margin), down from $130.9m (21.8% margin) in fiscal 2017.

Likewise, net income has fallen further, from $33.9m ($0.20 per diluted share) a year ago and $19m ($0.11 per diluted share) last quarter to $14.6m ($0.08 per diluted share). Full-year net income was $91.1m ($0.53 per diluted share) for fiscal 2018, down from $130.1m ($0.79 per diluted share) in fiscal 2017.

During the quarter, cash, cash equivalents, and short-term investments rose by about $19m from $304.4m to $323.1m (up from $257.5m a year ago).

"We recently received overwhelming stockholder approval for our proposed merger with Lumentum, which we continue to expect will close in the second half of this calendar year," says Dougherty.

www.oclaro.com



Acacia launches ZR coherent CFP & CFP2 DCO modules

Acacia Communications Inc of Maynard, MA, USA has announced the general availability of two new high-speed coherent optical interconnect products for ZR applications. Enabled by low-power, highly integrated designs leveraging its proprietary digital signal processor (DSP) and silicon photonic technologies, the firm believes that its new 100G/200G CFP2-DCO ZR and next-generation low-power 100G CFP-DCO ZR addresses demands for growing capacity in network access, edge and enterprise campus use.

The new products support the requirements of unamplified applications beyond the 40km reaches standardized in the industry and extend to 80km and beyond. The CFP-DCO ZR module is capable of supporting the 18W power class that has been widely deployed for 10km client applications. Both modules also offer high-capacity and low-power-consumption solutions designed to reduce the complexity, power usage and cost of high-bandwidth interconnects.

"Based on our experience with network operators, we see increasing demand for 100G and above in access aggregation markets," comments Jimmy Mizrahi, VP global portfolio at ECI Telecon Ltd. "Coherent 100G and 200G ZR solutions, in compact pluggable form factors, will be an attractive solution for network operators with requirements for reaches greater than 40km in applications such as 5G backhaul and cable access," he believes.

"Traditionally, coherent optical transmission was primarily used for longer-reach applications, but traffic patterns are changing in ways that are leading to the need for high-capacity interconnects that target shorter reaches in a power-efficient and cost-effective manner. ZR optics address this need," says Acacia's senior director of marketing Tom Williams. "Acacia pioneered the coherent ZR offering with our industry-first CFP-DCO form factor and our vision is to continue to expand the use of coherent technology in shorter-reach applications."

Shorter-reach applications are an emerging opportunity for coherent optical interconnects and are gaining attention from industry standards organizations. Standards are under development for coherent ZR-class interfaces at 100G, 200G and 400G, adapting traditional 80km ZR requirements for coherent transmission. Applications ranging from the interconnection of hyper-scale data centers to the aggregation of residential access networks and 5G backhaul are driving converging requirements for these coherent interfaces.

www.acacia-inc.com

NeoPhotonics' revenue grows 18% in Q2 to $81.1m

Growth of 30% outside China driven by data-center interconnect and metro deployments in Americas and EMEA

For second-quarter 2018, 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 networks) has reported revenue of $81.1m, up 18% on $68.6m last quarter and 11% on $73.2m a year ago (well above the $70–76m guidance), driven by robust demand in the Americas and improved demand in China.

High-Speed Products (for data rates of 100G-and-above) matched last quarter's record 86% of total revenue, after growing sequentially by $10m.

Sequential growth outside China was 30%, led by very strong demand for high-speed products used in data-center interconnect (DCI) and metro deployments by key customers in the Americas (22% of total revenue) and Europe, the Middle-East & Africa (EMEA, 21% of revenue). In particular, DCI applications (mostly 400G coherent products) are rapidly approaching $10m (and 10% of revenue).

China represented 57% of total revenue (down from 61% last quarter). Sequential growth in China was the result of deployments at the provincial level as well as exports from China, despite trade tensions and ongoing uncertainties there. "We do not see any share shift in China due to the ZTE ban [the US Department of Commerce's Denial Order] prior to it being lifted. Thus, the impact of the ban has been net subtractive from the China market," says chairman & CEO Tim Jenks. "With the ban resolved, we expect additional volume tenders and overall demand growth."

The top five customers grew 27% quarter-over-quarter (to 80–90% of total revenue) as these key customers succeeded in the market and NeoPhotonics had the capacity to support their rapid volume ramps. "Communication equipment companies' market share is consolidating among a few leaders, and NeoPhotonics is levered to those market-leading customers," notes Jenks.

Huawei Technologies (including its affiliate HiSilicon Technologies) remained the largest customer, but down from 48% to 43% of revenue. The next four largest customers comprised 47% of total revenue (up from 36%). Two of these were 10%-or-greater customers (one at 25% and the other 10%).

Due to the higher demand, net inventory has fallen from $69m last quarter to $61m (from 104 days of inventory on hand to 84 days, slightly below the targeted 90 days).

On a non-GAAP basis, gross margin was 20.1%, down from 23.9% a year ago but up from 14.7% last quarter (although the latter was below the expected 16–20% due partly to a $1.2m ZTE-related write-down). Of this, product margin was 30% (up four percentage points quarter-over-quarter due to higher manufacturing utilization and improved costs). This was offset by 9.5% in cost-of-sales charges, consisting primarily of: about five points of inventory revaluation at the new lower standard cost level; about three points of under-absorption (excess capacity) charges, primarily in the externally modulated laser (EML) fab (since factory loading is substantively less than the 80% average); and about 1.5 points of inventory write-offs.

Growth outside China was 30%, led by very strong demand for high-speed products used in DCI and metro deployments by key customers in the Americas and Europe, the Middle-East & Africa

Operating expenses (OpEx) have been cut further, from $24.2m (33.1% of revenue) a year ago and $22.9m (33.4% of revenue) last quarter to $21.8m (26.9% of revenue) due to the timing of R&D-related project spending.

Net loss was $6.3m ($0.14 per diluted share), cut from $14.6m ($0.33 per diluted share) last quarter and below the $6.6m ($0.15 per diluted share) a year ago.

Cash used in operations was $1m (down from $3.5m last quarter). Capital expenditure (CapEx) was $2m (cut from $8m). Free cash flow was hence –$3m.

During the quarter, cash and cash equivalents, short-term investments and restricted cash fell from $86.9m to $67.6m, due mainly to the repayment of $18.6m in debt as it became due, mostly in China. "We do not plan to re-borrow in China until our latest legal dispute with APAT Optoelectronics is resolved," says senior VP & chief financial officer Beth Eby. Shenzhen-based APAT Optoelectronics Components Co Ltd acquired NeoPhotonics' Low Speed Transceiver Product assets in January 2017. "This is the third dispute, adding to that previously reported in our 10-Q. This does not have an impact on our China operations, as we have cash and additional credit available in the USA," she notes.

"We saw continued progress on our new product initiatives," says Jenks. The firm increased volume shipments of high-baud-rate coherent receivers and ultra-narrow-linewidth tunable lasers for systems operating at 400Gb/s per wavelength which are being deployed in DCI and metro applications. Further, we continued to make good progress on new product design wins and initial shipments for products for applications at 600Gb/s per wave-

length, including our complete suite of 64Gbaud micro integrated coherent receiver, coherent driver modulator (CDM) and ultra-narrow-linewidth tunable lasers. For applications inside the data center, we are now making early shipments of 53Gbaud lasers and drivers for single-wavelength 100Gb/s applications. These products are key elements used in 400G client-side DD-QSFP and OSFP transceivers, which are expected to be deployed in large volumes starting next year," he adds.

"In the near term we continue to ship 28Gbaud lasers for 100G and 2x200G intra-data-center applications. For next-generation systems, we demonstrated at OFC (Optical Networking and Communication Conference & Exhibition) in March our 64Gbaud coherent optical subassembly (COSA) and our nano-tunable laser, and we are developing even higher-baud-rate components for the next generation of DCI and transport systems. We continued to see strong growth in our multi-cast switch shipments, reflecting both strength in metro deployments of colorless, directionless and contentionless (CDC) reconfigurable optical add/drop multiplexers (ROADMs) and the increasing use of contentionless switching solutions in data centers to manage densification," Jenks continues.

Coherent DCO module revenue grew through the quarter with customer wins and as volumes doubled quarter-on-quarter. "New China tenders will positively contribute to increases in DCO volumes," says Jenks. "We continue to press forward on our developments for next-generation DCO modules that are complementary to our existing market, as we view these to be important solutions going forward. As such, we are designing our 64Gbaud components into next-gen 400G-and-beyond DCO modules, as we demonstrated in March at the OFC conference."

"With our new product traction and increasing momentum in our core markets, we are optimistic for continued improvement," says Jenks.

With the ZTE resolution, China has returned to a normalized demand environment and will continue its 100G-and-beyond network builds in support of the roll-out of 5G wireless systems

For third-quarter 2018, NeoPhotonics expects continued demand strength in the Americas (from DCI) and in China (from provincial and metro build outs). "We have not yet planned for any material shipments to ZTE or its supply chain partners," notes Eby. Revenue should therefore be $79–84m. Gross margin will be 20–24%, a bit lighter than originally expected. "We continue to get that increased volume and cost reduction, but we expect it to be offset by a couple of points of price erosion and a couple of points due to a shift in product mix to lower-margin products," says Eby. "Because we are not seeing any of the ZTE benefit come back yet, we are still estimating about three points of excess-capacity charge from our EML fab." With operating expenses rising back slightly to $22–23m, diluted net loss per share should be $0.17–0.07.

"We are a little lighter on breakeven than we expected, as we are still taking underload charges in our EML fab," says Eby. "We are breakeven in the mid-$80m [of revenue], once we get through the underload charges," she adds. "We expect to be operating-profit breakeven in the fourth quarter."

"In Q4, we expect again a little bit of additional volume," says Eby. "We will start to see the price reductions for next year hit the tail end for December. But we should start to see some of that EML volume come back as the ZTE supply chain comes back," she adds. "Part of the EML underload was share loss to other laser form factors and part of it was the ZTE supply chain… ZTE has certainly re-engaged with us and each of their supply chain partners [in terms of initial orders]. It will take a quarter or two for two things to happen."

"We remain enthusiastic about our mid- and long-term prospects," says Jenks. "First, NeoPhotonics has focused on delivering components and modules with industry-leading performance, which puts us in position to benefit from the current demand acceleration as well as the transition to 400G data rates. We expect that in 2019 we will see 400G become a standard building block for data-center bandwidth and we are a key vendor for all distances. And even higher speeds are expected in the not too distant future, for which we are working with the leading global customers as we develop higher-speed, highly integrated, low-power products. Second, deployments of coherent systems into metro and increasingly metro-edge applications is continuing, first in North America and across the globe. Third, we believe that with the ZTE resolution, China has returned to a normalized demand environment and will continue its 100G-and-beyond network builds in support of the roll-out of 5G wireless systems," he adds.

"Industry momentum toward fully contentionless networks continues to build, with new adoptions happening which will include certain data-center applications that we expect to drive growth of multi-cast switches over multiple years. And we are actively engaged to extend application of our coherent product suite to adjacent markets such as LiDAR for autonomous vehicles."

After the end of Q2/2018, NeoPhotonics received a letter of intent for the purchase of its Russia factory for approximately book value. "We do not expect any material gain or loss on this potential transaction," says Eby. "If a transaction occurs, it would be slightly accretive to gross margin."

www.neophotonics.com

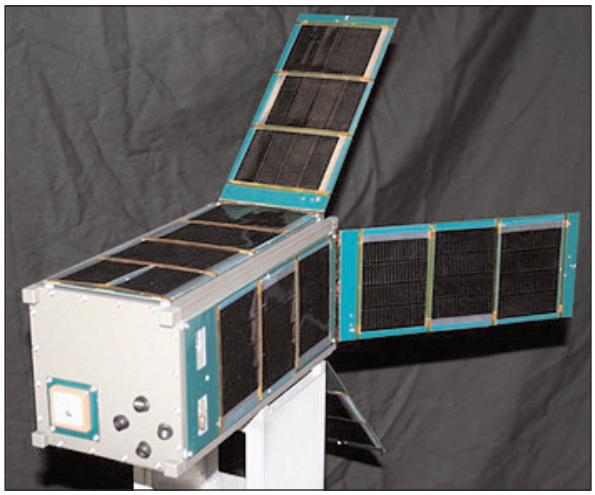
Alta Devices' solar cells power CubeSat mission

Alta Devices of Sunnyvale, CA, USA (a subsidiary of Hanergy Thin Film Power Group Ltd of Beijing, China since 2014) says that its solar cells have powered a CubeSat mission by Twiggs Space Lab LLC (TSL), NearSpace Launch Inc (NSL) and their launch logistics partner NanoRacks LLC. The Asgardia-1 satellite was based on NSL's FastBus platform and powered by about 24W of Alta solar cells. Launched in November 2017 on an Orbital ATK (now Northrop Grumman) cargo resupply mission, the 2U-size FastBus was inserted into a 475km low-earth orbit in December 2017 via the NanoRacks External Cygnus Deployer. The 2U satellite carried a payload that included a solid-state memory experiment and particle detectors used to determine the actual effects of on-orbit radiation.

TSL, NSL and NanoRacks are at the forefront of small-satellite innovation and are pioneering new, disruptive models of satellites that are much smaller, simpler and more affordable. Their mission is to broaden access to space for educational as well as commercial participants. They selected Alta Devices solar technology due to its unique modular, lightweight and high-efficiency characteristics.

"Our goal is to inspire future generations of engineers and scientists through innovation in the field of space," says TSL's founder Bob Twiggs. "Alta Devices technology is easy to integrate, and its modular form factor is well suited to the standardized dimensions of CubeSats. Our team is excited about the potential to innovate and rapidly prototype using this technology," he comments. "With the FastBus, we aim to provide a reliable, affordable and quick-turn CubeSat platform built on our heritage of communication and bus technologies," says NearSpace Launch's founder Dr Hank Voss.

"At Nanoracks, we're focused on lowering the barriers of entry to space. We see adoption of innovative solar and bus technologies as another critical piece of the puzzle in making space exploration accessible to entrepreneurs, scientists, students, corporations and space researchers around the world," says NanoRacks CEO Jeffrey Manber. "Any component that is more robust, withstands the launch loads and maintains a clean ride-share environment is going to make things easier for everyone on a practical and regulatory perspective," he adds. "The Alta [glass-free] solar cells came through with flying colors on the Asgardia-1 satellites."



The Asgardia-1 satellite.

CubeSats (satellites weighing less than 15kg) were originally developed for university students to participate in space research. The standard has now been adopted worldwide and has helped to ignite a small-satellite revolution. Typically placed into low-earth orbits, they often have standardized or off-the-shelf components and have facilitated more affordable and easier access to space. CubeSats are driving new industries via the explosion of big data accessible from space.

Alta Devices technology is easy to integrate, and its modular form factor is well suited to the standardized dimensions of CubeSats

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: solar cells are traditionally expensive, fragile, rigid and difficult to encapsulate and robustly attach to spacecraft.

Alta Devices says that its solar cells overcome these challenges because they are flexible, easy to encapsulate and mount, and provide high power conversion efficiencies. For example, the cells can be mounted to low-mass deployable structures including coiled carbon fiber booms, flat-packed, polymer-based accordioned arrays, and even inflatable structures, allowing creative design approaches to maximizing onboard solar power. Alta Devices says that it is empowering autonomy, as its cells provide a new level of mechanical and design flexibility for the small-satellite industry.

"Innovation in solar is essential to the continued evolution of small-satellite technology," comments CEO Jian Ding. "The industry has seen disruptive change in every technology area except in solar cells. Solar cells were expensive, challenging to integrate and hard to procure, until now," he adds. "The success of the FastBus mission provides another data point validating our technology and further cements our commitment to our partners as they plan their upcoming launches."

Alta Devices exhibited at the 32nd Annual Small Satellite Conference in Logan, UT, USA (4–9 August). On display were Alta Devices' solar technologies and TSL and NSL SmallSats. NanoRacks also attended the conference.

www.altadevices.com
www.nearspacelaunch.com

Midsummer recruits production manager from Saab

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 boosted its staffing by 30 (from 45 to 75) since the beginning of 2018 to ramp up production in response to increased demand. The firm says it is experiencing greater global interest in DUO, its proprietary system for fast, fully automated manufacturing of CIGS solar cells. To further accelerate production volume, it recently recruited new production manager Sven Pettersson, who most recently worked with logistics, purchasing and production planning at Saab Industrial Group.

Sven Pettersson.

Pettersson has been working at defence industry group Saab since 2011, most recently as production controller responsible for logistics and purchasing. He previously worked in similar roles in companies including Strålfors AB and Aerosol Scandinavia AB, and has long experience in logistics, purchasing and production planning. Pettersson has an education in information logistics and calculation from Sweden's Linné University.

Midsummer's shares were listed on Nasdaq First North Stockholm on 21 June, in conjunction with implementing a new issue of about SEK100m shares, to expand production capacity from about 10 to 40 DUO machines per year in order to establish a production line for 'Clix by Midsummer' (a plug & play metal roof with integrated solar cells) as well as for marketing and strengthening working capital.

Midsummer says that it also plans further recruitment in technology as well as marketing and sales.

Midsummer receives repeat order from Asia worth SEK30m

Midsummer has received a repeat order from Asia for production equipment (for delivery in first-half 2019) worth about SEK30m. A partial payment will be made within 30 days.

Midsummer says it is seeing greater global interest in its proprietary compact system for fast, fully automated manufacturing of CIGS solar cells.

"This repeat order is a strong indication that interest in our advanced solutions for the production and installation of thin-film solar cells is growing in the Asian market," says CEO Sven Lindström. "Several strong global trends support our business idea and operations, not just the general need to switch to renewable energy, but also technical and regulatory developments that make thin solar panels attractive in urban environments," he adds. "Now, we intend to strengthen our production capacity further to meet the increased demand for our products."

www.midsummer.se

Plasmon-enhanced mid-IR photodetection at room temperature

Devices combine two-dimensional subwavelength hole array (2DSHA) structure with indium arsenide antimonide photodiode.

Singapore's Nanyang Technological University and Georgia State University in the USA have developed mid-wavelength infrared (MWIR, 3–5μm) photodetectors that operate at room temperature [Jinchao Tong et al, Appl. Phys. Lett., vol113, p011110, 2018]. The devices combine a two-dimensional subwavelength hole array (2DSHA) structure with an indium arsenide antimonide (InAsSb) n-i-p photodiode to boost detectivity while maintaining fast response.

MWIR detection is needed/desired in security, communication, medical diagnostics and remote sensing, but equipment often has to be cooled, increasing system complexity and expense in terms of capital investment and running costs. The researchers comment: "The realization of a room-temperature mid-wave infrared photodetector makes the application systems more economic and easily extended to more application domains."

The n-i-p part of the device was grown on tellurium-doped n-type gallium antimonide (n-GaSb) substrate. A 1μm intrinsic i-$InAs_{0.91}Sb_{0.09}$ absorber layer was placed between 20nm layers of n- and p-type aluminium indium arsenide antimonide ($Al_{0.15}In_{0.85}As_{0.9}Sb_{0.1}$) doped with silicon and beryllium, respectively.

The epitaxial structure began with a 1μm beryllium-doped p-GaSb contact/buffer, and 40nm of beryllium-doped p-$Al_{0.42}Ga_{0.58}Sb$ as a wide-bandgap layer to block electrons forming a dark current on the p-side.

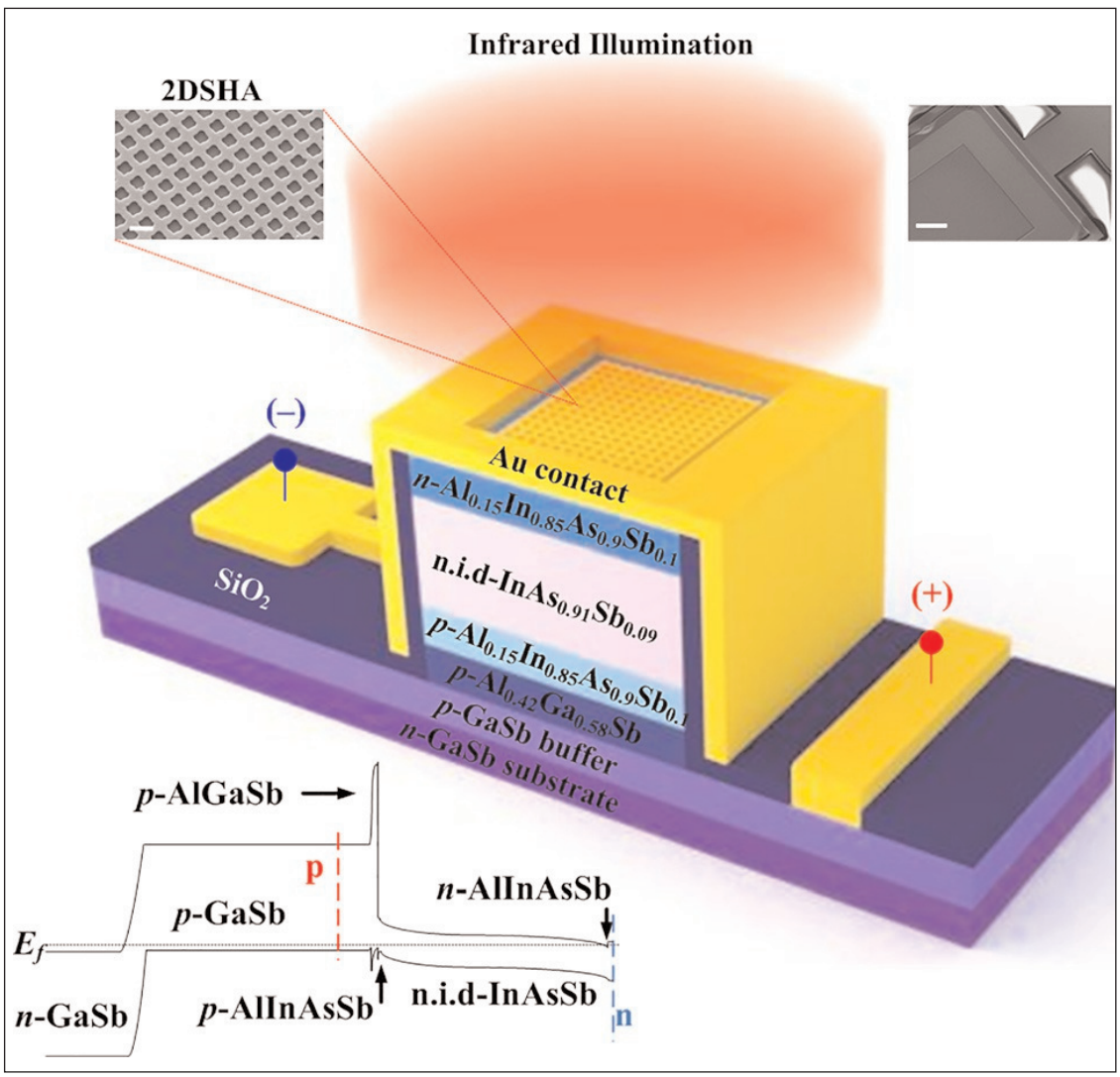


Figure 1. Design of 2DSHA-hetero n-i-p photodetector for enhanced MWIR photodetection. Inset: scanning electron micrographs of 2DSHA (left) and top view of 2DSHA-hetero n-i-p photodetector (at 30° angle), scale bars 1μm and 50μm, respectively. Left-bottom is a schematic band diagram of the heterojunction; p and n indicate positions of the metal electrodes.

At the same time, the p-$Al_{0.15}In_{0.85}As_{0.9}Sb_{0.1}$ layer limited type II electron–hole transitions from the absorber into the p-$Al_{0.42}Ga_{0.58}Sb$.

The device was fabricated with the aim of having the surface plasmon polaritons (SPPs) interact with the intrinsic absorber through the thin 20nm n-$Al_{0.15}In_{0.85}As_{0.9}Sb_{0.1}$. The top and bottom contacts consisted of 15nm of titanium (Ti) and 200nm of gold (Au). The square 300μm-side mesas were wet etched. The 350nm silicon dioxide (SiO_2) passivation to protect the mesa and to reduce surface leakage was created using plasma-enhanced chemical vapor deposition (PECVD).

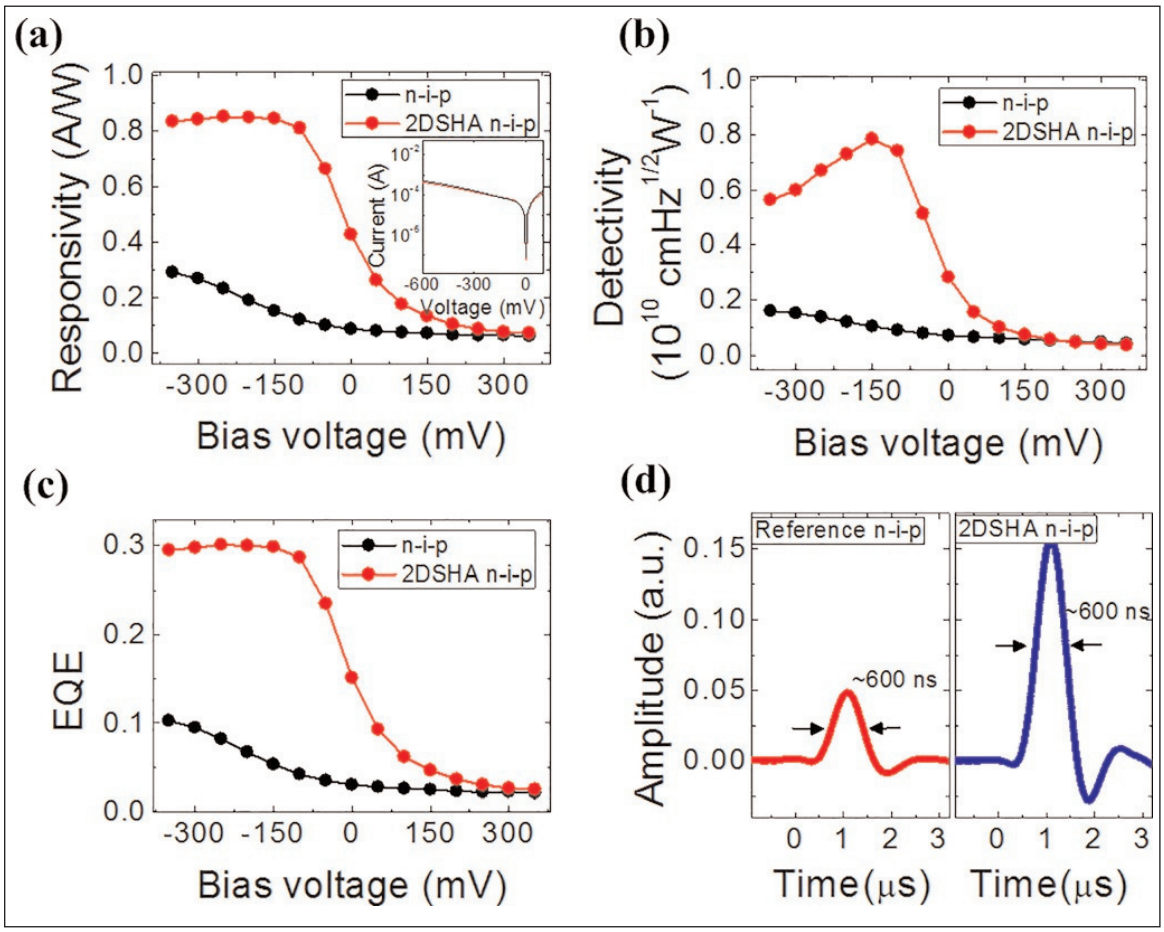


Figure 2. Room-temperature performance of 900nm-period 2DSHA-hetero n-i-p photodiode and reference. (a) Responsivity under biased voltages from –350mV to 350mV at room temperature. Inset: room-temperature current–voltage characteristics of photodiodes. (b) Blackbody detectivity. (c) External quantum efficiencies (EQE) at 3.5μm. (d) Impulse responses.

A gold-based two-dimensional subwavelength hole array (2DSHA) was fabricated using electron-beam lithography, metal evaporation and lift-off. The metal consisted of 3nm Ti adhesion and 70nm Au layers. The 70nm thickness for the Au layer exceeds the skin depth of 4.3–10.7nm for 1–6μm microwaves. This avoids direct transmission through the metal film.

In conventional p-i-n photodiodes there is a trade-off between responsivity and speed: thick intrinsic absorber layers are more responsive to optical radiation, but slower in tracking changes. The 2DSHA confines light near the metal-dielectric interface, allowing a thinner intrinsic layer to be used. The 'dielectric' in this case is the underlying semiconductor material.

The researchers estimate the surface plasmon resonance wavelength of their 2DSHA structure to be 3.5μm for the fundamental mode. This was aligned with the peak photocurrent response of the semiconductor heterostructure photodiode. The hole period of the 2DSHA was 900nm with the size of the square holes in the 2DSHA mesh being about half this. The team also explored other hole periods.

The 2DSHA with 900nm period showed the highest photocurrent at zero bias, in the wavelength range 2–5μm, over other 2DSHAs and over reference devices without 2DSHA. The enhancement over the reference for the 900nm-period structure was 3–4x.

The device was also characterized using a 700°C blackbody source (Figure 2). The response saturated at around –150V reverse bias, giving a value of 0.85A/W, compared with 0.15A/W for a reference device without 2DHSA. The reference device had a higher response of 0.3A/W at –350V bias. The 2DSHA and reference devices had similar dark current levels.

The room-temperature blackbody detectivity was $0.80x10^{10}$cmHz$^{1/2}$/W and $0.12x10^{10}$cmHz$^{1/2}$/W for the 2DSHA and reference photodiodes, respectively. The external quantum efficiency at –150mV was ~30% for the 2DSHA device, about 5x that of the reference.

The speed of both devices was determined from the ~600ns-wide response from 200ns pulses of a 4.77μm quantum cascade laser. The researchers comment: "These measured results show that the performance of the 2DSHA-hetero n-i-p photodetector can be improved a lot without sacrifice of the speed." ■

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Author: Mike Cooke

Hole gas boost for deep UV diode wall-plug efficiency

A strained layer of aluminium nitride gives rise to surface holes due to charge polarization effects.

US-based Bolb Inc and Semicon Light Co of South Korea have increased efficiency and reduced forward voltage for 280nm-wavelength deep ultraviolet (DUV) light-emitting diodes by creating a two-dimensional hole gas at the p-contact surface using variously strained layers of magnesium (Mg)-doped aluminium gallium nitride (AlGaN) [Jianping Zhang et al, Semicond. Sci. Technol., vol33, p07LT01, 2018].

The hole gas was formed at the surface of a strained heavily doped AlN layer due to strong polarization electric fields, which raised the valence band states above the Fermi level. The electric field arises from the spontaneous charge polarization of the III(Al,Ga)–nitride bond. An added component to the field comes from strain-dependent piezoelectric effects.

The technique is designed to overcome the problem of hole injection from the wider-bandgap high-Al-content AlGaN needed to emit DUV light. Magnesium doping becomes less effective at producing holes as aluminium content increases. And magnesium-doped pure GaN generally has low hole concentrations due to a high activation energy and consequent low activation efficiency of the acceptors into holes. Pure GaN also suffers from having a bandgap narrower than the energy of DUV photons, meaning that its inclusion in such LED structures will absorb the target radiation.

Contact	p^+-AlN	6nm
Contact	p-GaN	<1.0nm
Multilayer	p-AlGaN	50nm
MQW	5x($Al_{0.56}Ga_{0.44}N$/$Al_{0.4}Ga_{0.6}N$)	5x(11nm/4nm)
Contact	n^--$Al_{0.58}Ga_{0.42}N$	0.1μm
Contact	n^+-$Al_{0.58}Ga_{0.42}N$	0.2μm
Buffer	n-$Al_{0.58}Ga_{0.42}N$	2.5μm
Template	AlN	4.0μm
Substrate	c-plane sapphire	

Figure 1. DUV LED epitaxy.

DUV radiation is used to kill germs (among other applications such as curing), and compact, low-cost and efficient LEDs should find application in water purification and food sterilization, avoiding the overuse of antibiotics and the increase in resistant bacteria. Traditional DUV sources contain mercury, which is subject to the Minamata Convention that seeks to elimi-

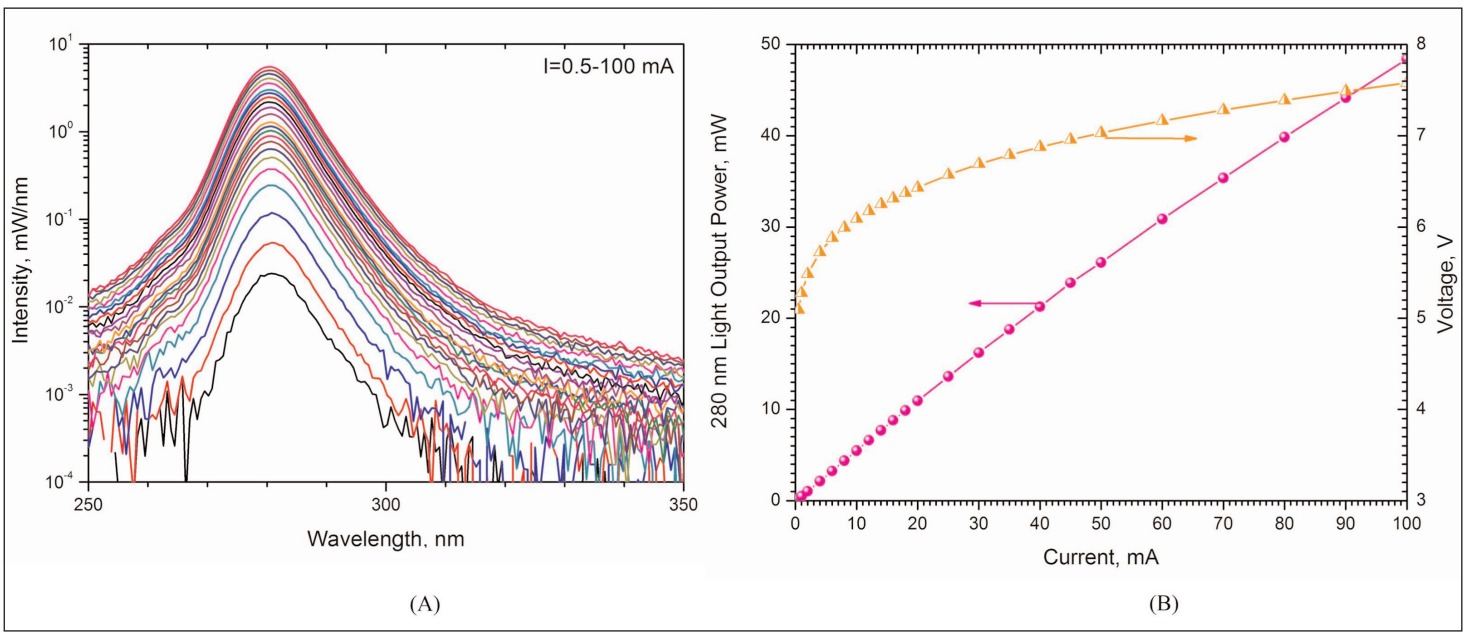

Figure 2. (A) Electroluminescence spectra taken at 0.5–100mA injection from transparent AlN-topped DUV LED. (B) Light output power and voltage characteristics versus current injection.

nate the toxic metal's use by 2020.

The DUV LED structure was grown on c-plane sapphire by metal-organic vapor phase epitaxy (Figure 1). The p-type layers were kept thin to ensure good hole conduction from the gas into the active multiple quantum well (MQW) region for efficient recombination with electrons into photons.

Chips were produced measuring 10milx20mil (0.25mmx0.5mm). The n-contact was made with titanium/aluminium/titanium/gold. Rhodium or palladium was used as p-contact. "It is worth noting that as-deposited Rh or Pd metal layers formed ohmic contacts to the thin heavily Mg-doped AlN layer, indicating high-concentration hole gases forming on the surface of the thin p-type AlN layer," the researchers write. The p-contact metal was 80nm thick.

The chips were flipped and bonded in 3.5mmx3.5mm ceramic packages. The packages included a half-dome sapphire lens. The rhodium p-contact devices were found to have higher light output due to the metal's higher reflectance of DUV, compared with palladium.

The light output power at 20mA current injection (55.4A/cm^2) was 10.95mW (Figure 2). The forward voltage was 6.43V, a reduction on that of conventional DUV LEDs with a p-GaN hole injection layer. The external quantum efficiency (EQE) and wall-plug efficiency (WPE) were 12.40% and 8.41%, respectively (Figure 3). The light output increased almost linearly up to 48.4mW at 100mA.

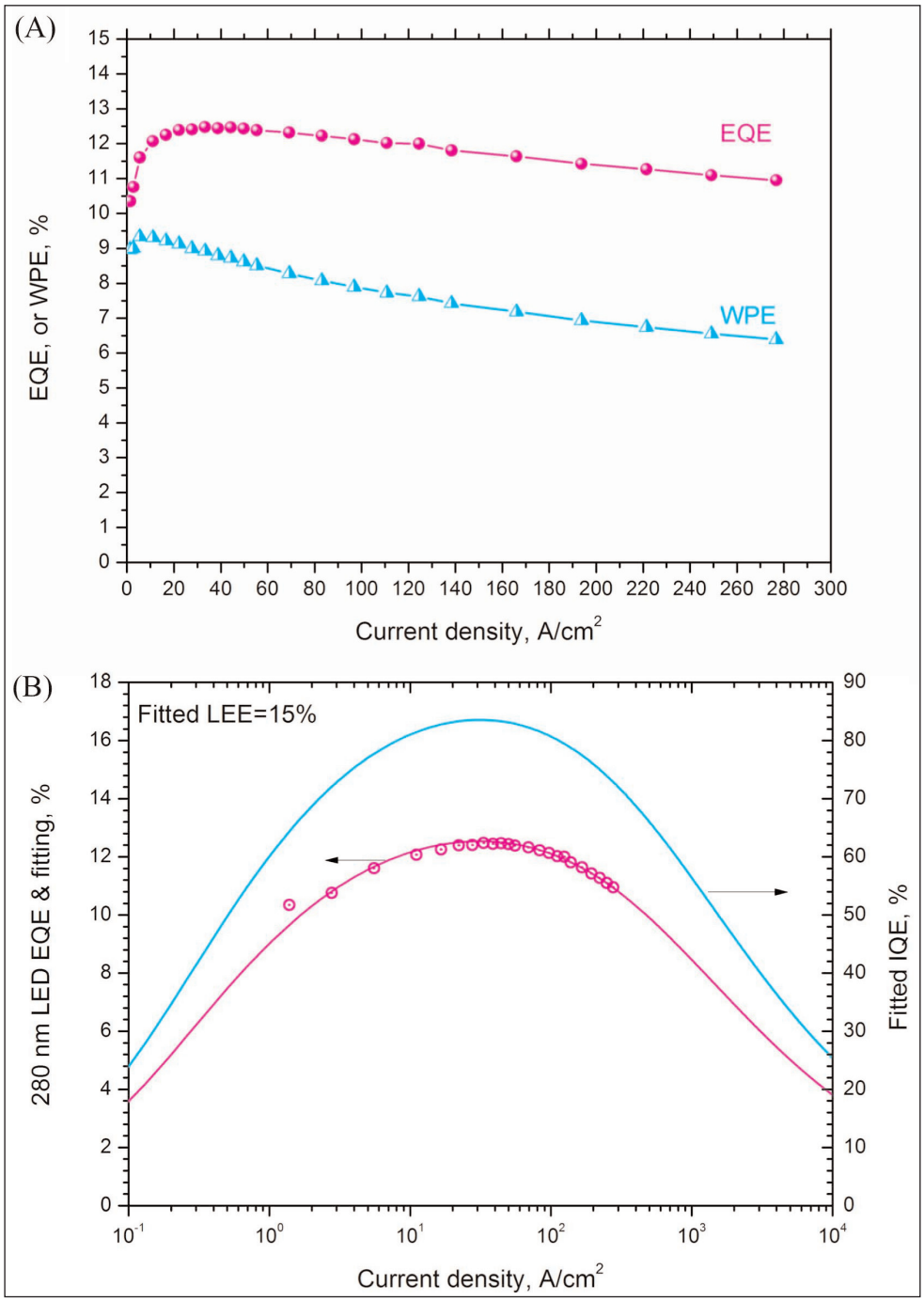

Figure 3. (A) External quantum efficiency and wall-plug efficiency curves derived from figure 2(B). (B) Carrier recombination model fitting of EQE curve to give IQE and light extraction efficiency (LEE).

Typical WPEs for DUV LEDs with p-GaN contact layers are less than 3%. EQE can be raised to around 10%, and even recently 20%, with the addition of a low amount of Al into the p-GaN, but the WPE is still 5.5–5.7%. The low WPEs are related to low conductivity or to the formation of a Schottky contact, raising the forward voltage.

The researchers estimate that the internal quantum efficiency (IQE) was 83.5% at 12mA injection and 83.0% at 20mA. The light extraction efficiency was put at around 15%. The assessment was based on an approach that uses the different rates for radiative recombination and non-radiative (Auger and Shockley–Read–Hall) recombination to extract IQE from the EQE–current curve. Broader EQE peaks are associated with higher IQE.

The researchers believe that optimization of the device could lead to WPEs of up to 40%. The p-contact using AlN is also expected to benefit other wide-bandgap III–nitride optoelectronics (lasers) and non-optoelectronics (high-temperature, high-power-density bipolar power devices). ■

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Author: Mike Cooke

Monolithic InP on silicon growth for optoelectronics

Hong Kong University of Science and Technology has fabricated near-1.5μm wavelength laser diodes using on-axis silicon substrate.

Hong Kong University of Science and Technology (HKUST) in China has been advancing technologies for direct growth of indium phosphide (InP) on silicon (Si) substrate with a view to monolithic integration of optoelectronics on a low-cost platform.

In particular, professor Kei May Lau's group at HKUST claims the first indium gallium arsenide/indium aluminium gallium arsenide (InGaAs/InAlGaAs) multi-quantum-well (MQW) laser diodes grown directly on on-axis V-grooved (001) Si by metal-organic chemical vapor deposition (MOCVD) [Si Zhu et al, Optics Express, vol26, p14514, 2018]. Miscut silicon substrates are often used to grow III–V materials to avoid defects such as anti-phase boundaries. Last year, HKUST reported 1.55μm optical-pumped lasers on silicon using InAs dots and nanowires on InP [Semiconductor Today, May/June 2017, p78].

Integration of lasers with on-axis (as opposed to miscut) silicon is desired for interconnection of photonic integrated circuits and optical-fiber large-scale networking with the efficient complex complementary metal-oxide-semiconductor (CMOS) electronics that powers today's communications technologies.

Efficient laser devices are particularly needed for dense wavelength division multiplexing (DWDM) to increase telecommunication service capacity. InP-based lasers have wavelengths extending out to the C-band ~1.55μm (1530–1565nm)-wavelength region, which represents the minimum loss region for silica-based optical fiber.

Monolithic integration, it is hoped, will reduce the costs arising from additional processing needed for wafer bonding, and also allow the use of more economic, larger-diameter substrates. However, there is a large (approximately 8%) mismatch between InP and silicon that can give rise to high defect densities consisting of threading dislocations (TDs), stacking faults (SFs), twins, and anti-phase boundaries (APBs).

Many of the standard techniques for avoiding such defects have been tried: aspect ratio trapping (ART), selective-area growth (SAG), epitaxial lateral overgrowth (ELOG), compositional graded/intermediate buffers, two-dimensional (2D) strained interlayers or superlattices (SLs), thermal cycle annealing, offcut substrates, and so on. GaAs on Si has a smaller lattice mismatch of ~4%.

An efficient, low-defect-density InP-on-silicon technology would go beyond III–V laser diodes, allowing integration of more sensitive III–V photodetectors, and high-frequency and high-speed III–V transistors.

Laser diode

The V-groove silicon was created by etching with potassium hydroxide solution through a silicon dioxide (SiO_2) mask. The parallel stripes were made with a 130nm pitch. The silicon surface was prepared for

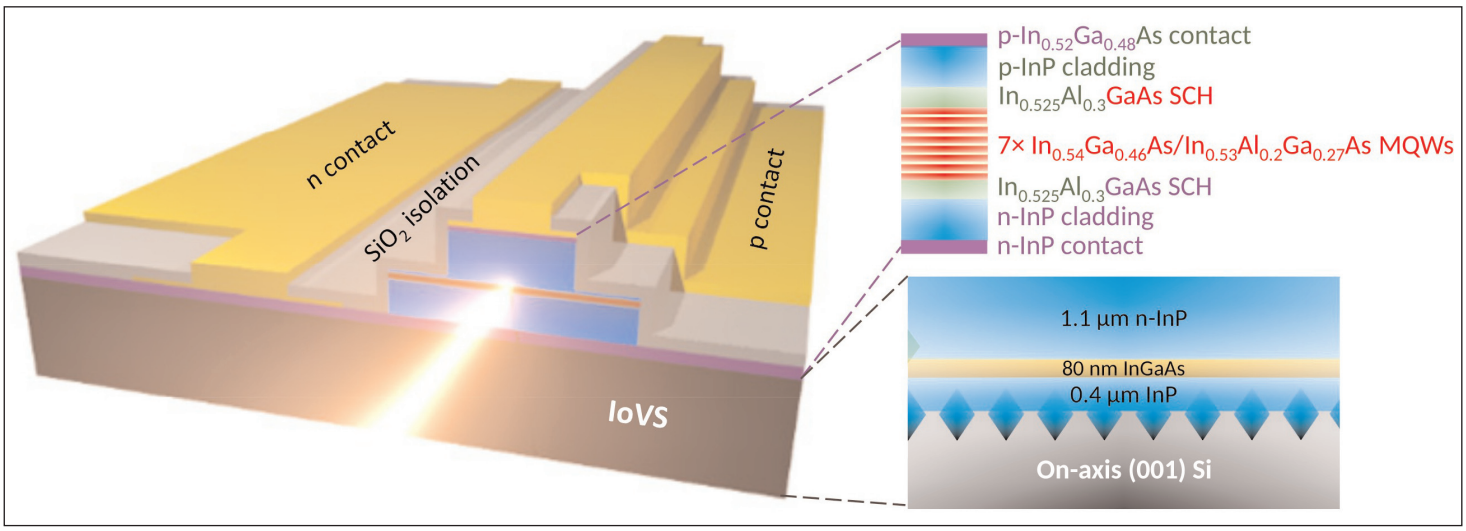


Figure 1. Schematic architecture of InGaAs/InAlGaAs MQW laser diode directly grown on on-axis (001) Si.

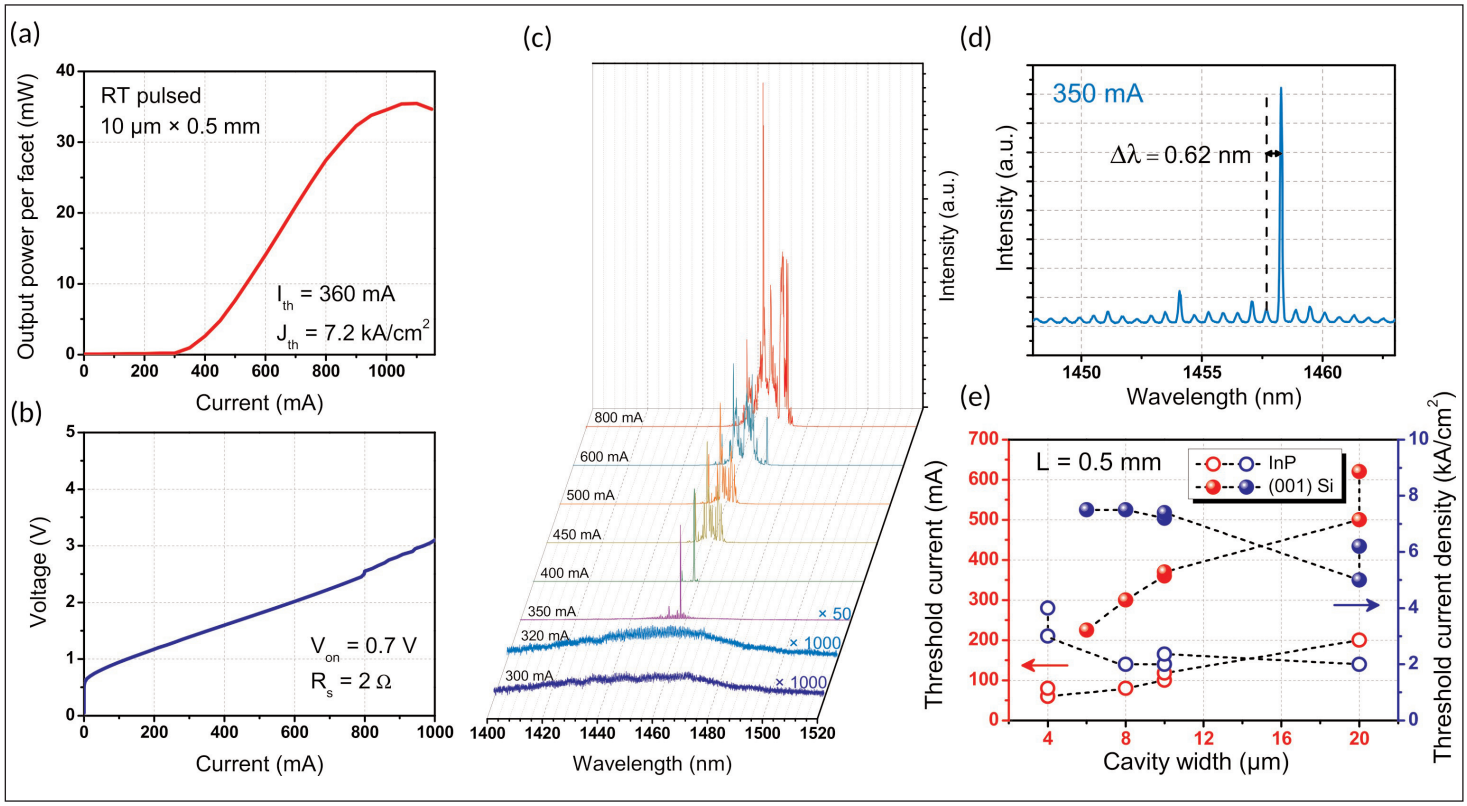


Figure 2. (a) Light output power and (b) current versus voltage characteristics for 20ºC. (c) Emission spectra at various injection currents. (d) Enlarged emission spectrum at 350mA current injection. (e) Threshold current and threshold current density as function of laser cavity width with fixed cavity length of 0.5mm on (001) Si and InP substrates.

MOCVD with 800ºC thermal desorption of native oxide.

The III–V growth for the laser diode (Figure 1) began with a 10nm GaAs wetting layer on the (111) facets of the grooves at 400ºC. The wetting layer was found to avoid non-uniformities and large InP clusters that can be detrimental to further growth and coalescence into thin films.

InP growth began with 435ºC nucleation and 540ºC buffer, forming an array of nanowires. The silicon dioxide masking was removed and further 600–630ºC InP growth coalesced the film into a 1.5μm-thick layer. This film included an 80nm strained InGaAs dislocation filter. The surface had a 3.31nm root-mean-square roughness, according to atomic force microscopy. There was some evidence of stacking faults with a density of 1.2x10^8/cm^2. The threading dislocation density (2.4x10^8/cm^2) was estimated to be a factor of 3.7 lower than for InP grown on planar silicon (1.1x10^9/cm^2).

The InP template was then the basis for the laser structure with 77nm $In_{0.525}Al_{0.3}Ga_{0.175}As$ separate-confinement heterostructure (SCH) waveguide layers sandwiching the InGaAs/InAlGaAs MQW active region (7x(8nm/23nm $In_{0.54}Ga_{0.46}As/In_{0.53}Al_{0.2}Ga_{0.27}As$)). Cladding layers consisted of InP: 1μm upper p-type, 630nm lower n-type. The p-contact layer was 65nm $In_{0.52}Ga_{0.48}As$. The n-InP contact layer was 120nm thick.

The material was fabricated into ridge-waveguide laser diodes. The ridge widths varied between 2μm and 70μm. The ridge consisted of a narrower mesa and a wider one around the MQW. The aim of the wider regions was to keep the current flow away for the sidewalls, avoiding non-radiative surface recombination. Electrical isolation was achieved with 500nm-thick SiO_2. The p- and n-contacts were titanium/platinum/gold and germanium/gold/nickel/gold, respectively.

The final stage of the fabrication involved thinning the wafer to 100μm thick and cleaving into laser bars without surface coatings on the end facets.

The threshold current for lasing in pulsed mode from a 10μmx0.5mm device was 360mA, which corresponds to 7.2kA/cm^2 density (Figure 2). At 1A injection, the output power was 35mW per facet (70mW total).

The main emission peak was at 1.46μm wavelength, but there was some emission from higher longitudinal modes. Similar lasers produced on native InP substrates emit 1.48μm radiation. The researchers attribute the blue-shift on silicon to strain effects arising from thermal expansion mismatches between InP and silicon.

Also, the threshold currents of devices on silicon were about three times higher than those produced on InP substrate. "This disparity is mainly due to the penetration of some defects through the QWs on Si, though most of them have been annihilated inside the buffer layers",

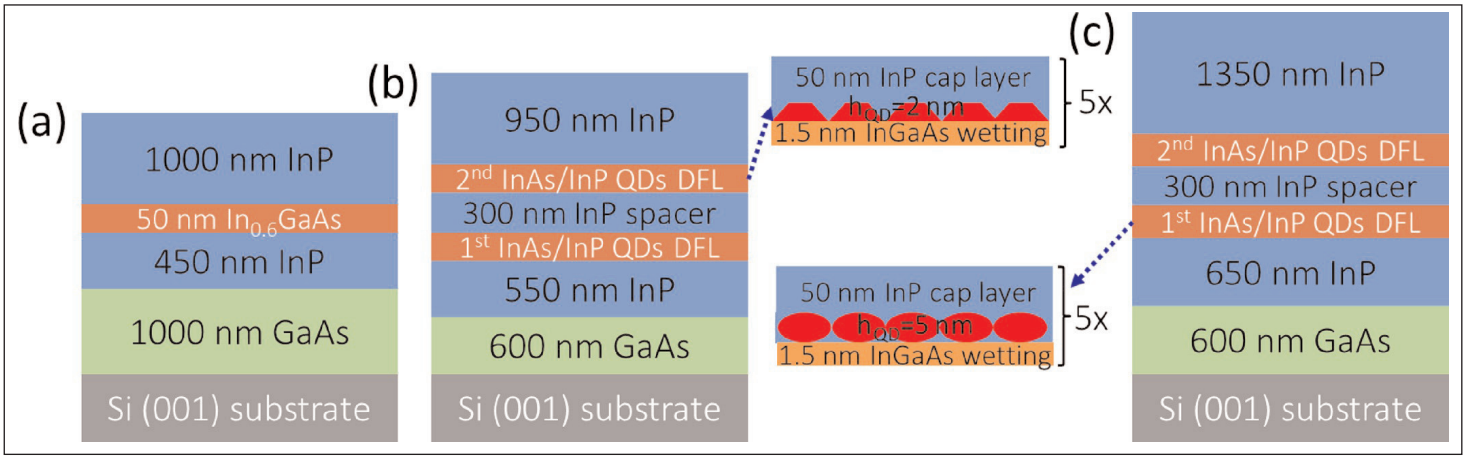
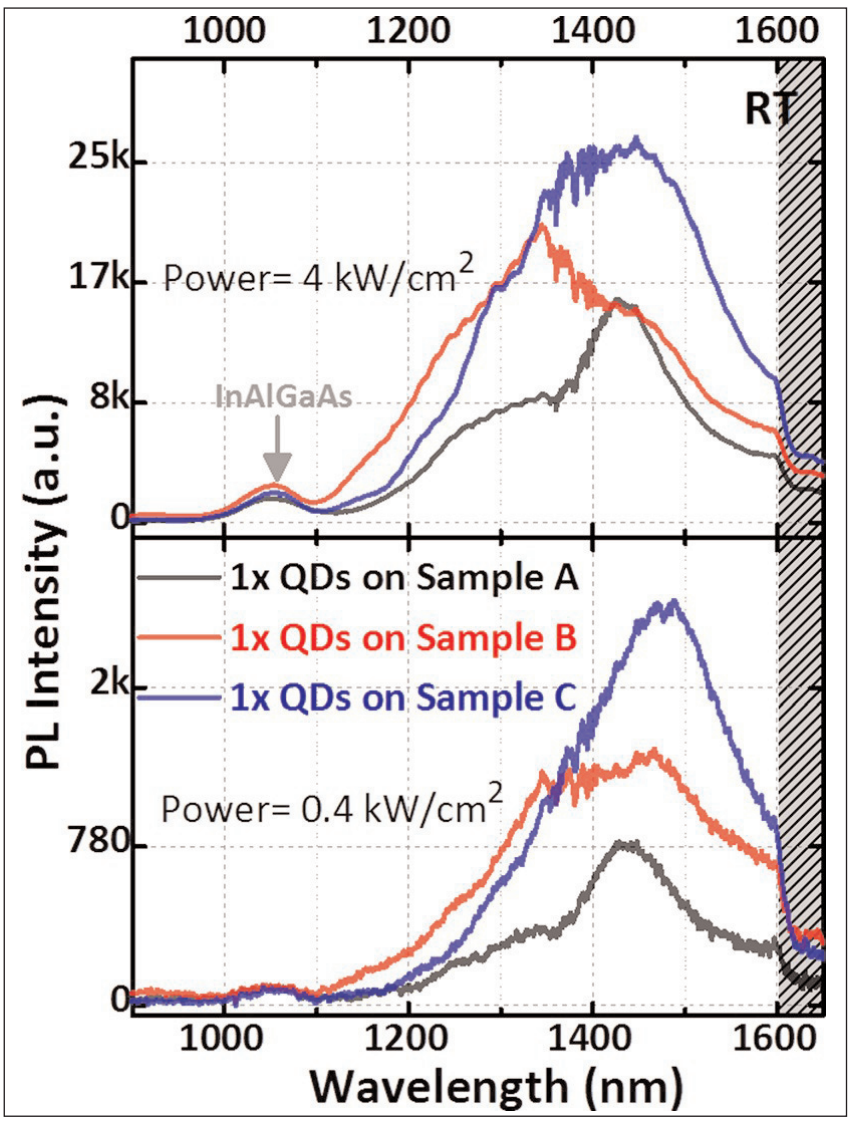


Figure 3. Schematic illustration of InP grown on planar silicon with (a) single strained InGaAs interlayer and two periods of 5-layer InAs/InP QD DFLs with dot height of (b) 2nm and (c) 5nm, respectively.

the team comments. Internal quantum efficiency assessments put the Si-based laser diodes at a 1/2.6 disadvantage compared with devices on InP. Again, defects are blamed. The researchers suggest that more dislocation reduction approaches, such as thermal cycled growth and multiple dislocation filters (see below), could improve intrinsic performance.

Longer laser diodes allowed lower threshold current density — 3.3kA/cm^2 for a 20μmx2mm device.

Performance measurements at different temperatures gave a characteristic temperature for the threshold (T_0) of 133K in the range 20–40ºC and 46.3K for 40–60ºC. InP-based devices manage 174K for 20–60ºC, 51.5K for 60–75ºC, and 15.1K for 75–85ºC.



Quantum dot dislocation filter

Kei May Lau's group at HKUST has also reported on using quantum dots (QDs) as a potential dislocation filter in InP layers on planar silicon (IoPS) [Bei Shi et al, J. Appl. Phys., vol123, p193104, 2018].

MOCVD began with 10nm 400ºC GaAs nucleation, 550ºC GaAs to smooth the growth front, and 600–630ºC high-quality GaAs. The growth rate increased as the temperature was raised. Next, the InP buffer was grown on the GaAs, starting at 435ºC, moving through 550ºC and ending with 600–630ºC MOCVD.

InAs/InP QD dislocation filter layer structures (DFLs) were compared with an $In_{0.58}Ga_{0.42}As$ interlayer (Figure 3). The InAs QD layers and the first part of the InP cap were grown at 510ºC. The density of dots was around 3x10^{10}/cm^2. Increased numbers of QD layers were expected to "facilitate the interaction of dislocations and the strain field of the QDs, enhancing the bending effect of propagated dislocations."

However, too many layers could lead to excessive strain that would generate new dislocations. Although theoretical considerations suggested a critical number of InAs/InP

Figure 4. RT-μPL spectra of single sheet InAs/InAlGaAs QDs on top of the three samples in two different excitation regimes (spectra cutoff beyond 1600nm).

QD layers at more than 20, the researchers decided to use just two filter layers with five stacks each. The growth temperature was increased to 600ºC to complete the InP cap. The samples B and C differed in the height of the low-temperature InP cap — 2nm and 5nm, respectively.

X-ray analysis suggested upper bounds to the defect density of $1.74x10^9/cm^2$, $1.43x10^9/cm^2$, and $8x10^8/cm^2$ for samples A, B and C, respectively. Plan-view transmission electron microscopy gave corresponding threading dislocation densities of $1.2x10^9/cm^2$, $5.5x10^8/cm^2$ and $3.0x10^8/cm^2$. Sample B suffered particularly from stacking faults, which were seen as dashes in the microscopy images. Sample C, however, suffered from regions of extended InAs islands forming during the QD growth process.

Room-temperature (RT) photoluminescence (PL) experiments were carried out on samples with an extra layer of InA/InAlGaAs QDs in 200nm InAlGaAs cladding on a 100nm InP buffer layer. Samples A, B and C were used as InP/Si templates. The structure was capped with a 1.5nm InGaAs wetting layer and an uncapped layer of InAs QDs. The buried InAs QD layer was grown at 510ºC and capped with 1.3nm InAlGaAs. The cladding was grown at 630ºC. The dot density was $3.4x10^{10}/cm^2$ on sample A and $3x10^{10}/cm^2$ on C. The researchers hope that similar structures could lead to InAs QD laser diodes on silicon.

The QD layer on template C delivered the highest photoluminescence of all the samples (Figure 4). The linewidth for sample C was a broad 136meV, due to QD inhomogeneity with a bimodal character, giving two peaks. The higher photon energy peak increased in relative intensity at higher excitation power.

The researchers explain: "At RT, the larger QDs dominate the luminescence for two reasons. First, the carrier capture efficiency for larger QDs is higher, compared to the smaller QDs. Second, the thermally assisted tunneling of carriers via coupled excited states (CESs) contributes to the charge carrier transfer to the larger QDs from the smaller ones. However, in a high excitation regime, the excessive carriers can still easily diffuse into the smaller QDs to enhance the shorter-wavelength PL emission."

The researchers also assessed internal quantum efficiency by comparing the RT-PL with that at 20K. The RT IQEs for samples A–C were estimated at 12.2%, 13.7% and 17.3%, respectively. The researchers see progress to even better results coming from "optimizing the QD growth condition, minimizing the defect density, and improving the surface smoothness of the IoPS templates." ■

Author: Mike Cooke is a freelance technology journalist who has worked in the semiconductor and advanced technology sectors since 1997.

Undoped gallium nitride upper waveguide for reduced laser threshold

Researchers reduce losses by confining the optical field away from the p-type doped regions.

Researchers in China have used an undoped gallium nitride (u-GaN) upper waveguide (WG) to reduce the threshold current density for an indium gallium nitride (InGaN) laser diode (LD) [Feng Liang et al, Jpn. J. Appl. Phys., vol57, p070307, 2018].

The u-GaN waveguide was positioned between the last quantum barrier of the multiple quantum well active region of the device and the p-type aluminium gallium nitride (p-AlGaN) electron-blocking layer (EBL). This reverses the conventional order for III–nitride laser diodes (Figure 1). The use of an undoped rather than doped GaN waveguide reduced optical losses, allowing lasing to occur at lower current injection. The upper waveguide layer confines the optical field away from the lossy p-type regions. Also, the new structure with u-GaN upper waveguide avoids diffusion of dopants into the active region, which also saps recombination into photons.

The research team included engineering scientists from Institute of Semiconductors, University of Chinese Academy of Sciences, Suzhou Institute of Nano-tech and Nano-bionics, Microsystem and Terahertz Research Center, and Jilin University. The researchers see III–N laser diode applications in high-density optical data storage, optical coherence tomography, small portable projectors, and laser-based TVs.

Table 1. Target structural parameters of LD I and LD II.

Layer	Thickness	Doping level (/cm^3)
n-GaN substrate	1μm	3×10^{18}
n-$Al_{0.08}Ga_{0.92}N$ contact	1μm	3×10^{18}
n-GaN lower WG	20nm	5×10^{19}
p-GaN upper WG (only in LD I)	100nm	2×10^{19}
u-GaN upper WG (only in LD II)	100nm	1×10^{17}
p-$Al_{0.06}Ga_{0.94}N$ contact	600nm	2×10^{19}
p-GaN ohmic contact	40nm	1×10^{20}

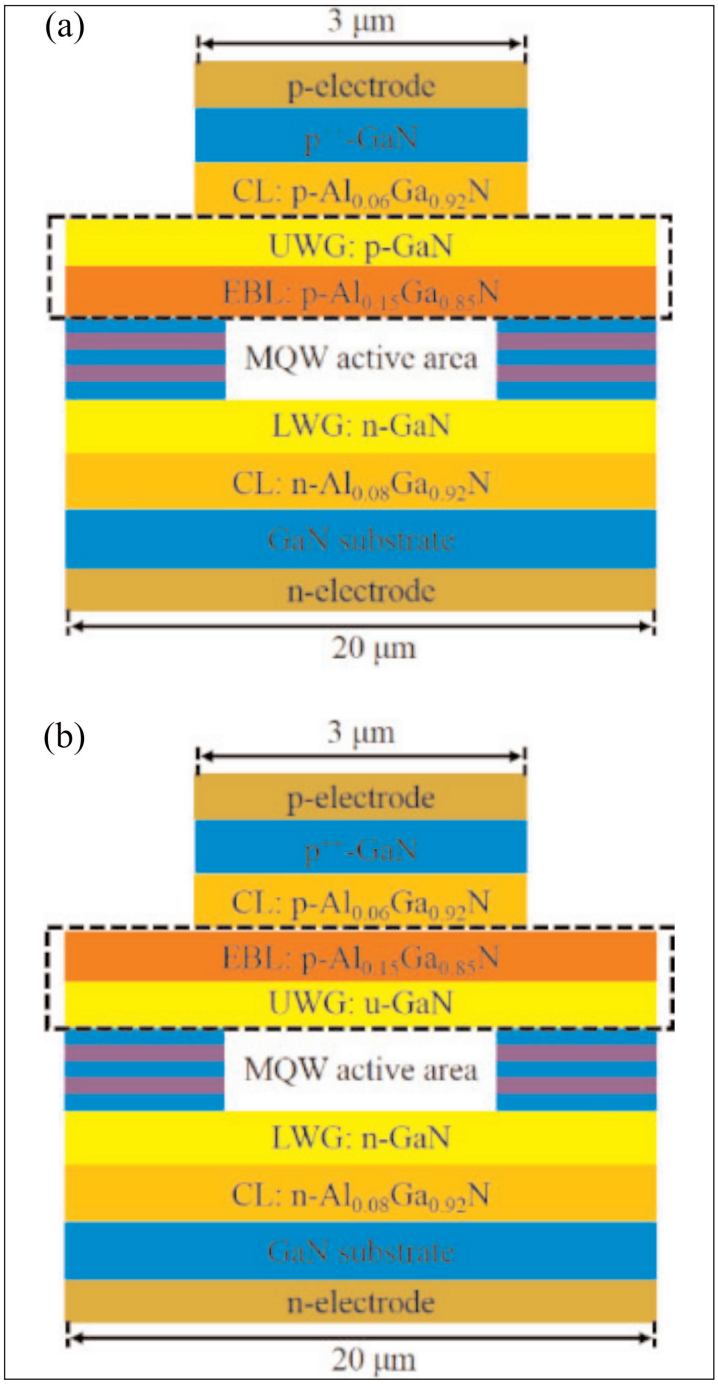


Figure 1. Schematic structures of (a) conventional laser diode with p-GaN upper waveguide after electron-blocking layer (LD I) and (b) improved structure with u-GaN waveguide before EBL (LD II). Dashed line frames emphasize regional differences of respective laser diodes.

The laser diode structures (Table 1) were grown by metal-organic chemical vapor deposition (MOCVD) on c-plane GaN substrates. The fabricated laser diodes had a 10μm-wide ridge, dry etched along the <1$\bar{1}$00> direction. The cavity length was 600μm, defined by cleavage along the {1$\bar{1}$00} plane. Facet coatings gave front and rear reflectivities of 10% and 90%, respectively. Ohmic contacts were made with metal stacks of titanium/platinum/gold (n-type) and palladium/platinum/gold (p-type).

With 20kHz 500ns pulses, the output spectrum at 550mA current injection peaked at 410nm wavelength with 1.2nm full-width at half maximum (FWHM). The laser diode with u-GaN upper waveguide had a 229mA (3.8kA/cm^2) laser threshold current, which compares with 425mA (7.1kA/cm^2) for the reference device with more conventional structure (Figure 2). The light output power at 1200mA of the improved design also received a 137% boost from the u-GaN upper waveguide structure.

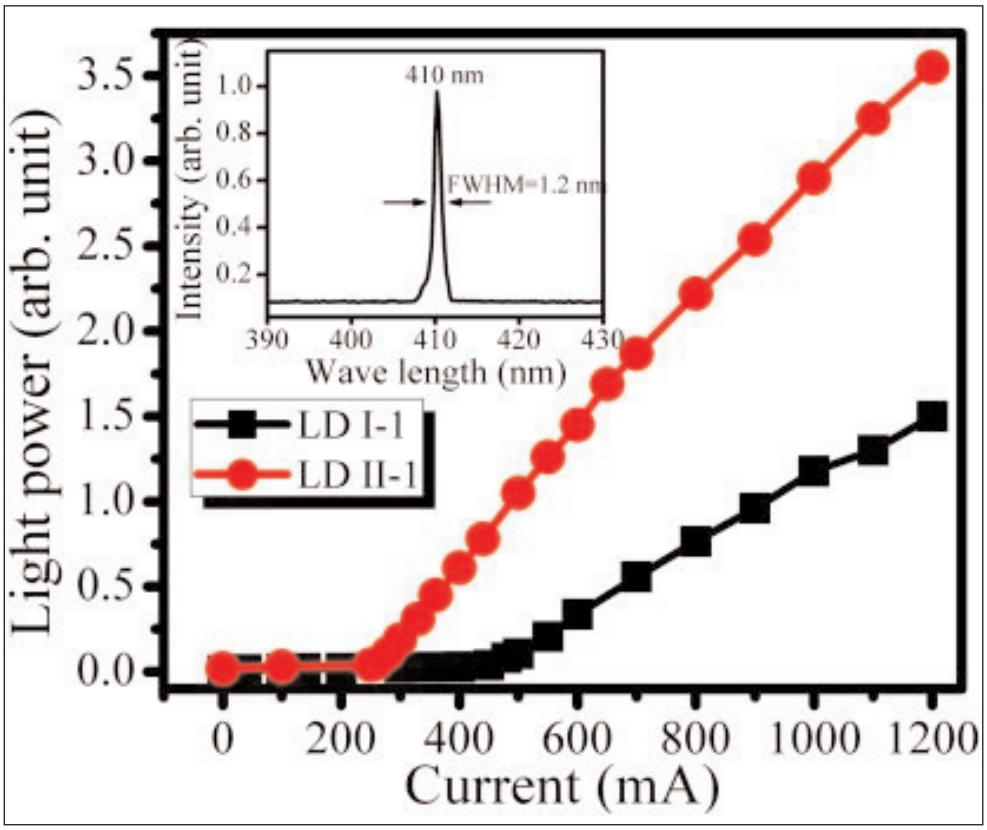


Figure 2. Light output power of LD I-1 (black) and LD II-1 (red, u-GaN upper WG) under pulsed current injection. Inset: optical spectrum of stimulated emission for reference LD I-1.

Although the 3.8kA/cm^2 threshold is somewhat higher than the best achieved for III–N laser diodes (2.3kA/cm^2), the researchers note that this was realized through a special 'plasmonic' GaN substrate from ultra-high doping in a high-pressure hydride vapor phase epitaxy (HVPE) growth process. The team suggests that their structure might be more economically feasible. Also, combining the u-GaN upper waveguide structure with plasmonic substrate might lead to further threshold reduction. ■

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Author: Mike Cooke

High-material-yield halogen-free vapor phase epitaxy of GaN

Reducing gallium crucible distance to the seed as well as reducing the process pressure enables up to 47% use of source material.

Toyota Central R&D Labs Inc in Japan has been exploring ways to improve gallium use in growing gallium nitride (GaN) by vapor-phase epitaxy (VPE) on sapphire [Daisuke Nakamura and Taishi Kimura, Appl. Phys. Express, vol11, p065502, 2018]. Fast growth by hydride VPE typically incorporates less than 10% of the source gallium metal. The Toyota researchers comment: "This low yield is probably due to several factors, including a reverse reaction (etching) and the presence of a thick stagnant boundary layer on the seed surface (since the process is carried out under atmospheric pressure)."

The US Geological Survey estimates the global annual supply of gallium to be 300–400 tons, typically as a by-product of aluminium extraction, so this is clearly not a material to be wasted. It is further estimated that gallium constitutes 18–19 parts per million of the Earth's crust.

And III–nitride applications such as short-wavelength light emission and high-power and high-frequency electronics are not the only demands made on the chemical element. Gallium turns up in III–arsenide, III–phosphide and III–antimonide formations for longer-wavelength light and low-power-consumption and high-speed electronics. In the old days of the Soviet Union, gallium was favored as a neutrino detection material.

Toyota, as a car manufacturer, is interested in high-power applications of GaN for "electric and fuel-cell vehicles and industrial machines". Vertical devices have

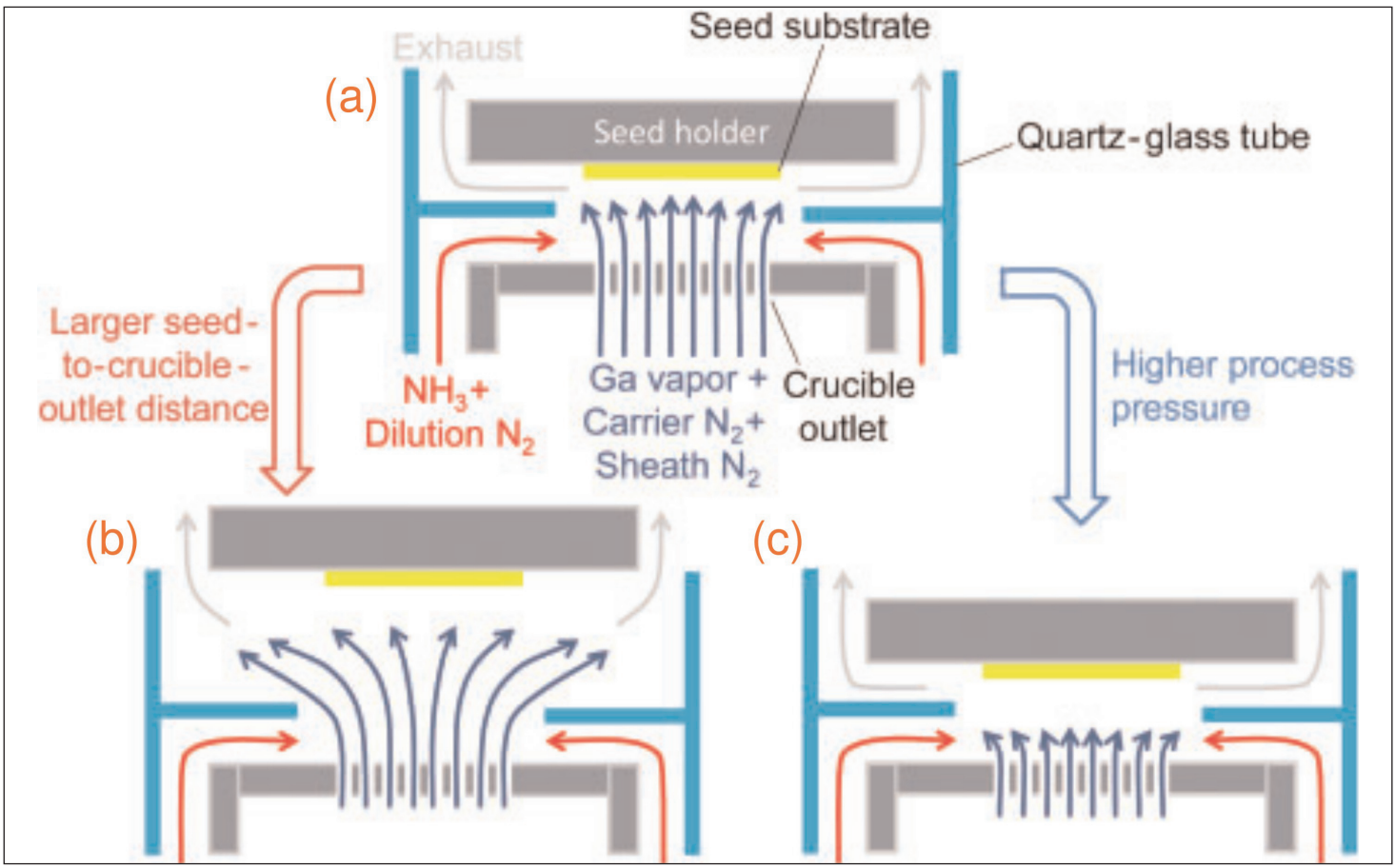

Figure 1. Schematic drawings of gas-stream pathways for Ga vapor from crucible outlet to seed substrate in cases of (a) low pressure and small seed-to-crucible-outlet distance, (b) larger seed-to-crucible-outlet distance, and (c) higher pressure (lower gas-stream velocity). Arrow length corresponds to gas-stream velocity for Ga vapor emitted from the crucible outlet.

many advantages over the more intensely researched lateral devices. Vertical devices need thick layers of GaN separated from the insulating sapphire growth substrate. Hydride VPE has been used to create free-standing GaN substrates for such vertical device research. However, for wider commercial application, costs need to be much reduced to the range of silicon carbide (still relatively expensive) or even silicon.

Rather than converting Ga to gallium chloride, as in hydride VPE, Toyota has been developing halogen-free VPE. The sources are gallium vapor and ammonia (NH_3), giving solid GaN and hydrogen ($3/2H_2$) gas. The simpler reaction process allows lower chamber pressures, reducing the stagnant boundary layer thickness and increasing transport of gallium to the growth front.

Toyota's VPE vertical reactor uses radio frequency heating. The gallium and ammonia were delivered in a nitrogen carrier gas. The gallium was sourced from a crucible with porous tantalum carbide ceramic evaporator. The sapphire seed wafer was initially 2-inch diameter.

The important growth parameters were found to be reducing the seed-to-crucible-outlet distance and decreasing the process pressure (Figure 1). The ammonia supersaturation level, as given by the 'gas-flow-rate ratio', had a lesser effect, mainly in affecting the amount of GaN polycrystals forming on or near the crucible outlet rather than contributing to growth on the substrate (Figure 2).

With the 2-inch substrates, the Toyota team found halogen-free VPE material yields for Ga to GaN in the range 14–23%, compared with 5–10% for hydride VPE.

Further experiments for ultra-high material yield growth were carried out on 3-inch and 4-inch diameter sapphire wafers. Here, it was hoped that more gallium would be deposited on the substrate rather than being wasted in the exhaust gases. This compensated somewhat for the limits on reducing the seed-to-crucible-outlet distance as a means to increased material yield. For the 4-inch seed substrate, the material yield increased to ~47%.

The Toyota team comments: "With this ultra-high material yield, we believe that HF-VPE can be used to produce a sufficient number of GaN wafers for high-power vertical GaN devices at moderate prices without depleting the global Ga supply."

The result on the 3-inch seed wafer was intermediate between the 2-inch and 4-inch substrates, suggesting a linear relation.

The researchers also estimated what the material yield for halogen-free VPE would be with pressures (~100kPa) and seed-to-crucible-outlet distance (~10cm) typical of hydride VPE — the result was 7–8%. Hence, the higher material yields come from the lower process pressure achievable with a chlorine-free chemistry. Also, the RF heating allows the gallium crucible to be heated to higher temperatures (~1200°C) than the rest of the reactor. This enabled a steep temperature gradient in the growth zone, allowing shorter seed-to-crucible-outlet distances. ■

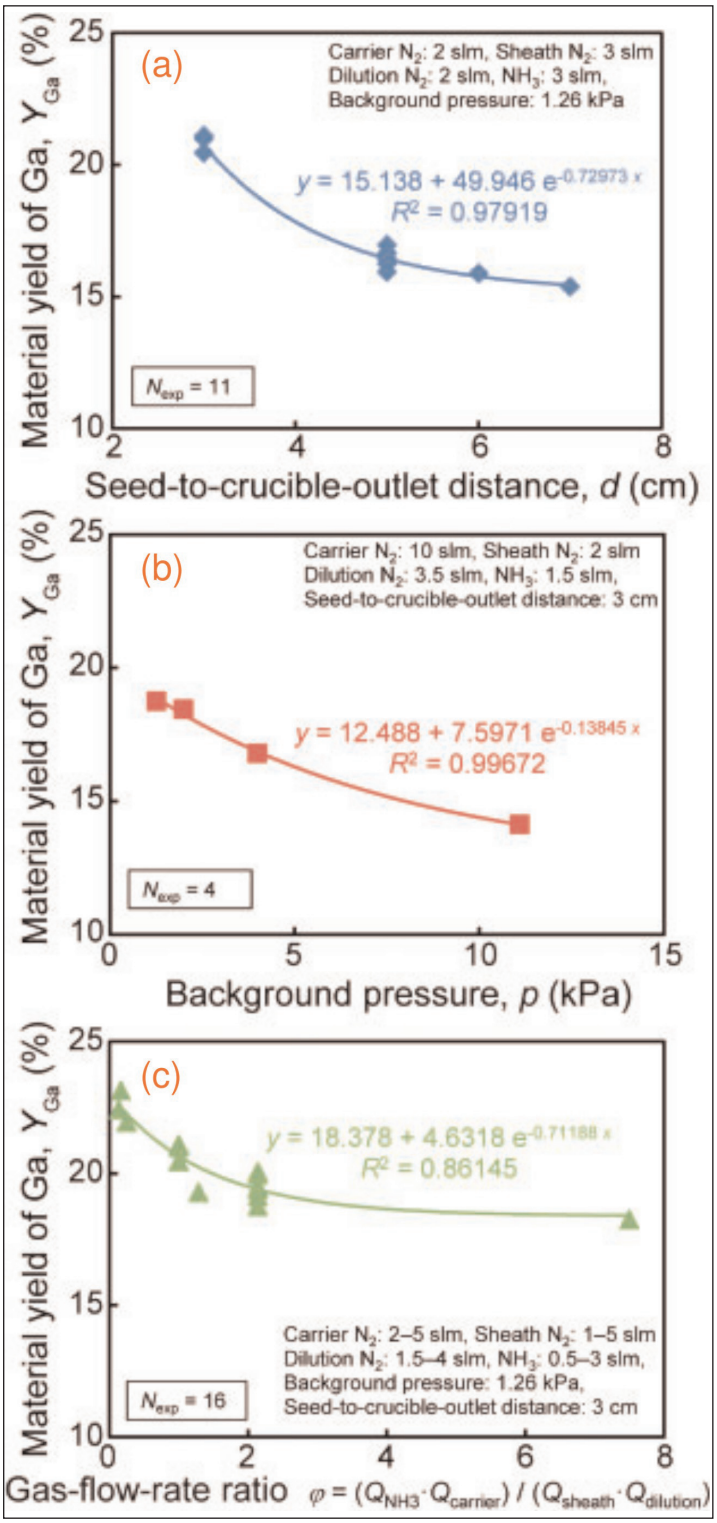

Figure 2. Dependences of material yield of Ga in HF-VPE GaN growth on (a) seed-to-crucible-outlet distance, (b) background pressure, and (c) gas-flow-rate ratio. Regression formulae were based on the exponential decay function with a y offset.

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Author: Mike Cooke

Improving AlGaN transistor channel performance

Researchers in China enable higher drain current and lower off-leakage current to give ultrahigh on/off ratio of ~10^9.

Xidian University in China claims record results for aluminium gallium nitride (AlGaN)-channel high-electron-mobility transistors (HEMTs) [Ming Xiao et al, IEEE Electron Device Letters, vol39, issue 8 (August 2018), p1149]. The improved performance covers high maximum drain current, low gate leakage current, low off-state drain current, high on/off current ratio (I_{on}/I_{off}), high maximum transconductance, and high electron mobility. The researchers say that these are the best results to date of any other AlGaN-channel HEMT reported in the literature.

The team comments: "These results not only drastically reduce the performance gaps between the AlGaN-channel HEMT and the GaN-channel HEMT in the maximum drain current, the maximum transconductance and the electronic mobility, but also demonstrate better performances in the gate leakage current, the off-state drain current, I_{on}/I_{off} ratio, and the breakdown voltage."

In principle, the wider bandgap of AlGaN compared with conventional GaN-channel HEMTs should give higher breakdown voltages, indicating potential for power conversion applications. However, development is at an early stage and AlGaN channels presently have lower electron mobility and sheet density than GaN, impacting performance.

The researchers fabricated HEMT devices using materials with AlGaN and pure GaN channels (Figure 1).

For the AlGaN channel, metal-organic chemical vapor deposition (MOCVD) on sapphire produced a three-stage AlGaN buffer, starting with 1μm of GaN, then 500nm of graded AlGaN, and finishing with 200nm of $Al_{0.10}Ga_{0.90}N$. The barrier layers consisted of a 2nm AlN spacer, 12.5nm of $Al_{0.35}Ga_{0.65}N$, and a 2nm GaN cap. The GaN comparison device had an $Al_{0.25}Ga_{0.75}N$ barrier layer.

The graded AlGaN part of the buffer was designed to adjust stress and improve crystal quality. The two-dimensional electron gas (2DEG) channel that formed near the buffer/barrier junction has a Hall sheet electron density of $6.1x10^{12}/cm^2$ and mobility of $807cm^2/V\text{-}s$. The mobility value is lower than that typically achieved in GaN channel material, but higher than previously reported for AlGaN channels. Alloy disorder in AlGaN tends to reduce mobility.

HEMT fabrication included dry-etch mesa isolation, annealed ohmic source/drain contacts of titanium/aluminium/nickel/gold, and 60nm of plasma-enhanced chemical vapor deposition (PECVD) silicon nitride passivation. The 1μm-long gate was nickel/gold, placed 1.5μm from the source contact.

With the gate at −10V, giving an off state, the drain current with 16V bias was 0.96nA/mm for the AlGaN channel, comparing with 69nA/mm for the conventional GaN HEMT. The gate leakages were 1.37nA/mm and 112nA/mm, respectively. The I_{on}/I_{off} was $0.93x10^9$ for the AlGaN channel, and $1.3x10^7$ for a GaN channel.

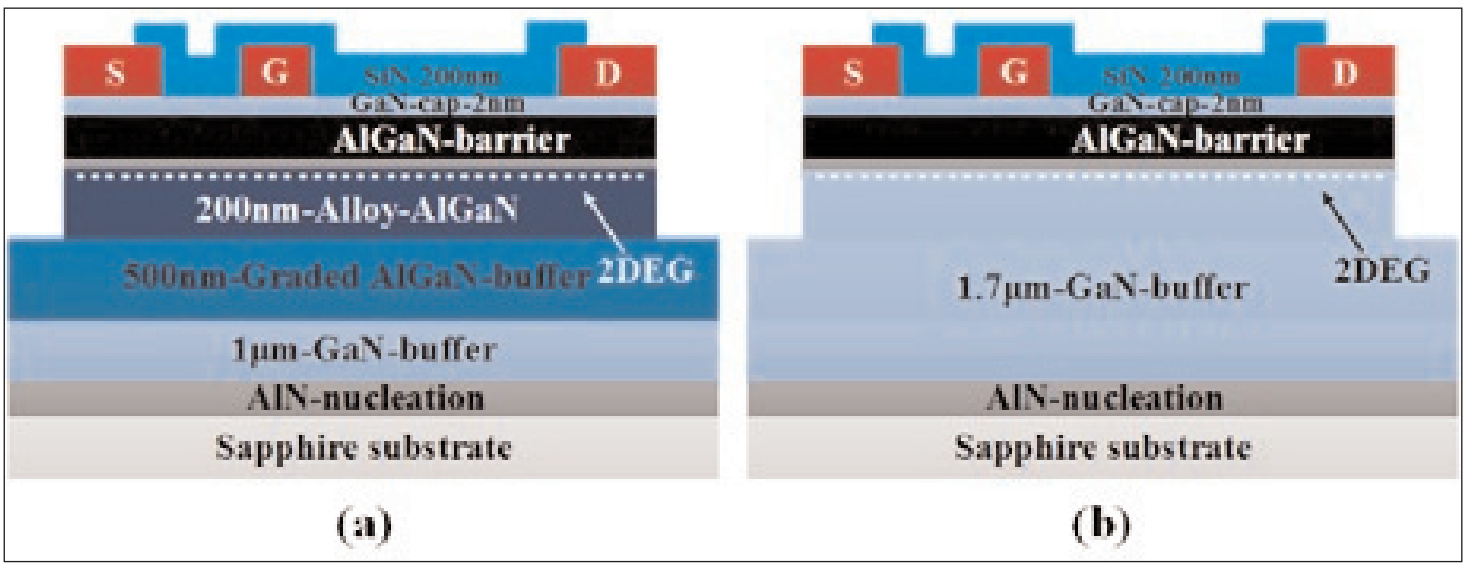

Figure 1. Device structures: (a) AlGaN-channel HEMT and (b) GaN-channel HEMT.

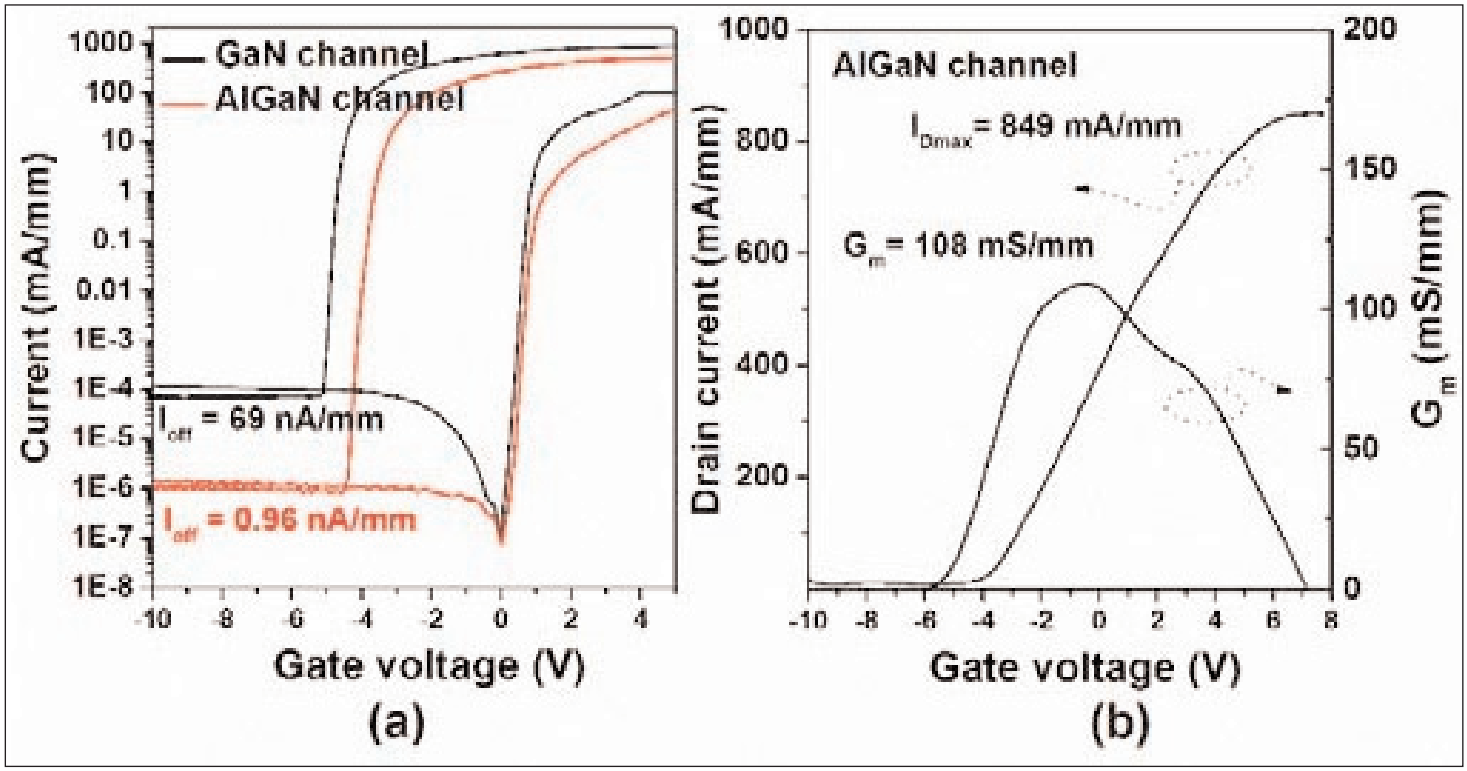

Figure 2. (a) Semilog DC transfer characteristic and gate leakage current curves and (b) linear gate-pulse transfer characteristic and transconductance curves of 1.5μm gate–drain HEMTs at 16V drain bias.

The researchers explain: "For AlGaN-channel devices, low off-state drain current and high I_{on}/I_{off} resulted from the low gate leakage current because the AlGaN channel material has deeper energy-level traps and lower background carrier concentration than the GaN channel material."

For positive gate potential, the gate leakage continued to be lower for the AlGaN HEMT — the gate potential was ~2.1V higher than for a GaN channel with a 40mA/mm gate current. Thus, AlGaN channels should allow a wider operating range in terms of gate voltage. The maximum drain current was 849mA/mm with 500ns pulses and 10ms cycle for the quiescent point of –4V gate potential and +8V drain voltage. Pulsed operation was used to avoid thermal performance degradation since the sapphire substrate has low heat conductivity. In the same tests the peak transconductance was 108mS/mm.

The team comments that the maximum drain current is the largest in reported AlGaN-channel HEMTs due to the high electronic mobility of 807cm^2/V-s and the high saturated electronic velocity. The improved material performance is attributed to high AlGaN/AlGaN heterostructure quality.

The gate–drain distances of the devices were varied between 1.5μm and 20μm. Longer distances mean higher on-resistance, but in compensation allow higher drain biasing without breakdown. The on-resistance varied between 6.1Ω-mm and 28.8Ω-mm, respectively, for the 1,5μm and 20μm gate–drain distances. With the gate at +6V, the saturation drain current exceeded 800mA/mm for all the devices.

Off-state (gate at –10V) breakdown voltages for 1.5μm and 5μm gate-drain distances were 150V and 408V, respectively. For GaN-channel HEMTs the corresponding values were 110V and 302V. The researchers point out that the devices did not have any breakdown-increasing features such as field plates or Schottky-source/drain contacts. ■

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Author: Mike Cooke

Fujitsu triples output power of gallium nitride HEMTs

Radar observation range could be extended by 2.3 times.

At the International Symposium on Growth of III–Nitrides (ISGN-7) in Warsaw, Poland (5–10 August), Tokyo-based Fujitsu Ltd and Fujitsu Laboratories Ltd have announced that they have developed a crystal structure that increases both current and voltage in gallium nitride (GaN) high-electron-mobility transistors (HEMT), effectively tripling the output power of transistors used for transmitters in the microwave band.

The GaN HEMT technology can serve as a power amplifier for equipment such as weather radar — by applying the new technology to this area, it is expected that the observation range of the radar will be expanded by 2.3 times, enabling early detection of cumulo-nimbus clouds that can develop into torrential rainstorms.

To expand the observation range of equipment like radar, it is essential to increase the output power of the transistors used in power amplifiers. With conventional technology, however, applying a high voltage could easily damage the crystals that compose a transistor. So, it was technically difficult to increase current and voltage simultaneously, which is required for realizing high-output-power GaN HEMTs.

Fujitsu and Fujitsu Laboratories have now developed a crystal structure that improves operating voltage by dispersing the applied voltage to the transistor, preventing crystal damage (patent pending). This technology has enabled Fujitsu to achieve record power density of 19.9 watts per millimeter of gate width for a GaN HEMT using an indium aluminium gallium nitride (InAlGaN) barrier layer.

Development background

In addition to having been widely used in recent years in high-frequency power amplifiers in long-distance radio wave applications (such as radars and wireless communications), GaN HEMTs are also expected to be used for weather radars to accurately observe localized torrential rainfall, as well as in millimeter-waveband wireless communications for fifth-generation mobile communications (5G). The spread of microwaves from the microwave and millimeter-wave bands used for radar and wireless communications can be extended by increasing the output power of the high-frequency GaN HEMT power amplifiers used for the transmitter. This allows expanded radar observation range as well as longer-distance and higher-capacity communications.

Fujitsu Laboratories has been conducting research on GaN HEMTs since the early 2000s, and currently provides aluminium gallium nitride (AlGaN) HEMTs used in a variety of areas. Recently, it has been conducting research on indium aluminium gallium nitride (InAlGaN) HEMTs as a new-generation GaN HEMT technology, which enables high-current operation as high-density electrons become available. Accordingly, Fujitsu and Fujitsu Laboratories have developed a

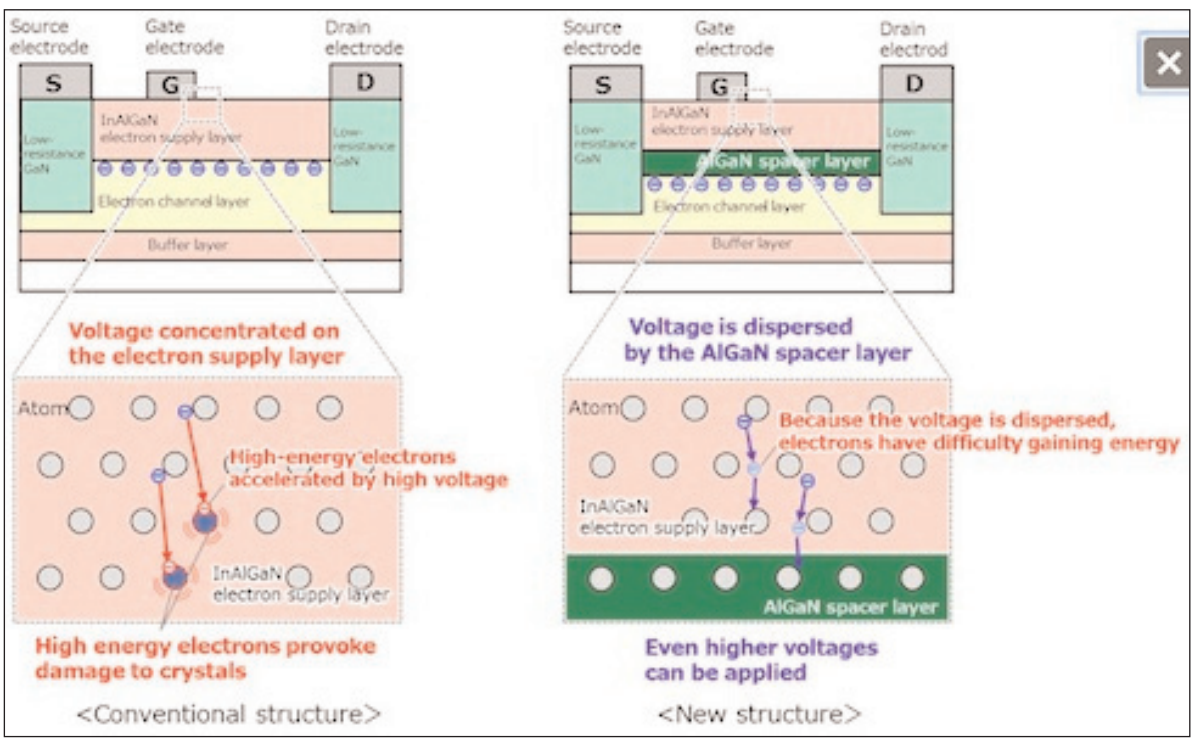

Figure 1: Mechanism for crystal damage and the new crystal structure.

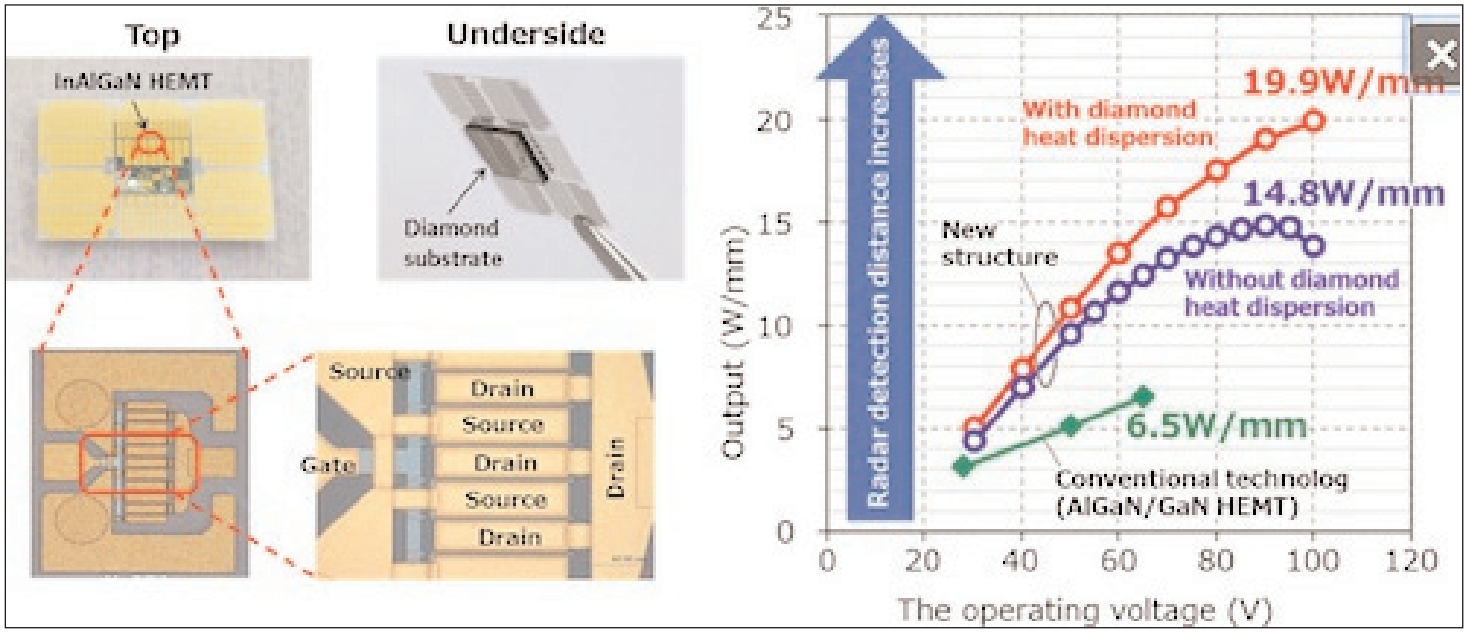

Figure 2: New GaN HEMT transistor structure and comparison of output power versus conventional technology.

crystal structure that achieves both high current and high voltage simultaneously.

Issues

To improve the output power of a transistor, it is necessary to realize both high-current and high-voltage operation. Research is ongoing on InAlGaN HEMTs for next-generation GaN HEMTs that would contribute to increased current, as InAlGaN HEMTs can increase electron density within the transistor. When a high voltage is applied, however, an excessive amount of voltage becomes concentrated on part of the electron supply layer, damaging the crystal within transistors. Consequently, these transistors had a serious issue where their operating voltage could not be increased (Figure 1).

The newly developed technology

Fujitsu and Fujitsu Laboratories have developed a transistor that can provide both high current and high voltage by inserting a high-resistance AlGaN spacer layer between the electron supply layer and the electron channel layer.

For conventional InAlGaN HEMTs, all of the applied voltage between the gate and drain electrodes are applied to the electron supply layer, and many electrons with high kinetic energy are generated in the electron supply layer. These subsequently violently strike the atoms comprising the crystal structure, causing damage. As a result of this phenomenon, there was a limit to the maximum operating voltage of the transistor.

By inserting the newly developed high-resistance AlGaN spacer layer, the voltage within the transistor can be dispersed across both the electron supply layer and the AlGaN spacer layer. By mitigating the concentration of voltage, the increase in the electrons' kinetic energy within the crystal is suppressed and damage to the electron supply layer can be prevented, leading to an improved operating voltage of up to 100V. This would correspond to over 300,000V if the distance between the source electrode and gate electrode were 1cm.

Effects

As well as Fujitsu and Fujitsu Laboratories inserting this new AlGaN spacer layer into InAlGaN HEMTs to achieve both high current and high voltage operation, by applying the single-crystal diamond substrate bonding technology that Fujitsu developed in 2017, the heat generation within the transistor can be efficiently dissipated through the diamond substrate, enabling stable operations. When GaN HEMTs with this crystal structure were measured in actual tests, they achieved the record output power of 19.9W/mm gate width (three times higher than the output power of conventional AlGaN/GaN HEMTs).

Future plans

Fujitsu and Fujitsu Laboratories will conduct an evaluation of the heat resistance and output performance of GaN HEMT power amplifiers using this technology, with the goal of commercializing high-output-power, high-frequency GaN HEMT power amplifiers for applications such as radar systems (including weather radar) and 5G wireless communication systems by fiscal 2020.

The research was partially supported by the Innovative Science and Technology Initiative for Security, established by the Japanese Ministry of Defense's Acquisition, Technology & Logistics Agency (ATLA). ■

www.fujitsu.com/jp/group/labs/en

Agnitron develops MOCVD capability for 10kV+ β-phase gallium oxide switches

New records have been set for β-Ga_2O_3 background concentration and bulk film electron mobility.

At the 3rd US Workshop on Gallium Oxide (GOX 2018) at Ohio State University, Columbus, Ohio (15–16 August), Agnitron Technology Inc of Eden Prairie, MN, USA presented a new metal-organic chemical vapor deposition (MOCVD) growth capability that is said to deliver an order-of-magnitude improvement to background concentration levels for beta-phase gallium oxide (β-Ga_2O_3) films.

The development has resulted in a new record, regardless of deposition technique, for room-temperature and low-temperature bulk film mobilities in β-Ga_2O_3. This advance is key to realizing the potential of the material system for operating at high voltages — an application with broad interest for the 4.9eV-bandgap semiconductor. Calculations indicate that this new capability can support the fabrication of field-effect transistor devices capable of operating beyond 10kV.

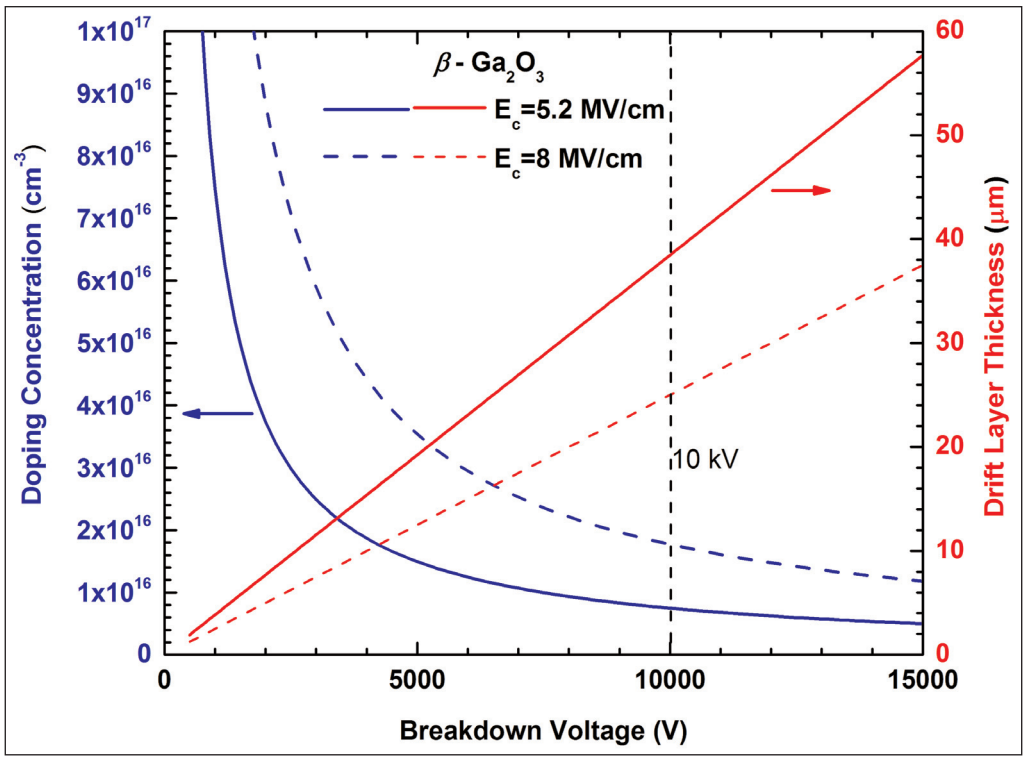

Figure 1. Doping concentration (blue traces) and drift layer thickness (red traces) versus breakdown voltage for β-Ga_2O_3. Solid lines are for β-Ga_2O_3 layer with critical breakdown field of 5.2MV/cm (experimentally demonstrated by Cornell University). Dashed lines are for β-Ga_2O_3 layer with the theoretical critical breakdown field of 8MV/cm. The vertical dashed line shows the doping concentration and the drift layer thickness needed to realize power devices that operate at a voltage of 10kV. Calculations and plot courtesy of professor Huili (Grace) Xing of Cornell University.

β-Ga_2O_3 and other wide-bandgap semiconductors exhibit material properties that can allow power electronic switches to improve performance in various aspects, i.e. lower on-resistance and switching losses, higher operating temperatures, and higher-frequency operation. If realized, these improvements will allow many types of voltage converter systems to reduce size, weight and complexity while improving energy efficiency. Over time this could translate to improved performance and tremendous energy savings on a large scale for electric drive vehicles, transportation infrastructure and distributed/renewable energy systems, among others.

The Agnitron team, led by its president Dr Andrei Osinsky as the program's principal investigator, hence recently performed a series of experiments to better understand how good MOCVD-grown β-Ga_2O_3 films can be. "It was clear that reducing background concentration is critical to the future commercial viability of β-Ga_2O_3. Thus, we focused on optimizing a number of key reactor and process parameters and managed to grow films with surprisingly low levels," says Osinsky. "Already a number of recent runs have produced films

near 10μm thick and shown the improved process can reproducibly offer background concentration levels in the ~$5x10^{15}cm^{-3}$ range, as measured by CV and Hall measurement techniques," he adds. The lowest concentration measured to date was by CV with an $N_d - N_a$ value of $3x10^{15}cm^{-3}$. These low background concentrations have led to the observation of electron mobilities in the films at room temperature and low temperature of $174cm^2/(V·s)$ and $2800cm^2/(V·s)$, respectively — new records for the material based on published literature. The films have also been produced with surface roughness levels <0.2nm root-mean-square (RMS) — a key property for both lateral and vertical conducting devices.

Over the last two years professor James Speck of University of California Santa Barbara (UCSB) has collaborated with Agnitron on multiple β-Ga_2O_3 projects, and his group performed measurements on the reported films. "This new capability by Agnitron sets yet another record for β-Ga_2O_3 mobilities by MOCVD or any technique," comments Speck. "It is a critical development for pushing voltage performance of power transistors higher and opens the door for a number of device types."

A number of important device properties dictate the ultimate voltage performance of a field-effect transistor. These include but are not limited to the film material properties and the dimensions and background impurity concentration of the drift layer/region. The background impurity concentration also directly influences the electron mobility of the films for all device topologies (generally requiring fewer impurities to achieve higher electron mobility). Since β-Ga_2O_3 exhibits a breakdown field well beyond that of silicon, silicon carbide (SiC) and gallium nitride (GaN), β-Ga_2O_3-based devices can potentially be thinner or smaller while operating at the same voltages as these other materials or go to levels not otherwise possible. Calculations indicate that a background concentration in the range now available from Agnitron's MOCVD process (~$5x10^{15}cm^{-3}$ range) will support device operation beyond 10kV, as shown in Figure 1 — a new voltage performance class for field-effect transistor devices.

Agnitron's ongoing β-Ga_2O_3 development work is in part supported by US Office of Naval Research (ONR) contract number N6833518C0192 (under the direction of Lynn Peterson) and Air Force Research Laboratory (AFRL) contract number FA9550-17-P-0029 (under the direction of Dr Ali Sayir). ■

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Speeding oscillation of double heterojunction bipolar transistors

Researchers use graded quaternary gallium indium arsenide antimonide to improve electron transport from base to collector.

Researchers at ETH Zurich, Switzerland, claim the fastest quaternary-base double heterojunction bipolar transistor (DHBT) reported to date with maximum oscillation (f_{MAX}) greater than the cut-off (f_T) frequency, grown by metal-organic chemical vapor deposition (MOCVD) [Wei Quan et al, IEEE Electron Device Letters, published online 21 June 2018].

The quaternary base consisted of graded gallium indium arsenide antimonide (GaInAsSb). Adding indium to GaAsSb improves electron transport properties such as mobility and sheet resistance. GaAsSb's conduction band has two types of valley — one at zero wavevector (the Γ point) and one in the 'L' directions of the crystal structure. In GaAsSb, the L-valley is close in energy to the central Γ-valley. Electrons can be trapped in the L-valley, reducing performance.

The researchers comment: "Consideration of the DHBT higher bandstructure suggests the performance improvement mechanism is a reduction of the L-valley population in the GaInAsSb base and an associated easier collection into InP."

The team sees promise for the device in high-linearity high-efficiency amplification in sub-millimeter wavelength radio frequency integrated circuit applications.

MOCVD (Table 1) was carried out on 2-inch semi-insulating InP. Carbon (C) was used for p-doping of the base region, achieved through constant carbon tetrabromide precursor flux. The grading of the GaInAsSb composition resulted in variation of the uptake of carbon, decreasing with higher In-content, giving linear concentration grading between 3.1×10^{19}/cm^3 and 8.1×10^{19}/cm^3.

The device was designed with type-I alignment between the emitter and base and type-II alignment between the base and collector. The type-II alignment avoids blocking of electrons flowing into the collector. The alignment types I and II describe how the conduction and valence bands change at heterojunctions between different material compositions. In the type I alignments, the two bands change in opposite directions, while in type II the bands step in the same direction.

The DHBTs were fabricated in a process involving self-aligned triple mesas using the emitter and base contacts as etch masks. The emitter and base contacts consisted of titanium/platinum/gold and palladium/nickel/platinum/gold, respectively. The etching involved dry and wet processes. Atomic layer deposition of aluminium oxide was used for passivation of emitter sidewalls and extrinsic base surfaces.

Table 1. Epitaxial layer structure.

Emitter	$Ga_{0.25}In_{0.75}As$	Si: 3.8×10^{19}/cm^3	5nm
Emitter	$Ga_{0.47}In_{0.53}As$ ---> $Ga_{0.25}In_{0.75}As$	Si: 3.8×10^{19}/cm^3	10nm
Emitter	$Ga_{0.47}In_{0.53}As$	Si: 3.8×10^{19}/cm^3	20nm
Emitter	InP	Si: 1.5×10^{19}/cm^3	130nm
Emitter	InP	Si: 2.5×10^{16}/cm^3	5nm
Emitter	$Ga_{0.20}In_{0.80}P$ ---> InP	Si: 2.5×10^{16}/cm^3	10nm
Emitter	$Ga_{0.20}In_{0.80}P$	Si: 2.5×10^{16}/cm^3	5nm
Base	$Ga_{0.83}In_{0.17}As_{0.62}Sb_{0.38}$ ---> $Ga_{0.94}In_{0.06}As_{0.70}Sb_{0.30}$	C: 3.1×10^{19}/cm^3 ---> 8.1×10^{19}/cm^3	20nm
Collector	InP	Si: 9.1×10^{16}/cm^3	125nm
Collector	InP	S: 2.8×10^{19}/cm^3	50nm
Collector	$Ga_{0.47}In_{0.53}As$	Si: 3.0×10^{19}/cm^3	20nm
Collector	InP	S: 2.8×10^{19}/cm^3	300nm
Substrate	InP	Semi-insulating	350μm

The collector mesa was produced using wet etching. Undercutting of the collector mesa reduced extrinsic base-collector capacitance. Probe pads were produced by evaporation of metal and a low-temperature Teflon-based etch-back and planarization process. Teflon has a lower dielectric constant (1.9 versus 2.7) compared with more conventional benzocyclobutene (BCB) polymer, allowing higher speed signal transmission and switching by reducing parasitic capacitance.

The researchers tested a device with 0.3μmx3.5μm emitter area (A_E). The base and collector current idealities were 1.78 and 1.04, respectively. The peak common emitter current gain was 16. Plasma etch damage reduced the gain. Larger devices fabricated with just wet etching achieved gains up to 32. Common emitter breakdown occurred at 5.1V, when the collector current density was 1kA/cm^2 (0.01mA/μm^2). The offset voltage of 70mV is described as "very low".

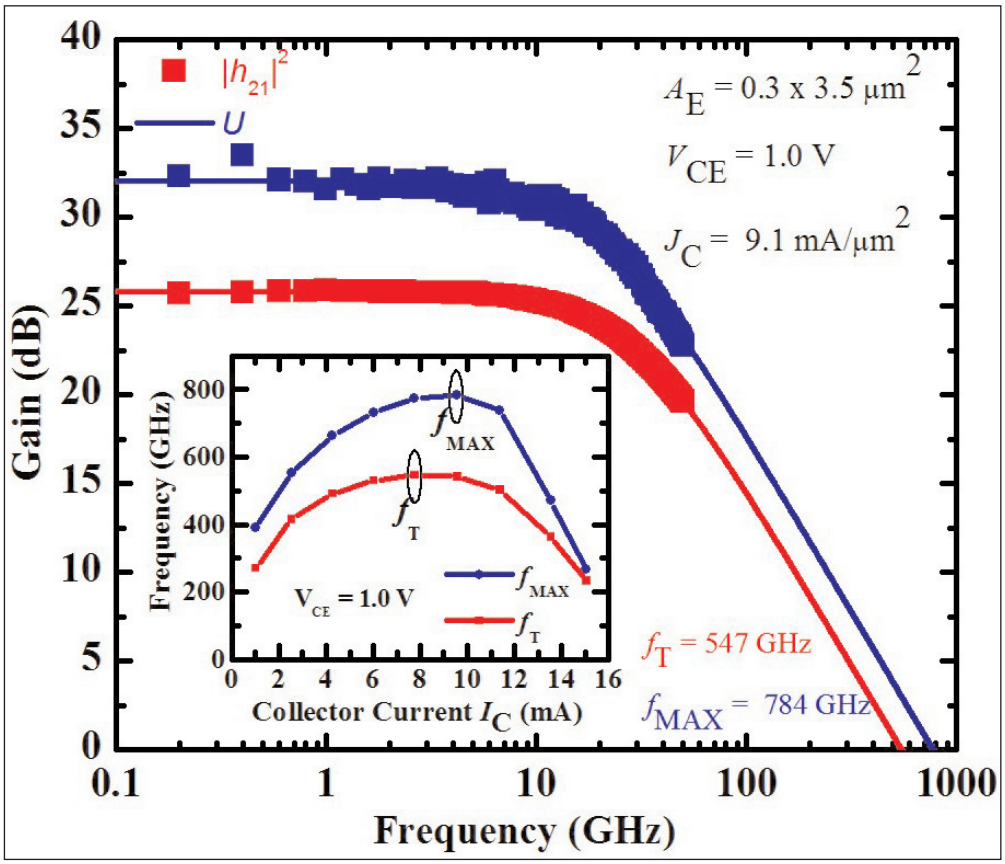

Figure 1. Short-circuit current gain (|h21|^2) and Mason's unilateral gain (U) measured between 0.2GHz and 50GHz. Inset dependence of f_T and f_{MAX} on collector current at 1.0V V_{CE}.

Radio frequency measurements up to 50GHz gave extrapolated maximum oscillation (f_{MAX}) and cut-off (f_T) frequencies of 784GHz and 547GHz, respectively (Figure 1). The collector–emitter voltage bias-point (V_{CE}) was 1.0V with the collector current (J_C) at 9.1mA/μm^2. Standard de-embedding gives 816GHz f_{MAX} and 552GHz f_T. Molecular beam epitaxy GaInAsSb-base devices have achieved f_T/f_{MAX} performance of 670GHz/185GHz. MOCVD graded-base DHBTs have clocked up 513GHz/637GHz.

The team reports: "The total base resistance extracted from RF measurements amounts to R_B = 25.3Ω with a contact contribution of 2.8Ω corresponding to a base contact resistance of 0.31Ω-μm^2. The f_{MAX} is therefore limited by the base sheet resistance in the present devices." ■

https://doi.org/10.1109/LED.2018.2849351

Author: Mike Cooke

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Umicore Indium Products
50 Simms Avenue,
Providence, RI 02902,
USA
Tel: +1 401 456 0800
Fax: +1 401 421 2419
www.thinfilmproducts.umicore.com

United Mineral & Chemical Corp
1100 Valley Brook Avenue,
Lyndhurst, NJ 07071,
USA
Tel: +1 201 507 3300
Fax: +1 201 507 1506
www.umccorp.com

2 Bulk crystal growth equipment

MR Semicon Inc
PO Box 91687,
Albuquerque,
NM 87199-1687,
USA
Tel: +1 505 899 8183
Fax: +1 505 899 8172
www.mrsemicon.com

3 Substrates

AXT Inc
4281 Technology Drive,
Fremont,
CA 94538,
USA
Tel: +1 510 438 4700
Fax: +1 510 683 5901
www.axt.com
Supplies GaAs, InP, and Ge wafers using VGF technology with manufacturing facilities in Beijing and five joint ventures in China producing raw materials, including Ga, As, Ge, pBN, B_2O_3.

CrystAl-N GmbH
Dr.-Mack-Straße 77,
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Fürth,
Germany
Tel: +49 (0)911 650 78 650 90
Fax: +49 (0)911 650 78 650 93
E-mail: info@crystal-n.com
www.crystal-n.com

Crystal IS Inc
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Green Island, NY 12183, USA
Tel: +1 518 271 7375
Fax: +1 518 271 7394
www.crystal-is.com

Freiberger Compound Materials
Am Junger Loewe Schacht 5,
Freiberg, 09599, Germany
Tel: +49 3731 280 0
Fax: +49 3731 280 106
www.fcm-germany.com

Kyma Technologies Inc
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Tel: +1 919 789 8880
Fax: +1 919 789 8881
www.kymatech.com

MARUWA CO LTD
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Owariasahi, Aichi 488-0044,
Japan
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www.maruwa-g.com/e/products/ceramic

sp3 Diamond Technologies
2220 Martin Avenue,
Santa Clara, CA 95050,
USA
Tel: +1 877 773 9940
Fax: +1 408 492 0633
www.sp3inc.com

Sumitomo Electric Semiconductor Materials Inc
7230 NW Evergreen Parkway,
Hillsboro, OR 97124,
USA
Tel: +1 503 693 3100 x207
Fax: +1 503 693 8275
www.sesmi.com

III/V-Reclaim
Wald 10,
84568 Pleiskirchen,
Germany
Tel: +49 8728 911 093
Fax: +49 8728 911 156
www.35reclaim.de
III/V-Reclaim offers reclaim (recycling) of GaAs and InP wafers, removing all kinds of layers and structures from customers' wafers. All formats and sizes can be handled. The firm offers single-side and double-side-polishing and ready-to-use surface treatment.

Umicore Electro-Optic Materials
Watertorenstraat 33,
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Belgium
Tel: +32-14 24 53 67
Fax: +32-14 24 58 00
www.substrates.umicore.com

Wafer World Inc
1100 Technology Place, Suite 104,
West Palm Beach,
FL 33407,
USA
Tel: +1-561-842-4441
Fax: +1-561-842-2677
E-mail: sales@waferworld.com
www.waferworld.com

4 Epiwafer foundry

Spire Semiconductor LLC
25 Sagamore Park Drive,
Hudson, NH 03051,
USA
Tel: +1 603 595 8900
Fax: +1 603 595 0975
www.spirecorp.com

Albemarle Cambridge Chemical Ltd
Unit 5 Chesterton Mills,
French's Road,
Cambridge CB4 3NP,
UK
Tel: +44 (0)1223 352244
Fax: +44 (0)1223 352444
www.camchem.co.uk

Intelligent Epitaxy Technology Inc
1250 E Collins Blvd,
Richardson,
TX 75081-2401,
USA
Tel: +1 972 234 0068
Fax: +1 972 234 0069
www.intelliepi.com

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Place Marcel Rebuffat, Parc de Villejust, 91971 Courtabouef,
France
Tel: +33 (0)1 69 31 61 30
Fax: +33 (0)1 69 31 61 79
www.picogiga.com

5 Deposition materials

Akzo Nobel High Purity Metalorganics
www.akzonobel.com/hpmo
Asia Pacific:
Akzo Nobel (Asia) Co Ltd,
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China
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Fax: +86 21 3360 7739
metalorganicsAP@akzonobel.com
Americas:
AkzoNobel Functional Chemicals,
Chicago,
USA
Tel. +31 800 828 7929 (US only)
Tel: +1 312 544 7000
Fax: +1 312 544 7188
metalorganicsNA@akzonobel.com
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Amersfoort,
The Netherlands
Tel. +31 33 467 6656
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metalorganicsEU@akzonobel.com

Cambridge Chemical Company Ltd
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French's Road,
Cambridge CB4 3NP,
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www.camchem.co.uk

Dow Electronic Materials
60 Willow Street,
North Andover, MA 01845,
USA
Tel: +1 978 557 1700
Fax: +1 978 557 1701
www.metalorganics.com

Matheson Tri-Gas
6775 Central Avenue,
Newark, CA 94560,
USA
Tel: +1 510 793 2559
Fax: +1 510 790 6241
www.mathesontrigas.com

Mining & Chemical Products Ltd
(see section 1 for full contact details)

Praxair Electronics
542 Route 303, Orangeburg,
NY 10962,
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Fax: +1 845 398 8304
www.praxair.com/electronics

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Power Road, Bromborough,
Wirral, Merseyside CH62 3QF,
UK
Tel: +44 151 334 2774
Fax: +44 151 334 6422
www.safchitech.com

Materion Advanced Materials Group
2978 Main Street,
Buffalo, NY 14214,
USA
Tel: +1 716 837 1000
Fax: +1 716 833 2926
www.williams-adv.com

6 Deposition equipment

AIXTRON SE
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Germany
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Fax: +33 (0) 1 39 47 45 62
www.riber.com

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Fax: +1 952 934 2737
www.svta.com

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7 Wafer processing materials

Air Products and Chemicals Inc
7201 Hamilton Blvd.,
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Tel: +1 610 481 4911
www.airproducts.com/compound

MicroChem Corp
1254 Chestnut St. Newton,
MA 02464, USA
Tel: +1 617 965 5511
Fax: +1 617 965 5818
www.microchem.com

Praxair Electronics
(see section 5 for full contact details)

8 Wafer processing equipment

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

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

Plasma-Therm LLC
(see section 6 for full contact details)

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

SPTS Technology Ltd
Ringland Way, Newport NP18 2TA,
UK
Tel: +44 (0)1633 414000
Fax: +44 (0)1633 414141
www.spts.com

SUSS MicroTec AG
Schleißheimer Strasse 90,
85748 Garching,
Germany
Tel: +49 89 32007 0
Fax: +49 89 32007 162
www.suss.com

Veeco Instruments Inc
(see section 6 for full contact details)

9 Materials & metals

Goodfellow Cambridge Ltd
Ermine Business Park,
Huntingdon,
Cambridgeshire PE29 6WR,
UK
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Fax: +44 (0) 1480 424900
www.goodfellow.com

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

10 Gas and liquid handling equipment

Air Products and Chemicals Inc
(see section 7 for full contact details)

Cambridge Fluid Systems
12 Trafalgar Way, Bar Hill,
Cambridge CB3 8SQ,
UK
Tel: +44 (0)1954 786800
Fax: +44 (0)1954 786818
www.cambridge-fluid.com

CS CLEAN SOLUTIONS AG
Fraunhoferstrasse 4,
Ismaning, 85737,
Germany
Tel: +49 89 96 24000
Fax: +49 89 96 2400122
www.csclean.com

SAES Pure Gas Inc
4175 Santa Fe Road,
San Luis Obispo,
CA 93401,
USA
Tel: +1 805 541 9299
Fax: +1 805 541 9399
www.saesgetters.com

11 Process monitoring and control

Conax Technologies
2300 Walden Avenue,
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Fax: +1 734 426 7955
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1-2221I, Milpitas,
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USA
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Fax: +1 408 875 4144
www.kla-tencor.com

LayTec AG
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Tel: +49 30 89 00 55 0
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www.laytec.de
LayTec develops and manufactures optical in-situ and in-line metrology systems for thin-film processes with particular focus on compound semiconductor and photovoltaic applications. Its know-how is based on optical techniques: reflectometry, emissivity corrected pyrometry, curvature measurements and reflectance anisotropy spectroscopy.

WEP (Ingenieurbüro Wolff für Elektronik- und Programmentwicklungen)
Bregstrasse 90,
D-78120 Furtwangen im Schwarzwald,
Germany
Tel: +49 7723 9197 0
Fax: +49 7723 9197 22
www.wepcontrol.com

12 Inspection equipment

Bruker AXS GmbH
Oestliche Rheinbrueckenstrasse 49,
Karlsruhe, 76187,
Germany
Tel: +49 (0)721 595 2888
Fax: +49 (0)721 595 4587
www.bruker-axs.de

13 Characterization equipment

J.A. Woollam Co. Inc.
645 M Street Suite 102,
Lincoln, NE 68508, USA
Tel: +1 402 477 7501
Fax: +1 402 477 8214
www.jawoollam.com

Lake Shore Cryotronics Inc
575 McCorkle Boulevard,
Westerville, OH 43082, USA
Tel: +1 614 891 2244
Fax: +1 614 818 1600
www.lakeshore.com

14 Chip test equipment

Keithley Instruments Inc
28775 Aurora Road,
Cleveland, OH 44139, USA
Tel: +1 440.248.0400
Fax: +1 440.248.6168
www.keithley.com

15 Assembly/packaging materials

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

Gel-Pak
31398 Huntwood Avenue,
Hayward, CA 94544, USA
Tel: +1 510 576 2220
Fax: +1 510 576 2282
www.gelpak.com

Wafer World Inc
(see section 3 for full contact details)

Materion Advanced Materials Group
2978 Main Street,
Buffalo, NY 14214,
USA
Tel: +1 716 837 1000
Fax: +1 716 833 2926
www.williams-adv.com

16 Assembly/packaging equipment

Ismeca Europe Semiconductor SA
Helvetie 283, La Chaux-de-Fonds,
2301, Switzerland
Tel: +41 329257111
Fax: +41 329257115
www.ismeca.com

Kulicke & Soffa Industries
1005 Virginia Drive,
Fort Washington, PA 19034,
USA
Tel: +1 215 784 6000
Fax: +1 215 784 6001
www.kns.com

Palomar Technologies Inc
2728 Loker Avenue West,
Carlsbad, CA 92010,
USA
Tel: +1 760 931 3600
Fax: +1 760 931 5191
www.PalomarTechnologies.com

TECDIA Inc
2700 Augustine Drive, Suite 110,
Santa Clara, CA 95054,
USA
Tel: +1 408 748 0100
Fax: +1 408 748 0111
www.tecdia.com

17 Assembly/packaging foundry

Quik-Pak
10987 Via Frontera,
San Diego, CA 92127,
USA
Tel: +1 858 674 4676
Fax: +1 8586 74 4681
www.quikicpak.com

18 Chip foundry

Compound Semiconductor Technologies Ltd
Block 7, Kelvin Campus,
West of Scotland, Glasgow,
Scotland G20 0TH,
UK
Tel: +44 141 579 3000
Fax: +44 141 579 3040
www.compoundsemi.co.uk

United Monolithic Semiconductors
Route departementale 128,
BP46, Orsay, 91401,
France
Tel: +33 1 69 33 04 72
Fax: +33 169 33 02 92
www.ums-gaas.com

19 Facility equipment

MEI, LLC
3474 18th Avenue SE,
Albany, OR 97322-7014,
USA
Tel: +1 541 917 3626
Fax: +1 541 917 3623
www.marlerenterprises.net

20 Facility consumables

W.L. Gore & Associates
401 Airport Rd, Elkton,
MD 21921-4236,
USA
Tel: +1 410 392 4440
Fax: +1 410 506 8749
www.gore.com

21 Computer hardware & software

Ansoft Corp
4 Station Square,
Suite 200,
Pittsburgh, PA 15219,
USA
Tel: +1 412 261 3200
Fax: +1 412 471 9427
www.ansoft.com

Crosslight Software Inc
121-3989 Henning Dr.,
Burnaby, BC, V5C 6P8,
Canada
Tel: +1 604 320 1704
Fax: +1 604 320 1734
www.crosslight.com

Semiconductor Technology Research Inc
10404 Patterson Ave.,
Suite 108, Richmond, VA 23238,
USA
Tel: +1 804 740 8314
Fax: +1 804 740 3814
www.semitech.us

22 Used equipment

Class One Equipment Inc
5302 Snapfinger Woods Drive,
Decatur, GA 30035,
USA
Tel: +1 770 808 8708
Fax: +1 770 808 8308
www.ClassOneEquipment.com

23 Services

Henry Butcher International
Brownlow House, 50–51
High Holborn, London WC1V 6EG,
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Tel: +44 (0)20 7405 8411
Fax: +44 (0)20 7405 9772
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Tel: +49 711 8804 1141
Fax: +49 711 8804 1950
www.mw-zander.com

24 Consulting

Fishbone Consulting SARL
8 Rue de la Grange aux Moines,
78460 Choisel,
France
Tel: + 33 (0)1 30 47 29 03
E-mail: jean-luc.ledys@neuf.fr

25 Resources

Al Shultz Advertising Marketing for Advanced Technology Companies
1346 The Alameda,
7140 San Jose, CA 95126,
USA
Tel: +1 408 289 9555
www.alshuktz.com

SEMI Global Headquarters
3081 Zanker Road,
San Jose,
CA 95134,
USA
Tel: +1 408 943 6900
Fax: +1 408 428 9600
www.semi.org

Yole Développement
45 rue Sainte Geneviève,
69006 Lyon,
France
Tel: +33 472 83 01 86
www.yole.fr

event calendar

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

2–6 September 2018
ECSCRM 2018:
European Conference on Silicon Carbide and Related Materials
International Convention Centre, Birmingham, UK
E-mail: ecscrm2018@warwick.ac.uk
https://warwick.ac.uk/fac/sci/eng/ecscrm2018

2–7 September 2018
ICMBE 2018:
20th International Conference on Molecular Beam Epitaxy
Shanghai, China
E-mail: mbe2018@mail.sim.ac.cn
http://mbe2018.csp.escience.cn

5–7 September 2018
SEMICON Taiwan 2018
Taipei Nangang Exhibition Center 1F&4F, Taipei, Taiwan
E-mail: semicontaiwan@semi.org
www.semicontaiwan.org/en

5–8 September 2018
CIOE 2018:
20th China International Optoelectronic Exposition
Shenzhen Convention and Exhibition Center, China
E-mail: derek.deng@cioe.cn
www.cioe.cn/en

17–21 September 2018
EPE'18 ECCE Europe:
20th European Conference on Power Electronics and Applications
Riga, Latvia
E-mail: info@epe2018.com
www.epe2018.com

23–27 September 2018
ECOC 2018:
44th European Conference on Optical Communications
Nuova Fiera di Roma, Rome, Italy
E-mail: registration@ecoc2018.org
www.ecoc2018.org

23–28 September 2018
13th European Microwave Integrated Circuits Conference (EuMIC 2018), part of 21st European Microwave Week (EuMW 2018)
IFEMA, Madrid, Spain
E-mail: eumwreg@itnint.com
www.eumweek.com/conferences/eumic.html

24–28 September 2018
EU PVSEC 2018:
35th European Photovoltaic Solar Energy Conference
SQUARE - Brussels Meeting Centre, Belgium
E-mail: pv.conference@wip-munich.de
www.photovoltaic-conference.com

advertisers' index

25–27 September 2018
8th International LED professional Symposium + Expo (LpS 2018)
Opera House Bregenz, Austria
E-mail: info@LpS2018.com
www.led-professional-symposium.com

30 September – 4 October 2018
31st Annual Conference of the IEEE Photonics Society (IPC 2018)
Reston, VA, USA
E-mail: c.c.scott@ieee.org
https://ieee-ipc.org

10–11 October 2018
Photonex EUROPE LIVE!
Ricoh Arena Coventry, UK
E-mail: ld@xmarkmedia.com
www.photonex.org

17–19 October 2018
6th International Workshop on Power Supply-on-Chip (PwrSoC18)
National Chiao Tung University (NCTU), Hsinchu, Taiwan
E-mail: trifon@wlmtech.com
http://pwrsocevents.com

23 October 2018
POP2-2018: 2nd International Conference on Photonics and Opto Packaging
South Devon College, Paignton, UK
E-mail: office@imaps.org.uk
www.imaps.org.uk/events/pop2-2018-the-2nd-international-conference-on-photonics-and-opto-packaging

24–26 October 2018
BIT's 8th Annual Congress of Nano Science and Technology-(Nano S&T-2018)
Kongresshotel Potsdam am Templiner See, Germany
E-mail:stella@bitconferences.com
www.bitcongress.com/nano2018

31 October – 2 November 2018
6th IEEE Workshop on Wide Bandgap Power Devices and Applications (WiPDA 2018)
Georgia Institute of Technology, Atlanta, GA, USA
E-mail: ieee-mce@ieee.org
www.wipda.org

4–7 November 2018
2nd IEEE International Power Electronics and Application Conference and Exhibition (PEAC 2018)
Shenzhen, China
E-mail: peac@cpss.org.cn
www.peac-conf.org

3–5 December 2018
IEEE International Electron Devices Meeting (IEDM 2018)
Hilton San Francisco and Towers, San Francisco, CA, USA
E-mail: iedm@his.com
www.ieee.org/conference/iedm

5–8 December 2018
49th IEEE Semiconductor Interface Specialists Conference (SISC 2018)
San Diego, CA, USA
E-mail: meetings@ucsd.edu
www.ieeesisc.org

2–6 February 2019
IEEE International Solid- State Circuits Conference (ISSCC 2019)
San Francisco, CA, USA
E-mail: Issccinfo@yesevents.com
www.isscc.org

2–7 February 2019
SPIE Photonics West 2019, including OPTO 2019 – Optoelectronic Materials, Devices, and Applications
Moscone Centre, San Francisco, CA, USA
E-mail: customerservice@spie.org
www.spie.org/SPIE_PHOTONICS_WEST_Conference
www.spie.org/SPIE_OPTO_conference

17–21 March 2019
APEC 2019: IEEE Applied Power Electronics Conference and Exposition
Anaheim Convention Center, CA, USA
E-mail: apec@apec-conf.org
www.apec-conf.org

7–9 May 2019
PCIM Europe (Power conversion and Intelligent Motion) 2019
Nuremberg Messe, Germany
E-mail: daniela.kaeser@mesago.com
www.mesago.de/en/PCIM/main.htm

15–17 May 2019
Intersolar Europe 2019
Munich, Germany
E-mail: info@intersolar.de
www.intersolar.de

27–31 May 2019
10th International Conference on Power Electronics (ICPE 2019 – ECCE Asia)
BEXCO, Busan, South Korea
E-mail: icpe2019@icpe2019.org
www.icpe2019.org

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