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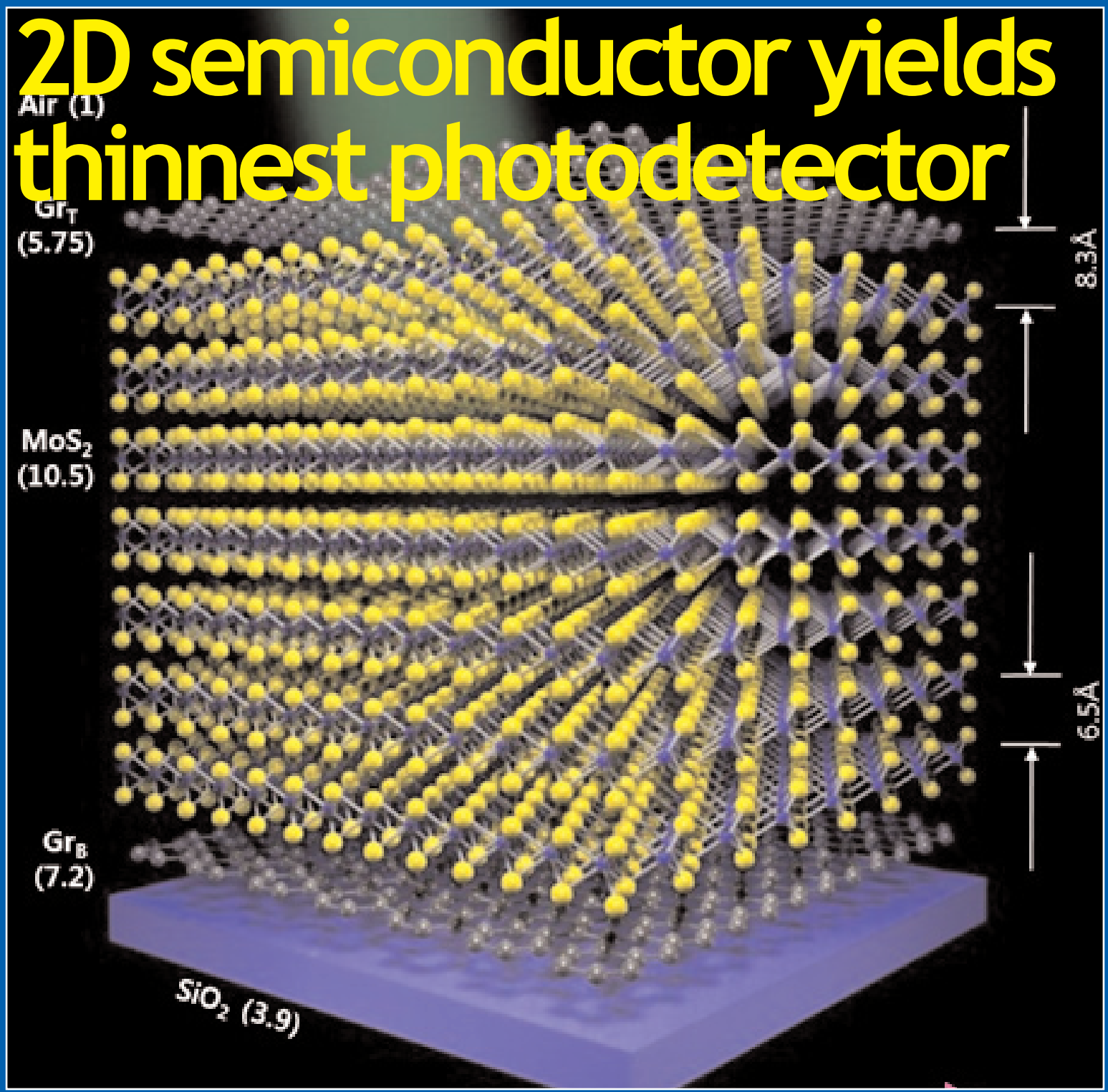
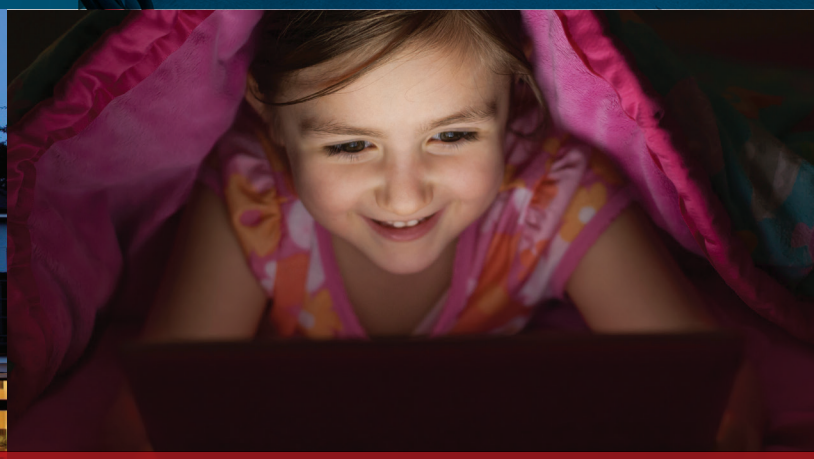
2D semiconductor yields thinnest photodetector



MACOM acquiring AppliedMicro • BluGlass and IQE collaborate
EpiWorks breaks ground on expansion • First Solar restructures

Lower Cost LEDs



Faster LED Adoption

Another breakthrough from Veeco. This time it's EPIK.

Introducing Veeco's new TurboDisc® EPIK700™ GaN MOCVD system

As global consumption for LED general lighting accelerates, manufacturers need bigger, better MOCVD technology solutions that increase productivity and lower manufacturing costs.

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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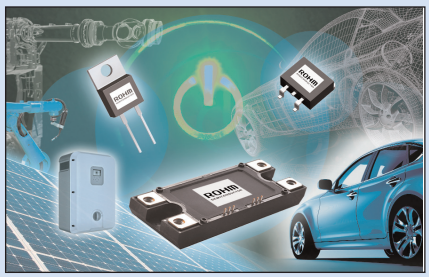
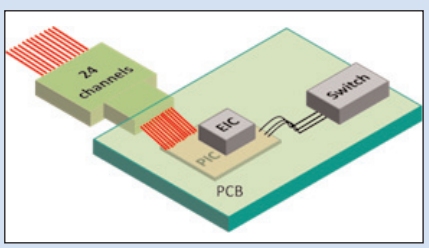
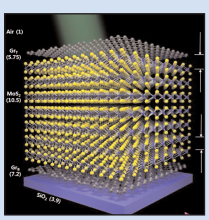


p16 Rohm presented its third generation of SiC MOSFETs, Schottky barrier diodes and SiC modules at electronica 2016.

p26 City Council planners have approved the latest phase of Cardiff University's £300m Innovation Campus, which will host the Institute for Compound Semiconductors.



p55 The EU-funded project COSMICC has been launched to combine CMOS electronics and silicon photonics with high-throughput, fiber-attachment techniques.



Cover: By using 2D technology comprising molybdenum disulfide (MoS_2) sandwiched in graphene, South Korea's Institute for Basic Science (IBS) Center for Integrated Nanostructure Physics at Sungkyunkwan University has developed what is reckoned to be the world's thinnest photodetector. **p68**

editorial

Diversifying from nitride LEDs

The effect of the slowdown in the LED market (particularly for backlighting applications), the consequent overcapacity and depressed prices over the last few years has been borne out throughout the supply chain. Faced with shrinking prices and revenues for 2-4" substrates, sapphire substrate maker Rubicon says that, while it had been trying to stay in the LED market by limiting its products to 6" wafers and cutting costs, the continual price declines have "made the prospects of becoming profitable in the LED substrate market unlikely for the foreseeable future" (see page 40). As it aims to focus on optical and industrial markets, the firm is closing its substrate manufacturing plant in Malaysia by end-2016. It now also says that, since it has excess crystal growth capacity in the USA, it is consolidating operations into its leased space in Bensenville and Franklin Park, IL, involving vacating its largest plant in Batavia, IL (which it aims to sell).

Further down the manufacturing chain, to avoid the price war in blue LEDs, Taiwan's Arima Optoelectronics has ceased production of nitride-based LED chips and shifted production to infrared AlGaInP LEDs (page 46). The firm has shut down 40 MOCVD systems used to produce blue LED epiwafers and chips, while 18 have been transferred to produce AlGaInP LED wafers and chips. "Due to the high technological entry barrier, there are relatively few manufacturers of AlGaInP LED chips," the firm notes.

Nevertheless, the volume of LED chips used in TV backlighting globally will rise slightly in 2017 (driven by increasing adoption of Ultra HD TV), according to Digitimes Research (page 7).

MOCVD system maker Veeco in third-quarter 2016 reported that revenue for its Lighting, Display & Power Electronics segment (mainly MOCVD) doubled quarter-on-quarter, as it is seeing "a clear improvement in LED industry conditions" (page 30). In particular, it is "expanding its positions in red, orange and yellow (ROY) LEDs". The firm's total order bookings rose 73%, driven by a sharp recovery in demand for MOCVD systems as it is "starting to see customers making investments in MOCVD capacity", winning "multiple tool orders from both Epistar [in Taiwan] and HC SemiTek [in China] in support of their LED production plans... We are seeing positive indications for additional MOCVD investment to occur in the near term," Veeco adds.

Fellow MOCVD system maker Aixtron reported Q3 equipment revenue up 64% (page 32). Some of this was due to low-margin sales from its surplus inventory of AIX R6 system (for GaN LEDs), but throughout Q3 there were strong shipments of systems for both ROY LEDs and power electronics. "We continue to be in a solid position in MOCVD outside GaN LEDs," notes CEO Martin Goetzeler. Increased demand for production systems for LED, telecom and optoelectronics applications, as well as for the silicon industry, has driven growth in not only revenue but also orders (up 35%).

The increasing adoption of wide-bandgap materials such as GaN in RF and power electronics applications is helping firms such as Aixtron to diversify to non-LED applications. However, it is also a reason why the technology becomes more strategically sensitive. Aixtron's acquisition by China's Fujian Grand Chip has been put on hold by German and US authorities on the grounds that GaN MOCVD has applications in defense electronics. President Obama will decide within days regarding blocking the deal (pages 33 & 74). Given the likelihood of increasing protectionism, such diversification may face more widespread obstacles.

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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news

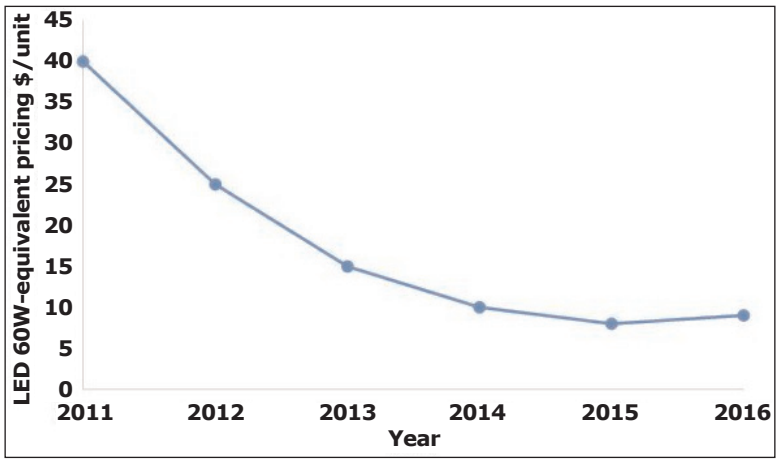
Li-Fi/visible light communication market to grow at 116.8% CAGR to $115bn by 2022

Retail sector comprises over 30% of market, but healthcare sector to grow fastest

The global Li-Fi market will rise at a compound annual growth rate (CAGR) of 116.8% from 2016 to $115bn by 2022, according to the report 'Light Fidelity (Li-Fi)/Visible Light Communication Market — Global Opportunity Analysis and Industry Forecast, 2014 – 2022' by Allied Market Research. In 2015, North America contributed the major share of the market and will continue to lead throughout the forecast period.

Li-Fi is a very high-speed, two-way wireless communication technique that uses visible light from LEDs to transmit data. The technology is an apt replacement for incumbent Wi-Fi technology, says the report, as Li-Fi is considerably faster, has almost 10,000 times broader bandwidth (because it uses visible light), and is safe to operate in electromagnetic sensitive areas. The Li-Fi market is currently in its introductory phase, although it is expected to growth rapidly in the next 5–6 years due to its exclusive advantages, such as being safe to use with medical and aviation equipment (due to the absence of electromagnetic interference), the very high data transmission speed, enhanced data security and the broader bandwidth compared with existing Wi-Fi technology.

Li-Fi incorporates three major components: the LED, photodetector, and microcontroller. Of these, in 2015, LEDs dominated the market by contributing more than 40% of the overall component segment revenue. Also, this segment is expected to grow at the highest CAGR (118.1%) during the forecast period due to its low cost and increased adoption in different applications (e.g. households, offices, vehicles, airplanes and retail stores etc). Further, LEDs are preferred over other lighting systems as they can easily be turned off and on using a microcontroller.



By industry vertical segment, the retail industry accounted for more than 30% of the overall Li-Fi market in 2015, and is projected to grow at a CAGR of 112.8% during the analysis period. Li-Fi enables storekeepers to monitor the positioning of customers by tracing their location and to provide notifications on their cellphones. However, the healthcare sector should be the fastest-growing industry and is expected to register the highest CAGR of 125.3% during the forecast period, since Li-Fi does not cause any electromagnetic interference and can safely be used with other medical apparatus (such as CT scanners, MRI machines, x-ray machines, and ultrasound machines etc).

North America dominated the market in 2015 by accounting for about 40% of total revenue, and is expected to remain dominant throughout the forecast period. This is attributed to the presence of various R&D facilities in the region and investment in implementation of this technology by the major companies in the region.

The Asia-Pacific region is expected to be the fastest-growing region, at a CAGR of 121.7%, due to the large electronics market in China and Japan as well as the presence of several developing regions where governments are promoting the use of LED lights. In the Asia-Pacific, China comprises about 50% of the market and is expected to maintain its lead throughout the forecast period.

The key players in the Li-Fi market are focused on intensive R&D (such as ongoing research at the University of Edinburgh and the research facility of pureLiFi in the UK) to improve their product quality and partnerships in order to reach untapped regions. Key players have adopted product launch as their key strategy to grow in the market (e.g. the launch of enhanced lighting named Atlanta for precise indoor positioning by Acuity Brands Inc and the Li-Fi-enabled route LiFi-x by pureLiFi). The key players profiled in the report include General Electric, Oledcomm S.A.S, Renesas Electronics Corp, pureLiFi, LVX System, Acuity Brands Lighting Inc, Qualcomm Technologies Inc, IBSENtelecom Ltd, Koninklijke Philips N.V., and Panasonic Corp.

www.alliedmarketresearch.com/light-fidelity-visible-light-communication-market

VCSEL market to rise at 22.3% CAGR to $4728.8m by 2024

The global market for vertical-cavity surface-emitting lasers (VCSELs) is rising at a compound annual growth rate (CAGR) of 22.3% from $775.2m in 2015 to $4728.8m in 2024, according to a report from Transparency Market Research (TMR).

Currently, there is demand for efficient, low-cost and compact illumination systems, replacing traditional thermal imaging systems, notes the report. VCSELs are used for infrared illumination since they offer advantages including low cost, high reliability, efficiency, a narrow emission spectrum, and a low-divergence cylindrical beam. Infrared illuminators, in turn, find application in surveillance, imaging, covert operations and detection in several end-use sectors such as the military. This has had a considerable impact on the demand for VCSELs, says the report.

GaAs most widely used material

By raw materials, the VCSEL market is led by gallium arsenide (GaAs), which accounted for a massive 77% share in 2015. The segment is expected to register a CAGR of 41.1% during the forecast period.

By application, the overall VCSELs market is dominated by optical fiber data transmission, followed by laser printers and computer mice. Chip-sale atomic clocks and absorption spectroscopy, on the other hand, will register strong growth through 2024.

By geographical region, Europe accounts for the leading share of the VCSELs market, at just under 30% in 2015, but the Asia-Pacific will see an impressive CAGR of 23.1% over 2016–2024.

Demand for GaAs rising in low-power applications

"The growing usage of VCSELs in several high-volume applications, such as gesture recognition, data communications, and illumination in infrared (IR) cameras, has emerged as the leading factor driving the global VCSELs market," states the report's lead analyst. Companies have been using VCSELs in gesture recognition technology for gaming as well as navigation applications. In IR cameras, VCSELs enable safety, night vision, and security. In datacoms, VCSELs offer advantages including low-energy optical storage, fast switching in servers, and high-capacity data centers.

With VCSELs rapidly replacing edge-emitting LEDs in low-power applications, the demand for GaAs has surged significantly, especially in atomic clock technology, datacoms, bar-code sensors, and plastic optical fiber (POF)-based home networking. This will, in turn, propel the overall VCSELs market, says the report.

On the flip side, although long-wavelength indium phosphide (InP)-based VCSELs show a lot of promise, the lasers are in the early stages of commercialization and can prove to be a challenge concerning the design, cost and manufacturing.

The VCSEL market is currently fragmented, with Finisar (USA), Broadcom (Singapore), Lumentum (USA), Sumitomo Electric Industries (Japan), and II-VI Laser Enterprise (Switzerland) accounting for under 47% of the market in 2015. However, Transparency Market Research notes that, due to a rise in mergers and acquisitions within the industry, the dynamics of the market have changed over the years.

Players have also resorted to product innovation and investment in technological advancement as key growth strategies. "Product innovation is important to sustain in a highly competitive environment, and companies have been involved in strong R&D work so as to gain a larger share in the VCSELs market," the report's author states. For instance, to retain its dominance Finisar has occasionally introduced new products in the VCSEL market (e.g. the 64 Gbaud high-bandwidth integrated coherent receiver in 2016).

www.transparencymarketresearch.com/vertical-cavity-surface-emitting-laser-market.html

Usage of LED chips in TV backlights to grow in 2017

Ultra HD TVs to comprise 36.5% of shipments, HDR TVs and quantum dot TVs 5% each, and OLED TVs just 0.72%

The volume of LED chips used in TV backlighting globally will increase slightly year-on-year in 2017, with usage of Ultra HD, HDR and quantum dot models rising while direct-type backlights, OLED and the adoption of flip-chip LED backlighting falls, says Digitimes Research.

The increase will come mostly from Ultra HD TVs, since such models will comprise 36.5% of all LCD TVs to be shipped in 2017 (rising 11.6 percentage points year-on-year) and an Ultra HD TV uses 30–50% more LED chips than a Full HD TV, Digitimes Research notes.

HDR and quantum dot TVs will contribute only slightly to the increase as their shares of 2017 shipments will be under 5% each, although they use many LED chips.

Direct-type LED-backlit TVs will see major reductions in the use of LED chips in 2017, and they will comprise 64% of all LED-backlit TVs (the remaining 36% will be edge-type). In addition, the adoption of flip-chip LED devices will also reduce the use of chips in TV backlighting.

Finally, the impact of organic light-emitting diode (OLED) TVs on the LED backlighting sector will be minimal, notes Digitimes Research, since such TVs will comprise only 0.72% of shipments.

www.digitimes.com

Qorvo grows a more than expected 23.8%, as China migrates from three-mode to full-mode smartphones

For fiscal second-quarter 2017 (to 1 October 2016), Qorvo Inc of Greensboro, NC, USA (which provides core technologies and RF solutions for mobile, infrastructure and defense applications) has reported revenue of $863.7m, up 23.8% on $697.6m last quarter and 22.1% on $707.4m a year ago (and above the guidance of $820–850m given on 2 August), reflecting broad-based demand.

Mobile Products (MP) revenue was a record $706.1m, up 29% on $547m last quarter and 22% on $578m a year ago, driven by continued RF content growth, the ramp of a key customer product, and strong Asia customer demand, supported by growth in premium-tier and mid-tier 4G LTE mobile devices. "In the performance-tier smartphones, we enjoyed strong demand for our RF Flex solutions," notes president & CEO Bob Bruggeworth. MP also saw strong demand for bulk acoustic wave (BAW)-based multiplexer solutions. "In Wi-Fi for handsets, Qorvo's RF Fusion for mobile Wi-Fi delivered customers a unique, highly integrated solution combining our high-performance BAW filters with our Wi-Fi front-end modules," he adds.

Infrastructure & Defense Products (IDP) revenue was $157.6m, up 5% on $151m last quarter and up 22% on $129m a year ago, supported by growth across all major market segments, highlighted by wireless infrastructure, WiFi, defense & aerospace, and Internet of Things (IoT) as the focus on higher-growth segments continue to bear fruit. In connectivity, IDP saw growth in both Wi-Fi and low-power wireless. "With the acquisition of GreenPeak [of The Netherlands, in April], Qorvo is a recognized leader at ultra-low-power short-range RF communications," states Bruggeworth. "We are expanding our low-power product portfolio to include highly integrated RF systems-on-a-chip for the connected home and the IoT, and our target markets are growing faster than 40%," he adds.

"We've seen a continued recovery in the base-station market, and we enjoy broad-based market share across all OEMs," notes Bruggeworth. "This helps buffer IDP from the ups and downs of any one customer."

IDP saw broad-based design-win activity, highlighted by GaN-on-SiC products for military S-band radar applications and 5GHz WiFi PAs for retail and enterprise. "In Wi-Fi, our growth was supported by continued wins in both the retail and set-top-box market segments," says Bruggeworth. "In transport, growth was driven by strength in our cable TV products to support the rollout of DOCSIS 3.1, our traditional long-haul optical driver business, and ramping data-center interconnect products," he adds.

"In Defense, our growth was driven by international and domestic GaN-on-SiC sales and a major ASIC program ramping," says Bruggeworth. "Design wins for our GaN-on-SiC devices have been exceptionally strong in market segments that are growing at over 25% per year."

On a non-GAAP basis, gross margin has fallen further, from 49.7% a year ago and 48.2% last quarter to 42.8% (well below the expected 47%). As well as higher volumes of one lower-margin product, this is due mainly to lower-than-expected manufacturing yield in die singulation and wafer-level packaging for TC-SAW filters at one fab during a steep product ramp of Qorvo's highest-volume part (a low-band PAD [power amplifier duplexer] module) for a large customer. "To protect our long-term customer relationships, we did everything we could to assure supply of high-quality material to the customer while working through the internal yield issues [with modules being scrapped at the finished good level], and this significantly impacted our gross margin," says Bruggeworth. "We now have new die-level screens which are targeting the issue."

Operating expenses have risen further, from $156.8m a year ago and $168.6m last quarter to $172.9m. "We had higher expenses to support ongoing development programs, higher sales commissions, and the full-quarter effects of our GreenPeak acquisition," says chief financial officer Mark Murphy. Despite this, OpEx still achieved the target 20% of sales.

Operating income was $196.8m (operating margin of 22.8% of sales), up from $167.6m last quarter and $194.8m a year ago. Although up from $143.1m (diluted earnings per share of $1.08) last quarter, net income was $170.4m (diluted EPS of $1.29, below the expected $1.35–1.45), down from $183.3m (diluted EPS of $1.22) a year ago.

Driven by operating income growth and efficient working capital management (particularly inventories), net operating cash flow has risen from $59m last quarter to $250m. Property & equipment expenditures were $120m (addressing growing demand for premium filters through SAW investments in North Carolina and BAW investments in Texas). Free cash flow was hence $130m. During the quarter, Qorvo repurchased $91m worth of common stock. Cash and short-term investments rebounded from $447m to $469m. Qorvo's board has now authorized a new $500m repurchase program.

During the quarter, Mobile Products secured multiple placements of RF Fusion high-, mid- and low-band 4G LTE solutions in upcoming flagship smartphones at leading China-based smartphone OEMs. In China, MP is benefiting as smartphone makers migrate from three-mode to full-mode devices. "By the end of this year, we expect more than half of all 4G smartphones manufactured for the China market will be full-mode," says Bruggeworth. "Our largest customers in China are looking for ways to introduce fewer models with higher levels of RF content to provide broader coverage of additional geographies as they move towards more of an export market. Huawei is adding more RF content to their smartphones as they build their

global brand." Huawei was one of two 10% customers for Qorvo in fiscal Q2 and its largest customer in China.

"Integration [after the merger of RFMD and TriQuint in January 2015] has gone well in many ways, validated our vision for the combined company and yielded a common culture and synergies," says Murphy. "But there is more that can be done on both the integration and general productivity... This past quarter was the first full quarter in which most of the company was on a common ERP system," he adds. "We expect that improved visibility, increased financial discipline and rigor, and a broad-based commitment to operational excellence will help drive additional synergies."

"We brought up and released our TC-SAW process in Greensboro, ahead of schedule, giving us the ability to support additional customer demand," says Bruggeworth. "We are increasing the mix of 6" TC-SAW in Florida while moving all GaAs capacity to Oregon, transitioning all GaN products to Richardson [Texas]. We are also ramping our new assembly & test facility into Dezhou, China," he adds. "In Richardson, the organization has done an outstanding job, releasing our most advanced next-generation BAW process, which delivers a significant improvement over our prior generation in key performance metrics. We've also brought up and are now designing products on our new 8" BAW line in Richardson. We are enjoying broad-based demand for BAW filter solutions and we expect the ramp of new customer programs to improve our utilization rates in calendar 2017... We continue to enjoy strong demand for our BAW-based multiplexer solutions and we have delivered module prototypes containing our BAW-based hexaplexers."

IDP is closing on its model of 60% gross margin and 30% operating margin. Bruggeworth is pleased with revenue growth, initiatives to target faster-growing market segments, and the rate and pace of new product introductions. In September, IDP released 49 new products including power amplifiers for small-cell, dual and quad linear drivers for optical applications, LNAs, and filters for automotive and integrated front-end modules for Wi-Fi. "The continued aggressive pace of product releases is creating a broad-based pipeline of differentiated solutions with long production tails," Bruggeworth adds.

For fiscal Q3/2017 (to end-December 2016), Qorvo expects revenue of $800–840m, up by over 30% year-on-year but down significantly quarter-on-quarter at Asian customers (although IDP will still be flat to up slightly). "Yields have stabilized in the fab, which will help support even stronger customer demand for that module," says Murphy. "We do expect margins to improve on more stable production, however higher mix of the low-band PAD will partially offset the improvement." Gross margin should rise 100–200 basis points (to 43.8–44.8%) due to better yield and fewer associated inventory write-offs (offset by higher volume associated with the lower-margin product). OpEx should remain near 20% of sales and trend down in dollars through the rest of the fiscal year on lower commissions and an increase in productivity initiatives. Diluted EPS should be $1.15–1.35.

"We currently expect gross margins to improve from the second quarter and through the second half of the fiscal year 2017, as our mix of low-band PAD peaks in the third quarter and our operations stabilize," says Murphy. "We expect to exit fiscal year 2017 above 46% gross margin... additional yield improvements, factory loading, sourcing and other productivity initiatives will help drive margin expansion in fiscal year 2018. Factory yield improvements from process maturity and larger-wafer production in SAW and BAW are expected to add approximately 100 basis points to gross margin... Higher volumes are projected to add over 150 basis points of margin based on higher utilization of our BAW, SAW and GaAs lines as well as ramping our new Dezhou assembly & test facility," he adds. "Next year, considering projected volumes and the impacts of consolidation efforts and measured capacity additions, we expect our global operations to be running near capacity," Murphy adds. "We project ongoing supply chain consolidation and procurement initiatives, along with additional efforts to wring out merger savings, should drive another 150 basis points of gross margin expansion... By the end of fiscal year 2018, we expect these efforts and a more favorable mix of higher-margin products should result in greater than 50% gross margins."

"CapEx will remain elevated through the rest of the fiscal year, as we invest in premium filter capacity to support forecasted customer demand," notes Murphy. "In fiscal year 2018, our OpEx is expected to grow at no more than half the rate of sales, which will drive OpEx to under 20% of sales."

"Within six quarters we expect to be at our targeted operating performance. We currently expect double-digit [above-market] sales growth to continue through fiscal 2018 and forecast over 30% operating margins by fiscal Q4/2018," says Bruggeworth.

Mobile Products should benefit from further content growth and demand for complex modules using premium filters. "We made progress advancing core technologies and developing highly integrated Qorvo solutions for large customer opportunities in 2017 and 2018," says Bruggeworth. IDP has been repositioned to serve higher-growth markets including Wi-Fi, automotive, IoT, and wireless infrastructure. "We are continuing our focus on the [base-station] market's higher-growth segments, with an emphasis on the transition of base-station power amplifiers to GaN technology and the implementation of massive MIMO," says Bruggeworth. "Through fiscal-year 2018, we expect IDP's growth to be in line with Mobile Products," he adds.

"We plan to exit fiscal year 2018 at over 50% gross margins, OpEx below 20% of sales, and operating margins over 30%," says Murphy. "This performance will generate substantial free cash flow, which we plan to use for acquisitions and returning capital to our shareholders."

www.qorvo.com

Skyworks' revenue grows a more-than-expected 11%

For full-year fiscal 2016 (ending 30 September), Skyworks Solutions Inc of Woburn, MA, USA (which makes analog and mixed-signal semiconductors) has reported record revenue of $3.29bn, up 9.4% on fiscal 2015's $3.26bn (or up 11–12%, excluding headwinds at its largest customer).

For fiscal Q4, Skyworks has reported revenue of $835.4m, down 5% on $880.8m a year ago but up 11% on $751.7m last quarter and exceeding the $831m guidance.

Compared with Q3, integrated mobile systems (IMS) rose from 55% to 60% of revenue and broad markets fell from 29% to 25% (mostly due to infrastructure, as the Internet of Things sector held steady), while the power amplifier sector was steady at about 16%. "Skyworks is capitalizing on the strength of both Mobile and IoT eco-systems," says president & CEO Liam K. Griffin.

Skyworks had two more-than-10% customers: Foxconn at about 40% and Samsung at about 10%. China comprised 25% of total revenue.

Fiscal Q4 business highlights were:

- leveraging SkyOne across Huawei's Honor 8 global platform;
- powering Google's flagship Pixel 4G LTE smartphones;
- securing multiple 4G LTE design wins with leading Chinese OEMs;
- commencing volume production of diversity receive and antenna tuner solutions;
- supporting Amazon's Echo and Tap virtual assistant devices;
- enabling Netgear's Orbi router with connectivity and analog control ICs;
- launching linear power amplifiers supporting small-cell ramps in China;
- delivering integrated 4G LTE modules for Jaguar and Land Rover;
- ramping vehicle-to-vehicle communication modules for Alps;
- capturing ZigBee content in Trilliant's smart-grid communication systems;
- designed into a premier medical imaging OEM for MRI applications;
- integrating GPS, connectivity and switching solutions for GoPro drones.

"As a virtual hub for e-commerce, enterprise to the cloud, social media, gaming and entertainment, mobile devices are rapidly evolving to address the massive demand for data and speed across an increasingly crowded spectrum," says Griffin. "Skyworks is resolving this daunting complexity with customized system-level solutions to ultimately improve the user experience with higher levels of efficiency, enhanced streaming capabilities and expanded network coverage. As a result, we are well positioned to continue delivering above-market growth," he adds.

On a non-GAAP basis, gross margin has risen further, from 50% a year ago and 50.9% last quarter to 51%. Full-year gross margin has risen from 48.2% for fiscal 2015 to 51% for 2016, demonstrating strong operational execution. Operating expenses were $107.5m (12.9% of revenue), level with last quarter.

Operating income was $318.4m (operating margin of 38.1%), down from $335.2m a year ago but up from $274.7m (36.5%) last quarter. Full-year operating income is up from $1.17bn (36% margin) for 2015 to $1.24bn (37.8% margin) for 2016.

Although down from $296.1m ($1.52 diluted earnings per share) a year ago, net income rebounded from $238.1m ($1.24 diluted EPS) last quarter to $277.6m ($1.47 EPS, better than the $1.43 guidance). Full-year net income is up from $1.03bn ($5.27 EPS) for 2015 to $1.07bn ($5.57 EPS) for 2016.

Operating cash flow rebounded from $141m last quarter to a record $455m, driven by high profitability and sequential improvements in working capital: days sales outstanding fell from 69 to 45 days, and inventory was cut from 108 to 94 days. This contributed to full-year operating cash flow rising from $1bn for 2015 to a record $1.1bn for 2016.

Capital expenditure has fallen further, from $150.8m a year ago and $57m last quarter to just $15.7m ($189m for full-year fiscal 2016). The drop reflects the lower investment now required for the firm's temperature-compensated surface acoustic wave (TC-SAW) filter production.

This allowed the firm to more than double the cash returned to shareholders from $360m (64% of free cash flow in fiscal 2015) to $727m (81% of free cash flow) in 2016 in the form of over $200m in dividends (up 63% year-on-year) and repurchasing 8 million shares (including 3 million in fiscal Q4) at an average price of just under $66 each. The board has since declared a cash dividend of $0.28 per share.

"Entering fiscal year 2017, we are leveraging our scale, customer partnerships and differentiated system solutions to capture increasing content per platform across mobile connectivity and IoT applications," says chief financial officer Kris Sennesael. Hence, for fiscal Q1/2017 (to end-December 2016), Skyworks expects revenue to grow by 7–9% sequentially. "Our largest customer is seasonally strong… going into a seasonal ramp," notes Griffin. "The top-three tier-1 accounts are also ramping aggressively into Q1." At the mid-point of $902m, gross margin should in the low 51% range. Operating expenses are expected to be $112m (up on fiscal Q4's $107.4m, but falling from 12.9% to 12.4% of revenue). Diluted EPS should rise to $1.58. Days of inventory should be cut further, from 94 to 85 days.

"We want to continue to further drive operational efficiencies," says Sennesael, who believes that gross margins can be improved another 100 basis points exiting fiscal 2017.

For full-year fiscal 2017, Skyworks targets CapEx of $200–220m (up from $189m for 2016). A few years ago annual CapEx was $400–430m to outfit and install its TC-SAW fab, which is a 3 billion unit per year producer of high-performance filters. "With that behind us, the run-rate CapEx is sustainable," says Griffin. "We can do a great job with that capital and monetize our assets and filters as well."

www.skyworksinc.com

Skyworks unveils CATV infrastructure portfolio for DOCSIS 3.1; secures design win with European OEM

Skyworks has launched its portfolio of cable TV (CATV) infrastructure solutions targeting DOCSIS 3.1 and EuroDOCSIS 3.1 cable applications.

The suite of products includes ultra-linear RF amplifiers — the first devices commercially available for frequencies up to 1218MHz in Europe — optimized to support high signal fidelity. Skyworks says that, by combining linearity with reliability, the products ensure ultra-fast data throughput and high-quality streaming while minimizing downtime for multiple system operators (MSOs) and paving the way for hybrid fiber coaxial (HFC) systems capable of greater data speeds. Skyworks has already secured a key design win with a major European CATV OEM.

"The pace of technology is continually changing the way consumers receive information and entertainment," says Carlos Bori, VP of sales & marketing. "We are supporting this massive upsurge in data requirements for consumers around the world via smartphones, the connected car and wearables, as well as equipment and services into the home. With our newest suite of solutions for network operators, Skyworks is addressing the growing CATV market, enabling the delivery of new, high-speed data channels while providing MSOs the ability to continue pushing fiber networks deeper into their infrastructure platforms."

According to market research firm Strategy Analytics, consumer demand for new, faster video and broadband services, the global transition to digital, and the drive towards new back-end systems are all driving growth in CATV infrastructure networks. Customer subscriptions for digital CATV jumped 18% to 16.3 million across Europe in first-half 2016 alone as subscribers migrate to enhanced services, per Cable Europe and Screen Digest.

Skyworks' CATV infrastructure portfolio include the following wide-bandwidth DOCSIS and EuroDOCSIS 3.1-compliant ultra-linear RF amplifiers:

- the ACA1216 — a 1218MHz CATV MMIC power doubler amplifier (12V) with what is claimed to be the highest linear RF power for a high-gain 12V CATV surface-mount device;
- the ACA2429 — a 1218MHz high-output CATV power doubler amplifier (24V) featuring what is claimed to be industry-leading bit error rate (BER) across the full operational temperature range.

Skyworks' CATV products are currently available for sampling and production. The firm highlighted the portfolio at the electronica 2016 trade fair in Munich, Germany (8–11 November).

www.skyworksinc.com/Market/11/CATV

Skyworks launches fully integrated front-end modules for IoT

Skyworks has launched a suite of fully integrated front-end modules targeting the rapidly expanding Internet of Things (IoT) market including the connected home, industrial automation and energy management.

The newest modules are the first in a series of solutions powering multi-mode operation for next-generation Bluetooth, Thread and ZigBee wireless networking protocols. When paired with system-on-a-chip (SoC) platforms, the devices deliver an efficient wireless solution, maximizing battery life while simultaneously increasing the transmission range with improved power. To date, several leading SoC providers are leveraging the front-end modules as part of their reference designs.

"With consumers and enterprises requiring seamless connectivity, there is strong market demand for highly integrated, performance-driven analog solutions delivering significantly improved range and battery life," says John O'Neill, VP of marketing. Skyworks is offering "the first front-end modules that support multiple protocols, including the soon to be launched Bluetooth 5, while also addressing the most popular broadband platforms and Internet of Things applications."

In a recent report, ABI Research has forecast that the global wireless connectivity market (excluding cellular connectivity) will reach more than 10 billion annual IC shipments by 2021. With the introduction of Bluetooth mesh functionality, evolving Wi-Fi protocols, enhancements to 802.15.4 (such as ZigBee 3.0 and Thread) and the development of multi-protocol SoC solutions, there is a multitude of new opportunities in nearly every vertical market. Analysts forecast that the global ZigBee home automation market alone will grow at a compounded annual growth rate (CAGR) of 26% over 2016-2020.

The SKY66112-11 is designed for ease of use and flexibility. The multimode front-end module provides an integrated inter-stage matching and harmonic filter, with digital controls compatible with CMOS. The device operates over a wide supply voltage range of 1.2–3.6V, allowing it to be used in battery-powered applications over a broad spectrum of the battery discharge curve.

The SKY66112-11 is available for sampling and production. Skyworks highlighted its Internet of Things product portfolio at the electronica trade fair in Munich, Germany (8–11 November).

www.skyworksinc.com/Product/3152/SKY66112-11

Anokiwave leveraging GlobalFoundries' 130nm SiGe

Collaboration to develop silicon core ICs for mmWave active antenna

Anokiwave Inc of San Diego, CA, USA, which provides highly integrated silicon core chips and III-V front-end integrated circuits for millimeter-wave (mmW) markets and active electronically scanned array (AESA)-based terminals, is collaborating with GlobalFoundries of Santa Clara, CA, USA (one of the world's largest semiconductor foundries, with more than 250 customers and operations in Singapore, Germany and the USA) to deliver silicon core ICs for the emerging mmWave active antenna markets.

Active antennas have been used in military phase-array radar systems for many years and are now being deployed in record numbers in a wide range of commercial applications, says Anokiwave. The highly anticipated roll out of 5G infrastructure is expected to utilize active antenna technologies in both base stations as well as handsets.

Anokiwave says that silicon technology is playing a major role in reducing the cost of these new active antennas as well as offering unprecedented levels of functional integration, allowing the beam-steering application-specific integrated circuits (ASICs) to reside within the lattice of the array (resulting in low profile, planar arrays). Silicon-based active antennas will be key to the success of 5G networks operating at millimeter-wave frequencies, the firm reckons.

Leveraging GlobalFoundries' 130nm high-performance silicon germanium (SiGe) platform, Anokiwave will gain early access to new technology developed by GlobalFoundries, allowing accelerated product development that is expected to result in unprecedented time-to-market for users seeking high-performance SiGe solutions in the RF front end of 5G and fixed-wireless millimeter-wave infrastructure and other mmWave phased-array consumer applications.

"GlobalFoundries' world-class process technologies, process modeling, and packaging technologies combined with Anokiwave's team of established industry experts in IC and system design deliver the world's most advanced IC solutions for mmWave applications," reckons Anokiwave's CEO Robert Donahue. "Anokiwave and GlobalFoundries are innovating and delivering core ICs that will revolutionize emerging 5G, radar and SatCom markets with affordable active antenna solutions," he adds.

"Working with innovative companies like Anokiwave, in the early stage of technology development, enables functions and features that are tuned to marketplace requirements," comments Bami Bastani, senior VP of GlobalFoundries' RF business unit. "GlobalFoundries' SiGe 8HP and 8XP technologies enable customers to develop differentiated RF solutions for next-generation mobile and infrastructure systems."

GlobalFoundries' 8XP 130nm BiCMOS SiGe technology process blends high-performance bipolar and power-efficient MOS devices with the ability to integrate mmWave, analog and digital functionality on a single IC. The unique functionality of the 8XP process has allowed Anokiwave to reach what are reckoned to be unprecedented levels of integration, enabling low-cost planar arrays for mmW applications.

www.globalfoundries.com/SiGe
www.anokiwave.com

Anokiwave's Distinguished Fellow of Technology speaks at Interactive Workshop on mmWave technology for 5G

Anokiwave's Distinguished Fellow of Technology Dr Ian Gresham gave a presentation in the Technology Enablers session on 18 November at the International Wireless Industry Consortium (IWPC) Interactive Workshop 'What Role will mmWave Technologies Play in 5G?' in San Jose, CA, USA (16–18 November).

In the interactive workshop, which considered when and how 5G will be deployed (with a special focus on mmW systems that will deliver multiple gigabit-per-second data rates with improved mobility, latency, volume and service deployment times over current 4G systems), Gresham is discussing the changing mmW landscape, why active antenna technology is best for 5G, and offering an overview of Anokiwave's 5G IC solutions during his presentation 'The Last (Mile) Will Be First — Enabling Fixed Wireless and 5G Basestations with Active Antenna RFICs for 2017 Deployment'.

"As we predicted in 2014, 'Moore's Law' has enabled the massive migration of wireless communication and radar solutions into the mmW frequency spectrum with near complete reliance on silicon-based solutions," says Anokiwave's chief systems architect David Corman. "X-W band active antenna products will be embedded with our cell phones, lap-tops, homes, cars, and almost every other data-driven application we touch, and Anokiwave is well positioned to embrace this shift with our unique portfolio of active antenna core ICs for 5G," he adds.

Gresham, a 25 year veteran in the mmW industry and IEEE Fellow, is working on the development of Anokiwave's 5G products and technology driving the industry, with product offerings available now for early 5G systems trials.

www.iwpc.org

MACOM to acquire AppliedMicro for $770m

Acquisition to speed MACOM's growth in optical technologies for enterprise and cloud data-center customers

MACOM Technology Solutions Holdings Inc of Lowell, MA, USA (which makes semiconductors, components and subassemblies for analog RF, microwave, millimeter-wave and photonic applications) has agreed to acquire Applied Micro Circuits Corp of Santa Clara, CA, USA (which provides silicon-based computing and connectivity solutions for next-generation cloud infrastructure and data centers) for about $8.36 per share ($3.25 in cash plus 0.1089 MACOM shares per share of AppliedMicro), representing a 15.4% premium over the closing price of $7.25 on 18 November. AppliedMicro stockholders are expected to own about 15% of the combined company on a pro forma basis.

The transaction is valued at about $770m in diluted equity value, or about $688m net of AppliedMicro's $82m cash and short-term investments as of end-September 2016. MACOM expects to pay the cash portion of the acquisition price from cash on hand.

MACOM intends to commence a tender offer to purchase each outstanding common share of AppliedMicro. It will assume certain equity awards held by AppliedMicro employees.

AppliedMicro's trailing twelve months (TTM) revenue is about $165m (including the non-strategic Compute business, which MACOM intends to divest within the first 100 days of closing). The pro forma combined TTM revenue of MACOM and AppliedMicro is hence about $709m including AppliedMicro's Compute business (or $644m excluding the Compute business). MACOM expects to improve AppliedMicro's profitability by divesting the Compute business and by delivering on substantial revenue and cost synergies.

It is reckoned that AppliedMicro's Connectivity business is highly complementary to MACOM's product portfolio, through the addition of what are claimed to be market-leading optical transport network (OTN) framers, MACsec Ethernet networking components and the industry's leading single-lambda PAM4 platform.

The acquisition is targeted at accelerating MACOM's growth in optical technologies for cloud service providers and enterprise network customers serving the high-growth, high-margin data-center market.

MACOM expects that AppliedMicro's PAM4 solutions based on FinFET technology and custom engagements with top-tier data-center and service provider customers will strengthen its competitive position with those customers.

"MACOM will now be able to provide all the requisite semiconductor content for optical networks — analog, photonic and PHY — from the switch to fiber for long haul, metro, access, backhaul and data center," notes president & CEO John Croteau. "AppliedMicro's 100G to 400G single-lambda PAM4 platform should perfectly complement MACOM's leadership in analog and photonic components for data centers," he adds.

"The IEEE recently recommended the adoption of AppliedMicro's single-lambda PAM4 solution to be an industry standard for enterprise and data-center connectivity, positioning this technology as the solution of choice going forward. Additionally, AppliedMicro's Connectivity business aligns well with MACOM's differentiated, high-growth business model, offering non-GAAP gross margins well in excess of MACOM's long-term target operating model, long product life cycles, and sticky customer relationships," he continues.

MACOM will now be able to provide all the requisite semiconductor content for optical networks — analog, photonic and PHY

"AppliedMicro also provides value-added technologies including SerDes, high-speed analog-to-digital and digital-to-analog converters with industry-leading engineering competencies and long product lifecycles. Importantly, we expect that this transaction will establish MACOM with an incumbent position supplying strategic components and enterprise and cloud data-center customers."

"The transaction affirms the value that our employees have created and provides a strong path forward for our Connectivity business while delivering AppliedMicro stockholders a robust premium," says AppliedMicro's president & CEO Paramesh Gopi. "This transaction will create an industry powerhouse with the scale, deep customer relationships, innovative technology, and enabling products that will help deliver explosive growth in enterprise and cloud data centers," he adds. "In addition, this agreement provides a promising path forward for the Compute business, which is in the process of bringing AppliedMicro's highly competitive third-generation X-Gene processor to market," he adds.

Excluding the Compute business, the transaction is expected to be accretive to MACOM's non-GAAP gross margin, operating margin and EPS in fiscal year 2017.

The boards of directors of both firms have approved the transaction, which is subject to customary closing conditions and regulatory approvals. MACOM currently expects the transaction to close in first-quarter 2017.

www.apm.com
www.macom.com

Sivers IMA uses SiGe to launch first transceiver chip supporting FCC's new V-band

Final version to span entire 57–71GHz band; prototypes available in first-quarter 2017

At European Microwave Week (EuMW 2016) in London, UK (4–6 October), Sivers IMA of Kista, north of Stockholm in Sweden (which makes microwave and millimeter-wave components used in telecom links, radar sensors and test & measurement equipment), has launched a fully integrated V-band transceiver radio-frequency integrated circuit (RFIC).

The difference between this transceiver and previous generations from Sivers IMA is that all parts are made of silicon-germanium (SiGe). The circuit includes a complete millimeter-wave transceiver (transmitter and receiver), digital control, signal source, and a complete analog baseband.

"We are the first in the world to include coverage of the new FCC [US Federal Communications Commission] V-band frequencies 64–71GHz, which was recently made available in the USA," adds CEO Anders Storm. "Having the full transceiver in silicon-germanium for V-band provides a fundamental platform, including the relevant building blocks, for our ongoing development of the WiGig RFIC that will be released to the market in 2017."

We are the first in the world to include coverage of the new FCC V-band frequencies. Having the full transceiver in SiGe for V-band provides a fundamental platform, including the relevant building blocks, for our ongoing development of the WiGig RFIC that will be released to the market in 2017

The transceiver is packaged in a eWBL capsule for easy surface mounting on printed-circuit boards and only measures 7mm x 7mm. Since all parts are fabricated in SiGe technology, the cost of the transceiver can be kept low, and Sivers IMA says that it will be able to offer products with good price-performance to manufacturers of point-to-point links.

In the final version, the new RFIC will cover the entire V-band in the USA, from 57GHz to 71GHz. Prototypes of the circuit will be available to key customers in first-quarter 2017.

www.eumweek.com
www.siversima.com

InnoSenT launches surface-mountable radar motion detector using Infineon 24GHz SiGe transceiver MMIC

InnoSenT GmbH of Donnersdorf, Germany has launched a surface-mountable radar (SMR) motion detector operating in the 24.0–24.25GHz industrial, scientific & medical (ISM) band that incorporates the latest 24GHz silicon germanium (SiGe)-based transceiver MMIC (BGT24LTR11) from Infineon Technologies AG of Munich, Germany, offering what is claimed to be a unique combination of high functionality, low power consumption and easy-to-install solution.

Compared with passive infrared (PIR) technology, the use of radar in motion detection applications increases accuracy, since it allows a more precise measurement of object detection and provides new capabilities such as the detection of speed and direction of moving objects. Radar is also superior to camera-based systems by allowing detection of the objects while keeping identities anonymous.

Infineon's BGT24LTR11 transceiver MMIC features a fully integrated low-phase-noise voltage-controlled oscillator (VCO) and built-in temperature compensation circuit for VCO stabilization. It also has full ESD protection, Infineon Technologies' 200GHz bipolar SiGe: C technology (B7HF200), and a single supply voltage of 3.3V. The SMR module's ultra-compact design (20mm x 15mm x 3mm) eases integration, allowing installation in small spaces. It provides a solution for security applications, home automation, lighting control, intelligent machine control, touch-free switches, and movement detection.

InnoSenT's SMR series comprises three types with different antenna characteristics. In addition to the option of simple motion detection with a corresponding evaluation, it is also possible to determine speed information and the direction of movement to the detected object from the returned data. Infineon's SiGe radar MMIC was designed with Doppler radar applications in mind, which enables additional functionalities. Besides the 24GHz fundamental VCO, it also provides the SMR series with variants for FMCW (frequency-modulated continuous-wave) or FSK (frequency shift keying) operation mode.

www.infineon.com/24GHz
www.innosent.de/en/sensors/smr-radar-series

Guerrilla RF launches failsafe SPDT switch for cellular boosters, infrastructure and L-band satcoms

Guerrilla RF Inc of Greensboro, NC, USA — which provides monolithic microwave integrated circuits (MMICs) to wireless infrastructure original equipment manufacturers — has launched the GRF6011, the first member in its range of failsafe switch and amplifier devices.

The GRF6011 provides failsafe operation, with one RF path defaulting to a low-insertion-loss state, with all power removed, and the other path defaulting to a high-insertion-loss state.

At 1900MHz, typical 3.3V RF performance offers insertion loss of <0.45dB, IP1dB (input power at 1dB gain compression point) of >31dBm, and IIP3 (third-order input intercept point) of >50dBm.

A key application for the single-pole, double-throw (SPDT) switch is at the low-noise amplifier (LNA) in a tower-mounted amplifier (TMA), where the failsafe functionality is typically implemented using expensive mechanical relays or cumbersome Schottky diode switches external to a traditional LNA. Guerrilla RF says that the GRF6011 is suitable for applications including cellular boosters, cellular infrastructure and L-band satcoms. Since the device requires only a few external capacitors for DC blocking, it is housed in an ultra-small 1.5mm x 1.5mm DFN-6 package, providing an extremely compact application footprint.

"The device's flexible biasing capability allows for supply and control inputs anywhere in the 3.0–5.0V range," says VP of applications and technical marketing Alan Ake.

According to market research firm EJL Wireless, the ability to incorporate the failsafe capability within the GRF6011 switch and also eliminate the external relay or diode switches is a major step forward in reducing the overall size and bill-of-materials (BOM) cost of a typical TMA unit.

GRF6011 samples and evaluation boards are available now. Pricing is $1.45 each in 10,000-unit quantities.

http://guerrilla-rf.com

Infineon's radar chips used by RFbeam in low-cost 24GHz transceiver modules for motion detection and speed/distance measurement

At the electronica 2016 trade fair in Munich, RFbeam Microwave GmbH of St Gallen, Switzerland launched low-cost 24GHz Tx/Rx transceiver modules (K-LD2 and K-MD2) that, respectively, use the BGT24LTR11 and BGT24MR2 24GHz industrial, scientific & medical (ISM)-band monolithic microwave integrated circuit (MMIC) radar transceiver chips of Munich-based Infineon Technologies AG, which offer a fully integrated low-phase-noise voltage-controlled oscillator (VCO) and built-in temperature-compensation circuit for VCO stabilization, as well as full ESD protection, B7HF200 200GHz bipolar SiGe: C process technology, and a single supply voltage of 3.3V.

Using the BGT24LTR11 MMIC radar transceiver chip (consisting of one transmit channel and one receive channel), the K-LD2 single-transceiver module is claimed to be one of the smallest (25mm x 25mm) and lowest-power-consuming radar transceivers available. Incorporating integrated signal processing and 80° x 34° antenna pattern, the module can be used for applications where indoor/outdoor motion detection is required.

Using the BGT24MR2 MMIC radar transceiver chip (with two receive channels), the K-MD2 module supports speed, range and angle measurement and delivers a digital output. The integrated range-Doppler processing is suitable for high-end traffic applications. Each module offers what is said to be a reliable and robust solution defined for specific applications with a precise measurement of object detection.

The new modules hence provide a plug-and-play-solution for original equipment manufacturers needing either motion detection for persons or speed/distance measurement.

Possible applications include advanced motion detection, speed, direction and distance measurement. Examples are movement and presence detection that can be integrated in advertising panels, for instance. In traffic applications, the radar system can be used for red light management for roadworks or speed detection, as well as car classification systems such as toll roads or car park barriers. Combining the technical features of Infineon's 24GHz industrial MMIC with RFbeam's modules reduces time to market, reckon the firms, adding that the effort and cost of developing complex algorithm can be minimized.

RFbeam's modules include antennas either with or without integrated signal processing, enabling manufacturers of industrial radar systems to optimize their system's capability. If necessary, this allows the detection of speed and direction of movement (approaching or retreating) in addition to the easier detection of motion only. RFbeam's existing portfolio offers three modules with various antenna characteristics, for MCU signal processing and different options for Doppler, FMCW (frequency modulated) or FSK (frequency shift keying) operation modes.

www.rfbeam.ch

Rohm presents third-generation SiC MOSFETs, Schottky barrier diodes and modules

At the electronica 2016 trade fair in Munich, Germany (8–11 November), Rohm Semiconductor of Kyoto, Japan presented its third generation of silicon carbide (SiC) MOSFETs, Schottky barrier diodes (SBDs) and SiC modules. The new devices address the needs of efficient power delivery, offering solutions to reduce loss issues during power conversion. Rohm claims that it was first to mass produce SiC MOSFETs in 2010 and is developing products that target further power loss reductions.

Rohm is now mass producing what it claims are the first trench-type SiC MOSFETs. Compared with planar gate-type SiC MOSFETs, the new generation of SiC MOSFETs reduces ON-resistance by 50% across the entire temperature range and input capacitance by 35% in the same chip size. Optimum performance is achieved by combining low loss with high-speed switching performance. Increasing switching frequency also makes it possible to reduce the size of peripheral components such as coils and capacitors. As a result, conversion efficiency is improved, contributing to miniaturization, weight reduction, and greater energy efficiencies. The new SCT3080KL 1200V SiC MOSFET series in a TO-247 package serves as an example. In addition, Rohm will offer Automotive Electronics Council AECQ-qualified SiC MOSFET based on its second-generation planar series.

The third-generation of SiC Schottky barrier diodes (SBDs) realizes what are claimed to be the lowest forward voltage (V_F) and lowest reverse leakage current (IR) over the entire temperature range among all SiC SBDs currently on the market. In addition, they feature high surge current capability, which is suitable for power supply applications. Adding to the TO220ACP-packaged SCS3xxAP devices (launched in mid-October) operating at 650V/6A, 8A and 10A, Rohm has introduced D2PAK (LPTL)-packaged SCS3xxAJ and TO220FM-packaged SCS3xxAM devices while also adding lower-current (2A and 4A) options to the family.

Compared with silicon-based devices, SiC diodes exhibit ultra-short reverse recovery time, making them suitable for high-speed switching. Overall, these features contribute to the ongoing trend of high efficiency, high power density and highly robust designs, says Rohm.

Rohm's new full-SiC modules — including chopper-type modules for converters — integrate both mass-produced trench SiC MOSFETs and SiC SBDs. In addition to 1200V 2-in-1 (half-bridge)-type modules (the 80A BSM080D12P2C008, the 120A BSM120D12P2C005, the 180A BSM180D12P3C007, and the 300A BSM300D12P2E001), Rohm is preparing 1200V chopper-type modules (the 120A BSM120C12P2C201, the 180A BSM180C12P3C202, the 300A BSM300C12P3E201) for market. In addition, Rohm is working on a new power module with lower stray inductance.

www.rohm.com

United Silicon Carbide agrees for Richardson to distribute its SiC products globally, to expand to new customers

Richardson Electronics Ltd of LaFox, IL, USA (a global channel partner for electron devices, power electronics, and RF & microwave components) has announced a new distribution agreement with United Silicon Carbide (USCi) of Monmouth Junction, NJ, USA. The global agreement supports the expansion of USCi's products to new customers.

USCi specializes in developing high-efficiency SiC devices and customized products, using process expertise in Schottky barrier diodes and SiC switches. USCi says that its technology and products enable affordable power efficiency in key markets that will drive a greener economy.

"USCi's unique SiC cascodes offer a rapid and easy way to upgrade silicon MOSFET-based designs to the higher performance and greater efficiency of SiC," says Greg Peloquin, executive VP of Richardson Electronics' Power & Microwave Technologies group. "This unique technology and Richardson's world class global capabilities of bringing new products to market will accelerate the introduction of USCi to the global market and customer base," he reckons.

Richardson Electronics is a "design-in oriented and application-focused distributor with a worldwide presence and, through their highly technical expertise, they can support customers throughout the entire design cycle, which can make the difference between success and failure," comments USCi's sales director Christopher Rocneanu. "Furthermore, Richardson has an outstanding reputation for launching the newest products and latest technologies to the global marketplace, which will help us reach new customers and take advantage of increased opportunities for SiC applications."

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Fraunhofer ISE develops highly compact, high-frequency DC/DC converter for aviation applications

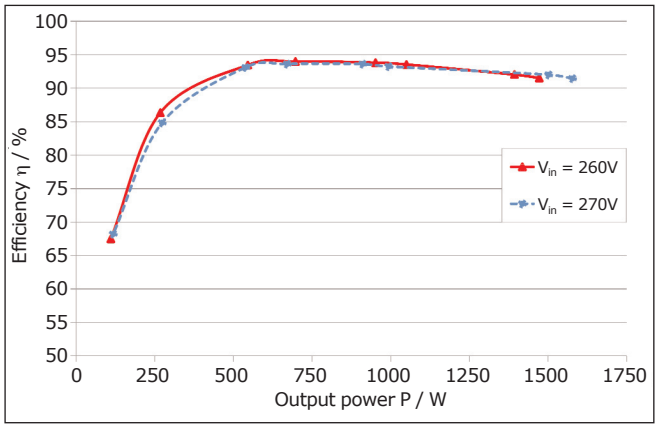
Three-year GaN-resonat project yields transistors enable switching frequencies in MHz range with power/weight ratio of 3.9kW/kg

The efficiency of power electronic systems is not solely dependent on electrical efficiency but also on weight (e.g. in mobile systems). When the weight of relevant components and devices in airplanes, for example, is reduced, fuel savings can be achieved and correspondingly greenhouse-gas emissions decreased. New materials and components based on gallium nitride (GaN) can help to reduce weight and increase the efficiency. Power electronic switches can hence be operated at higher switching frequency, resulting in higher power density and lower material costs. Researchers at the Fraunhofer Institute for Solar Energy Systems ISE in Freiburg, Germany, together with partners, have investigated how these materials can be used to make power electronic systems in aviation applications more efficient.

In the project 'GaN-resonat – Efficient, highly compact, high-frequency power electronics with GaN transistors', consortium partners SUMIDA Components & Modules GmbH, Liebherr Elektronik GmbH and Fraunhofer ISE complement each other in the fields of inductive components, aviation technology and power electronics. The aim was to develop a resonant DC/DC converter using GaN transistors, with switching frequencies significantly above 1MHz and a nominal power of 3kW. The converter was designed especially for applications in aviation, where compatibility between the economic and ecological challenges plays a major role.

Compact design, high efficiency

To achieve the project's target, the researchers and industry partners used GaN power transistors together with innovative inductive components. Typical switching frequencies for these applications of currently up to 350kHz for resonant converters could hence be increased to 2.5MHz.



Efficiency for different power outputs of the compact DC/DC converter (V_{out} = 28V_{DC}, f_{sw} = 1.8-2.5MHz). Maximum efficiency is 94.5%.

"With these higher frequencies, a large part of the weight due to the passive components and the volume of the 3kW DC/DC converters could be appreciably reduced," says Cornelius Armbruster, developing engineer in the team 'Efficient and High Frequency Power Electronics' at Fraunhofer ISE. By making the passive components smaller, less material (e.g. copper or ferrite) is required for manufacturing, saving scarce resources. The beneficial dynamic behavior of GaN transistors allows high efficiency despite the high frequency. "The developed converter has a power/weight ratio of 3.9kW/kg and a total efficiency of over 90% for a wide operating range," says Armbruster. "The converter reaches a comparatively high maximum efficiency of 94.5% at half its nominal power and a switching frequency of 2MHz," he adds. However, at such high frequencies special care must be taken with the printed-circuit board (PCB) design, the measurement and control technology, and the electromagnetic compatibility. In consideration of these aspects, an eight-layer PCB was produced for the demonstrator and, in particular, control of the GaN transistors was developed and optimized.

GaN — material with perspective

For years, Fraunhofer ISE has undertaken R&D on high-efficiency, high-frequency power electronics for renewable energy systems and applications using gallium nitride and silicon carbide (SiC) components. In the GaN-resonant project, the researchers and their project partners have developed a scenario for application in the aviation industry, designing the resonant voltage converter to meet the particular requirements of aviation electronics.

The results from the project can be transferred to other fields of application in the future, it is reckoned. One possible area of application is as a power supply for server farms, or for communication electronics in general. The amount of energy consumed worldwide to supply the existing communications infrastructure is immense, and all signs show that this will continue to rise. In this case, the design of the new compact, high-frequency DC/DC converter (saving on materials and reducing power losses) shows clear advantages, with not only higher efficiency but also lower cooling demand, says Fraunhofer ISE.

The GaN-resonant project was launched in 2013 and ran for a period of three years. It was funded with about €1.2m from the German Federal Ministry for Education and Research (BMBF) within the Hightech Strategy of the federal government under the IKT2020 Research & Development Program for Projects on Power Electronics ('Leistungselektronik zur Energieeffizienzsteigerung').

www.ise.fraunhofer.de

Wolfspeed wins 2016 R&D 100 Award for SiC-based underhood inverter for electric vehicles

During the R&D 100 Conference on 3 November, it was announced that Wolfspeed of Research Triangle Park, NC, USA had won a 2016 R&D 100 Award for its high-temperature, wide-bandgap (WBG) underhood inverter for electric vehicles.

"Our SiC inverter is the first traction drive optimized for wide-bandgap devices that utilizes a commercially available SiC power module," says Wolfspeed's chief technology officer John Palmour. "By increasing power in a smaller footprint, Wolfspeed is enabling hybrid and electric vehicles to become more attractive to end consumers, contributing further to a reduction in the domestic use of fossil fuels and greenhouse-gas emissions," he adds. "Additionally, through our partnerships with other industry leaders, Wolfspeed ensures that our technology is readily adoptable in vehicle applications."

Wolfspeed's high-temperature WBG underhood inverter was developed in response to the need for smaller, lighter and more efficient systems with higher power density in the electric vehicle market, and in collaboration with the Toyota Research Institute of North America, the US National Renewable Energy Laboratory (NREL), University of Arkansas National Center for Reliable Electric Power Transmission, and the Department of Energy (DoE) Vehicle Technologies Office.

Underhood inverters convert the DC power stored in hybrid, plug-in hybrid or all-electric vehicle battery packs to three-phase AC power that can be used to energize one or more electrical loads, and traditionally employ industry-standard silicon. Using Wolfspeed's WBG devices and packaging techniques in an underhood inverter allowed engineers to achieve faster switching with reduced system-level losses during high-ambient-temperature operation (140°C). Wolfspeed says that this WBG-based system significantly outperforms silicon technology and extends the possibilities for vehicle inverters, for which it has been named one of the top technical breakthrough products released in 2015.

The core of Wolfspeed's WBG underhood inverter consists of three commercial CAS325M12HM2 SiC half-bridge power modules, which are rated for 1200V and 325A of continuous RMS current at high temperatures. The inverter also includes: a liquid-cooled cold plate (which provides the thermal conduction path for energy losses); low-inductance power bussing (minimizing parasitic losses and maximizing switching efficiencies); snubber and filter components (which dampen over-voltage and over-current spiking and dampens resonances); control and drive circuitry (which performs the dynamic switching and provides users with feedback, control signals, and high-current gate drive signals); and an enclosure (providing the unit with EMI shielding, electrical cabling, and liquid cooling inlet/outlet connections).

Wolfspeed says that, using WBG materials, it has eliminated the need for the secondary radiator and thermal management system in the vehicle. This inverter allows the onboard power electronics to be cooled by the same coolant loop as the primary radiator and combustion engine, significantly decreasing the overall mass and volume of the system. In addition to reducing the system footprint within the car, Wolfspeed's WBG technology also increases the peak power delivery of the unit by 2–3x what is currently achievable, while operating at overall higher ambient temperatures.

Wolfspeed presents at Defense Manufacturing Conference

Wolfspeed exhibited and contributed to the technical program at the 47th annual Defense Manufacturing Conference (DMC 2016) in Denver (28 November– 1 December).

"The theme for DMC 2016 is 'Understand the challenges; seize the opportunities,' so both our exhibition and conference presentation focus on the specific defense industry challenges that Wolfspeed's advanced wide-bandgap technology can address," says Dr Jeff Barner, Wolfspeed's manager of foundry services. Wolfspeed not only provides the defense community with design assistance, proven processes, testing and support but does so with a track record of faster cycle times, higher first-pass design successes, and greater reliability, he claims.

At the exhibition, Wolfspeed promoted its RF foundry (claimed to be the world's largest dedicated, commercial wide-bandgap production device facility) in addition to its latest RF product introductions for defense applications, including the highest-power 50V GaN high-electron-mobility transistor demonstrated to date. Launched in September, the 900W CGHV14800 GaN HEMT delivers at least 800W of pulsed power at 1.2–1.4GHz and 50V operation with better than 65% drain efficiency, features high-efficiency, high-gain and wide-bandwidth capabilities, and is suitable for L-band radar amplifier applications including air traffic control (ATC) radar, penetration radar, anti-missile system radar, target-tracking radar and long-range surveillance radar.

Also, in the DMC technical program, director of business development Dr Ty McNutt gave the presentation 'Enabling SiC Power Module Technology for Advanced DoD Systems'.

http://dmcmeeting.com
http://wolfspeed.com/RF/Foundry-Services

Transphorm expands second-generation portfolio with lower on-resistance TO-220 650V GaN FET

Transphorm Inc of Goleta, near Santa Barbara, CA, USA — which designs and manufactures JEDEC-qualified 650V gallium nitride (GaN)-based devices for high-voltage power conversion applications — says its new TPH3212PS device (available in a TO-220 package) has an on-resistance of 72mΩ and targets AC-to-DC and DC-to-AC power supplies. When used in the former, the TPH3212PS — along with its fellow family members — enables the implementation of bridgeless totem-pole power factor correction (PFC) designs.

The firm's product portfolio consists of 600V and 650V discrete field-effect transistors (FETs) spanning TO-220, TO-247 and PQFN88 packages for power levels up to 4.5kW. The TPH3212PS fills a power level gap in its second-generation product line, specifically between the 52mΩ and 110mΩ FETs, offering greater design flexibility to battery charger, PV inverter, server and servo motor manufacturers.

Launch of the TPH3212PS remains in step with Transphorm's aim to enable design engineers to effectively implement GaN technology into designs. The firm develops its GaN in well-understood TO-XXX and PQFN88 packages. Further, it uses the high-reliability cascode configuration, which eliminates the need for custom drivers and — most importantly — considerably increases the GaN FET's gate safety margin.

"Transphorm aims to enable the market by delivering GaN in the highest-quality, highest-reliability format," says chief technology officer Umesh Mishra. "We recognize GaN is not just a drop-in replacement for silicon MOSFETs used today," he adds. "Board re-design and system modifications are required to capitalize on GaN's complete set of benefits, from performance through to system cost. If we can minimize that learning curve by working with well-known packages and a configuration that behaves similarly to a MOSFET, we believe the industry will move further faster."

Benefits of the TPH3212PS are said to include:

- a 30–40% increase in system-level power density;
- 2–4x faster switching compared with silicon; lowering crossover losses to increase system efficiency;
- compatible with off-the-shelf gate drivers, increasing gate safety margin to an unmatched ± maximum 18V gate drive; and
- for designs moving from standard PFC to bridgeless totem-pole, elimination of the use of a bridge rectifier, parallel FETs and additional passives as the power level increases, reducing overall system cost.

Fully qualified and in production, the TPH3212PS is priced at $8.94 in 1000-unit quantities. It is currently supported by a SPICE program and application notes. A full evaluation kit for 2.5kW hard-switched half-bridge, buck or boost designs is available for pre-order, priced at $250.

www.transphormusa.com

Navitas' CEO presents AllGaN Power IC key advantages of high-frequency, high-density and energy savings at WiPDA

In a keynote speech 'Speed Drives Performance' at the IEEE Power Electronics Society 4th IEEE Workshop on Wide Bandgap Power Devices and Applications (WiPDA) in Fayetteville, AR, USA (7–9 November), Gene Sheridan, CEO of Navitas Semiconductor Inc of El Segundo, CA, USA, presented the advantages of what it claims are the first gallium nitride (GaN) power ICs, which use the firm's proprietary 'AllGaN' technology. A technical paper '650V AllGaN Power IC for Power Supply Applications' was also presented by VP of IC design Marco Giandalia.

"Power systems can achieve a dramatic improvement in charging speed, power densities and cost reduction if high switching speeds can be combined with high energy efficiencies," says Sheridan. "Navitas is leading a high-speed revolution in power electronics with the invention of the industry's first GaN power ICs, which enable up to a 100x increase in switching speeds and a 3x increase in energy savings," he claims.

Navitas' AllGaN 650V platform monolithically integrates GaN power field-effect transistors (FETs) with GaN logic and drive circuits and enables 10–100x higher switching frequency than existing silicon circuits, it is reckoned, making power electronics smaller, lighter and lower cost. A new generation of high-frequency, energy-efficient converters is being enabled for smartphone and laptop chargers, OLED TVs, LED lighting, solar inverters, wireless charging devices and data centers.

"The IEEE has a long history of identifying and nurturing new generations of technology," says professor Alan Mantooth, who was general chair of WiPDA 2016. "GaN is clearly demonstrating efficiency and performance advantages over traditional power semiconductors," Mantooth concludes.

www.wipda2016.org/
www.navitassemi.com

US District Court grants MACOM preliminary injunction against Infineon on GaN-on-Si rights

MACOM Technology Solutions Holdings Inc of Lowell, MA, USA (which makes semiconductors, components and subassemblies for analog RF, microwave, millimeter-wave and photonic applications) says the US District Court for the Central District of California in Los Angeles has granted its request for a preliminary injunction in its lawsuit against Infineon Technologies Americas Corp over gallium nitride on silicon (GaN-on-Si) technology.

The court's decision on 31 October (i) confirmed MACOM's continuing exclusive rights in certain GaN-on-Si RF fields under a 2010 license deal between Nitronex LLC of Durham, NC (acquired by MACOM for $26m in 2014) and International Rectifier (acquired by Infineon in 2015); (ii) ruled that MACOM is likely to succeed in its claim that Infineon's purported termination of that agreement was improper and without effect; and (iii) granted MACOM's motion for a preliminary injunction prohibiting Infineon from engaging in activities inconsistent with the 2010 license deal pending the court's final decision.

When MACOM initiated the legal action in April, it alleged that Infineon had attempted to interfere with and usurp MACOM's rights under certain agreements between Nitronex and International Rectifier. "Nitronex and IR, and later, MACOM and IR, successfully collaborated for many years. Problems developed only after Infineon acquired IR and began to try to 'renegotiate' the Nitronex–IR agreements to reduce MACOM's rights," said MACOM's president & CEO John Croteau. "When MACOM declined to accede to Infineon's demands, Infineon concocted claims to interfere with our rights under the agreements," he alleged. "Infineon's behavior is clear validation that MACOM's GaN technology — the product of 15 years and over $100m in investment — is at the tipping point of market adoption, threatening large incumbents like Infineon," continued Croteau. "This has caused Infineon to engage in strong-arm tactics designed to retard, rather than accelerate, innovation."

MACOM's suit against Infineon includes claims for breach of contract, breach of the covenant of good faith and fair dealing, declaratory judgment of contractual rights, and intentional interference with contract. Among other relief, MACOM asked the court to grant it declaratory and injunctive relief confirming its rights under the Nitronex–IR agreements and ordering Infineon to assign to MACOM several Nitronex GaN patents.

"We were forced to file this lawsuit to stand up to Infineon's bullying and anticompetitive behavior," states Croteau now. "We are gratified by the court's preliminary decision confirming that the GaN-on-Si rights granted to us under the 2010 license agreement remain in full force and effect and that Infineon acted improperly in trying to operate in our exclusive field of use," he adds. "We are firmly committed to vigorously litigating this case to its rightful conclusion. We continue on the path to providing GaN-on-Si technology that promises to improve network data service and cell coverage of 4G/LTE and 5G base-stations."

www.infineon.com
www.irf.com

Panasonic starting mass production of high-speed gate driver for X-GaN power transistor

Japan's Panasonic Corp has started mass production of the AN34092B high-speed gate driver, optimized for driving its X-GaN power transistor, as well as two types of X-GaN (the 70mΩ PGA26E07BA and 190mΩ PGA26E19BA), providing solutions in combination with gate drivers.

GaN is one of the next generation semiconductor compounds that can achieve space and energy savings when applied to transistors used in various power units. A gate driver is required to drive a transistor, but general gate drivers for conventional silicon transistors cannot exploit the potential of GaN transistors due to their different gate structures.

Panasonic says that the new AN34092B high-speed gate driver helps the X-GaN to safely achieve high-speed switching performance. It can drive transistors at frequencies of up to 4MHz and integrates the active Miller clamp function that prevents malfunction during high-speed switching. Using proprietary technology, the X-GaN achieves a 600V breakdown enhancement mode and features high-speed switching and low on-resistance.

Panasonic reckons that the combination of X-GaN and dedicated gate drivers can contribute to significant space and energy savings in various power conversion units for industrial and consumer use.

X-GaN and dedicated high-speed gate drivers are suitable for various applications such as 100W to 5kW power supply units, inverters, data centers, mobile base-stations, consumer electronics, audio-visual equipment, industrial and medical devices.

Both X-GaN and the dedicated high-speed gate drivers were exhibited at electronica 2016 in Munich, Germany (8–11 November).

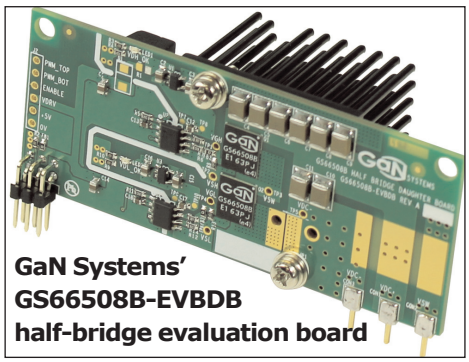
www.semicon.panasonic.co.jp/en/products/powerics/ganpower

GaN Systems launches evaluation platform for gallium nitride transistors

GaN Systems Inc of Ottawa, Ontario, Canada — a fabless developer of gallium nitride (GaN)-based power switching semiconductors for power conversion and control applications — has launched a daughterboard-style evaluation kit to help power design engineers to evaluate GaN enhancement-mode HEMT (E-HEMT) performance in any system design, along with a universal motherboard (GS665MB-EVB). Ranging from 750W to 2500W, the family of four daughterboards consists of two GaN Systems' 650V GaN E-HEMTs and all necessary circuits, including half-bridge gate drivers, isolated power supplies and an optional heat-sink to form a high-performance half-bridge power stage.

GaN Systems says that several features maximize the evaluation platform's utility:

- The platform serves as a reference design and evaluation tool as well as a deployment-ready solution for easy in-system evaluation.
- The vertical mount style has a 35mm height, which fits the majority of 1U design and allows evaluation of GaN E-HEMT in a traditional through-hole-type power supply board.



GaN Systems' GS66508B-EVBDB half-bridge evaluation board

- A current shunt position is provided for easy switching energy characterization testing.
- A universal form factor and footprint are used to allow users to compare various power levels for optimal cost/performance decisions.

Our evaluation kits facilitate development of AC/DC, energy storage, DC/DC and other power systems

The evaluation platform family of boards includes the following evaluation boards:

- GS66504B-EVBDB (using the GS66504B 650V/15A, 100mΩ GaN E-HEMT);
- GS66508B-EVBDB (using the GS66508B 650V/30A, 50mΩ GaN E-HEMT);
- GS66508T-EVBDB (using the GS66508T 650V/30A, 50mΩ, top-side-cooled GaN E-HEMT);
- GS66516T-EVBDB (using the GS66516T 650V/60A, 25mΩ, top-side-cooled GaN E-HEMT); and
- GS665MB-EVB (universal 650V motherboard using all the above GaN HEMTs).

GaN Systems is also launching the GS61008P-EVBBK, a highly efficient 48V to 12V synchronous buck converter based on the GS61008P 100V, 90A GaN E-HEMT. The firm says that this system demonstrates very high efficiency at frequencies up to 2MHz, commonly desired in 48V systems.

"By developing this family of GaN E-HEMT evaluation boards, we are providing power design engineers with the tools to easily evaluate and optimize GaN transistor performance in their systems," says VP sales & marketing Larry Spaziani. "Our evaluation kits facilitate development of AC/DC, energy storage, DC/DC and other power systems. The kits benefit developers across the consumer, data-center, industrial, transportation, and energy markets."

www.gansystems.com/eval-boards.php

GaN Systems co-founder & CTO delivers WiPDA 2016 keynote address showcasing GaN's value to automotive market

GaN Systems' co-founder & chief technology officer John Roberts delivered the keynote address at the 4th IEEE Power Electronics Society Workshop on Wide Bandgap Power Devices and Applications (WiPDA 2016) at The Chancellor Hotel in Fayetteville, AR, USA (7–9 November).

The presentation 'GaN Power Transistors – Powering Up' (to an audience of device scientists, circuit designers, and application engineers) will focus on the existing state of high-current GaN power transistors and will discuss how GaN Systems' 100V and 650V GaN transistors are positioned to meet automotive power systems requirements.

John Roberts.

Roberts has been a champion of gallium nitride technology for over a decade. Over that period, he has spearheaded the research, development, manufacturing and large-scale production of GaN devices that are now being designed into power systems across the consumer, data-center, industrial, transportation and energy markets. Roberts will share his perspective on where power design engineers are using GaN transistors to solve power management challenges. He will also present examples where GaN transistors have been used to make systems more efficient, smaller, lighter and less costly.

www.wipda2016.org
www.gansystems.com

Taiwan's JJPlus and EPC partner on GaN-based wireless charging designs

Collaboration prompted by Taiwan wireless power standards organization's adoption of AirFuel Alliance standard

To address the Taiwan wireless power standards organization's announcement of adopting AirFuel Alliance's resonant wireless charging standard, Taiwan-based JJPlus Corp (which designs and manufactures industrial-grade and high-power WIFI solutions) and Efficient Power Conversion Corp (EPC) of El Segundo, CA, USA — which makes enhancement-mode gallium nitride on silicon (eGaN) power field-effect transistors (FETs) for power management applications — are collaborating to design and implement GaN-based wireless power solutions. In addition to the Taiwan initiative, the designs will have application for wireless charging systems worldwide.

The AirFuel Alliance, a global consortium focused on enabling and accelerating the adoption of wireless power technology, recently signed a Letter of Intent with the Taiwan Association of Information and Communication Standards (TAICS) to establish a wireless charging ecosystem in Taiwan through the introduction of AirFuel's resonant technology standard.

"Our collaboration is in direct support of TAICS/AirFuel's initiative in their launch of public wireless charging spots at coffee shops, airports or hotels," says JJPlus' general manager Jeff Shu. "We look forward to employing EPC's leading gallium nitride technology and working with their expert teams, who work closely with Witricity, to take a leadership position in this fast-growing market," he adds.

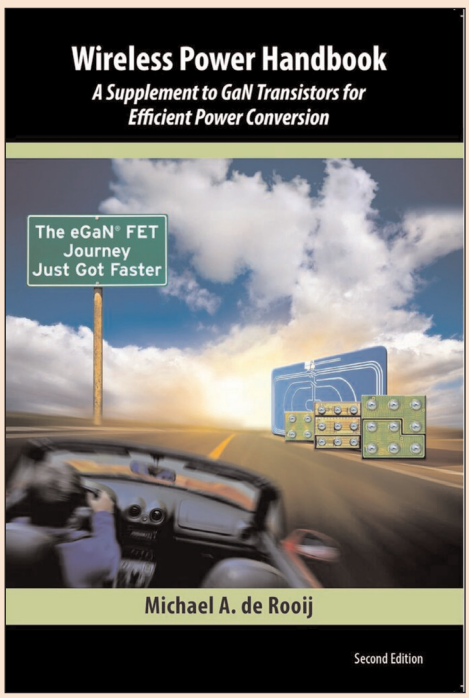
"Our eGaN technology has been supporting the wireless charging market development with our business partners and customers worldwide for over three years," notes EPC's CEO & co-founder Alex Lidow. "JJPlus is an exceptional team with technical know-how, dedication and expertise whose customer design solutions serve as market-leading solutions," he comments. "With the introduction of AirFuel's resonant technology in Taiwan's wireless charging ecosystem, the adoption of wireless charging applications will be accelerated, further fueling the overall expansion of the GaN power market."

www.airfuel.org
www.jjplus.com
www.epc-co.com

EPC presents user-friendly GaN-based multi-mode wireless charging solution at Wireless Power Summit

On 10 November at the Wireless Power Summit 2016 in Seattle, WA, USA (10–11 November), EPC's vice president of applications engineering Dr Michael de Rooij presented a multi-mode wireless power charging solution that works with either of the two wireless charging standards — Qi or Airfuel.

"The 8th annual Wireless Power Summit focuses on business strategies and technology developments in this rapidly changing field, with a focus on how wireless power has evolved to higher-power applications including laptops, tools and vehicles," say the conference organizers. Also giving presentations were leaders from major companies engaged in the development of wireless power products, such as Dell, Hewlett-Packard, Bosch and Witricity.



The presentation by de Rooij, 'Bridging the Differences Between the Wireless Power Standards to Improve the User Experience' focused on a multi-mode solution that provides a single system that accommodates both leading wireless power standards. This demonstrates the use of eGaN technology to aid ease of use regardless of the standard used in the receiving device. This multi-mode solution shifts the planning of wireless power to more pragmatic issues, such as how to reduce cost, improve efficiency and increase power, says EPC.

The presentation was based on the GaN applications R&D for wireless power that de Rooij has detailed in his Wireless Power Handbook, which is available via Amazon.com or Digi-Key Electronics.

http://epc-co.com/epc/Products/Publications/WirelessPowerHandbook
www.wirelesspowersummit.com/2016-agenda

Mentor Graphics joins Wide Band Gap integration power electronics consortium in Japan

Software provider to participate in thermal management and power cycling initiatives

Electronic hardware and software design and manufacturing solutions provider Mentor Graphics Corp of Wilsonville, OR, USA has joined the Wide Band Gap integration (WBGi) power electronics consortium to participate in thermal management and power cycling initiatives.

Established in 2013 by professors Katsuaki Suganuma and Tsuyoshi Fuaki of Osaka University in Japan, the WBGi Consortium assembles academics and industrialists worldwide to leverage the possibilities of wide-bandgap semiconductors materials such as silicon carbide (SiC) and gallium arsenide (GaN) — which enable devices to operate at much higher voltages, frequencies and temperatures than conventional silicon materials — and the associated challenges.

Mentor Graphics is already an active member of the US-based Center for Power Electronics Systems (CPES) and European Centre for Power Electronics Consortium (ECPE). WBGi is hence the third power electronics consortium that Mentor Graphics has joined, offering its expertise in the field and proven technologies to advance the power and performance of semiconductors, IGBTs, MOSFETs, and other devices.

"One of the key issues for SiC- and GaN-based power electronics is thermal dissipation," says Katsuaki Suganuma, professor at the Institute of Scientific and Industrial Research at Osaka University. "Mentor's T3Ster transient thermal tester hardware is the most advanced technology in its field and can contribute to understanding what is going on in WBG semiconductors," he comments. "There are standards for power LEDs already, and we believe that MicReD technology in the Mentor Graphics Power Tester can help in developing power cycling standards for WBG power electronics."

The WBGi Consortium is addressing all aspects of packaging and reliability in the next generation of power electronics, with 34 industrial company members plus several work groups, workshops and meetings in place. The WBGi is also involved with the ECPE in Europe, USA and Asian partner organizations to establish itself as a global consortium.

"Being a member of the WBGi Consortium in Japan is extremely valuable and important to us," says Roland Feldhinkel, general manager of Mentor Graphics' Mechanical Analysis Division. "Our proven technologies and our team of researchers, educators and scientists are eager to contribute to WBGi's initiatives and working groups," he adds. "Our collaboration with the WGBi and its members can help result in tremendous advancements for the power electronics systems industry worldwide."

www.mentor.com

AKHAN and Blue Wave partner to develop nanocrystalline diamond processes on HFCVD systems

AKHAN Semiconductor Inc of Gurnee, IL, USA, which specializes in the fabrication and application of nanocrystalline (NCD)-based materials & devices for semiconductor and electronic applications, has announced a partnership with Blue Wave Semiconductors Inc of Baltimore, MD, USA (which provides processing tools and thin-film technology components and materials to R&D customers, Federal Government, and industrial partners) that is reckoned to constitute a key step forward for the R&D of both companies, allowing both to expand the functionality and applications of their products and processes.

Blue Wave produces hot-filament chemical vapor deposition (HFCVD) equipment, representing an important differentiator as AKHAN is prepares to fabricate its Miraj diamond material from both microwave and hot-filament systems for a variety of thin-film substrates such as silicon, silicon carbide (SiC), and glass.

AKHAN is partnering with Blue Wave for nanocrystalline diamond process development on HFCVD systems. The partnership should allow AKHAN to optimize its diamond technologies for a variety of optical, mechanical & thermal/electronic product lines and is intended to also facilitate rapid and efficient commercial scaling.

"This partnership will greatly enhance our operational and commercial diamond capability, where our customers can benefit from an optimized lab-to-fab deployment schedule, while maintaining compliance with rigid electronics manufacturing standards," says AKHAN's president & chief operating officer Carl Shurboff.

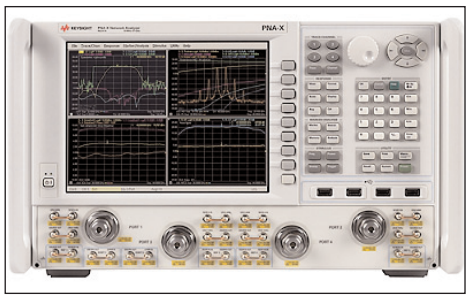
"This partnership strengthens our HFCVD product line for realizing diamond coatings applications to commercial opto-mechanical components," adds Blue Wave's CEO & CTO Dr R.D. Vispute.

www.akhantech.com
www.bluewavesemi.com

Chalmers chooses Keysight and Virginia Diodes to create first system for network & spectrum analysis up to 1.5THz

Capabilities enhance free-space, on-wafer & waveguide measurements of materials, devices and circuits at terahertz frequencies

Keysight Technologies Inc of Santa Rosa, CA, USA (which provides electronic measurement instruments, systems and related software used in the design, development, manufacture, installation, deployment and operation of electronic equipment) has collaborated with Virginia Diodes Inc (VDI, which makes test & measurement equipment for millimeter-wave and terahertz applications) to create a 1.5THz measurement solution for Chalmers University of Technology in Gothenburg, Sweden. Already up and running in Chalmers' national laboratory for terahertz characterization, the industry-first solution provides network and spectrum analysis capabilities for research on new materials, devices and circuits for applications at micro-, millimeter- and sub-millimeter-wave frequencies.



A Keysight PNA network analyzer

Chalmers' researchers are working in the terahertz gap between radio waves and infrared light. The measurement equipment from Keysight provides new capabilities that are enhancing their work with free-space, on-wafer and waveguide measurements in the terahertz gap.

The system is built around the Keysight's PNA-X microwave network analyzer, which covers 10MHz to 67GHz and reaches 1.5THz with external extension modules from VDI. Achieving an insightful understanding of device performance and behavior requires network and spectrum measurements, says Keysight, which claims that the PNA family is the first to provide integrated spectrum analysis capability that reaches into the terahertz range. The ability to access both capabilities in a single test setup — and make multiple measurements through one set of connections — saves time and enhances insight.

www.keysight.com/find/1.5THZ
www.chalmers.se/en
www.vadiodes.com

Tektronix launches Keithley S540 power semiconductor test system targeting SiC and GaN devices up to 3kV

Test, measurement and monitoring equipment supplier Tektronix Inc of Beaverton, OR, USA has introduced the Keithley S540 Power Semiconductor Test System, a fully automated, 48-pin parametric test system for wafer-level testing of power semiconductor devices and structures up to 3kV. Optimized for compound power semiconductor materials including silicon carbide (SiC) and gallium nitride (GaN), the S540 can perform all high-voltage, low-voltage and capacitance tests in a single probe touch-down.

As demand for power semiconductor devices continues to increase and as SiC and GaN become more commercialized, manufacturers are adopting wafer-level testing in their production processes to optimize yields and improve profitability, says Tektronix. For these applications, the S540 lowers cost of ownership by minimizing test time, test set-up time and floor space while achieving lab-grade high-voltage measurement performance, it adds.

"Many fabs are using custom-built, hybrid test systems for power semiconductor testing that require manually changing test setups when moving from low-voltage to high-voltage tests," says Keithley product line general manager Mike Flaherty. "As you might expect, this adds process steps and slows production," he adds. "In contrast, the S540 is a complete, fully integrated solution well suited for production environments where numerous devices must be tested quickly."

To deliver production-level performance, the S540 can perform parametric measurements on up to 48 pins without changing cables or probe card infrastructure. It can also perform transistor capacitance measurements such as Ciss, Coss, and Crss up to 3kV, again without manual reconfiguration of test pins. Further boosting test output, the S540 offers sub-pA measurement performance and can perform fully automated, high-voltage leakage current tests in <1s.

As a standard commercial product, the S540 offers fully traceable system specifications, safety compliance, diagnostics, and worldwide service and support, features that are often missing in home-built or custom systems. The S540 draws on Keithley's 30+ years of semiconductor parametric testing expertise, and safely and seamlessly integrates semiconductor test instrumentation with both low- and high-voltage switching matrices, cabling, probe card adapters, prober drivers and test software.

The Keithley S540 is available to order now, for delivery from March.

www.tek.com/keithley-s540-parametric-test-system

Cardiff University's £300m Innovation Campus approved by city planners

Campus to host Institute for Compound Semiconductors

Cardiff City Council planners have approved the latest phase of Cardiff University's £300m Innovation Campus, which will host a range of facilities geared to innovation, including the Institute for Compound Semiconductors (a UK-based translational research centre in compound semiconductors) and the Cardiff Catalysis Institute (featuring a catalysis facility to support Cardiff's research in chemical sciences).

Two new buildings (each covering 12,000m^2) will bring researchers, businesses, public sector backers and students together to forge processes that aim to create technological innovations, spin-out companies, partnerships and new products and services.

The fully funded £135m project on the city's brownfield Maindy Park is the third phase in Cardiff's mission to embed innovation in university life. The campus vision, outlined two years ago by Vice-Chancellor professor Colin Riordan, establishes centres of excellence that aim to push benefits back into the economy to create a self-sustaining cycle for growth. "Cutting-edge research, technology transfer, business development and student enterprise will put ideas to work," says Riordan. "We are hiring internationally renowned academics who can build world-class teams of post-doctoral researchers. We are equipping students with the skills they'll need to set up future ventures. And we're continuing to attract major UK and international funding across private and public sectors," he adds.

Artist's impression of Maindy Park building.

Lettable office and lab space will be available to ventures — from small start-ups through to major corporates — who want to work directly with one of the UK's leading research universities. Also, a bridge will link to the Cardiff Business School.

Architects Hawkins\Brown and HOK worked on the project alongside site masterplanners BDP and town planning consultancy DPP.

"We've worked closely with the university to develop new models for space use and the integration of industrial partners and collaborators in an HE [high education] context," says Hawkins/Brown partner Oliver Milton. This has resulted in a clear design with interactive working spaces organized around a central 'oculus' that connects the six storeys. Shared facilities include a Ted-ex auditorium and fabrication lab to trial new manufacturing technologies."

"We look forward to creating cutting-edge facilities that will reinforce the university's international reputation as a leading catalysis research centre and build on its strengths in the development of semiconductor devices and materials," says Adrian Gainer, regional leader for HOK's Science + Technology group. "Both the Institute for Compound Semiconductors and the Cardiff Catalysis Institute have been designed to enable multi-disciplinary research to flourish," he adds.

"The campus fulfils a number of aspirations for Cardiff University and aims to facilitate world-leading scientific research, inter-disciplinary mixing and increase student opportunities in an environment that's better for business," comments BDP's Martin Jones.

"We worked very closely with the university and Cardiff Council to ensure that this exciting scheme could be delivered within an outline planning consent dating back to 2010," says DPP's Gareth Hooper. "The result is the continuation of an exciting regeneration project, delivering physical change to the city through world-leading science."

Cardiff University hopes to start work on site early in 2017.

www.cardiff.ac.uk/innovation/campus-investment/translational-research-facility

RF/Power program manager for Compound Semiconductor Centre

The Compound Semiconductor Centre (CSC) — a joint venture formed in August 2015 between epiwafer foundry and substrate maker IQE plc of Cardiff, Wales, UK and Cardiff University — has appointed Robert Harper as RF/Power program manager.

CSC says that Harper's experience in semiconductor R+D/product delivery includes 16 years of fab experience at InMOS/ST and 14 years of epitaxy experience at IQE Silicon in technical and commercial roles. He joins CSC from his current role as global sales director at a global semiconductor process equipment provider.

In his new role, Harper's challenge will be to focus on delivering CSC's RF/Power roadmap across all its initiatives.

www.compoundsemiconductorcentre.com

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BluGlass and IQE collaborate

Nitride films for electronic devices to be co-developed on both silicon and IQE's cREO technology using BluGlass' low-temperature RPCVD

BluGlass Ltd of Silverwater, Australia — which was spun off from the III-nitride department of Macquarie University in 2005 to develop a low-temperature process using remote plasma chemical vapor deposition (RPCVD) to grow materials including gallium nitride (GaN) and indium gallium nitride (InGaN) on glass substrates — has entered into an exclusive 15-month collaboration agreement with epiwafer foundry and substrate maker IQE plc of Cardiff, Wales, UK.

IQE's products are used by major global chip companies to produce high-performance components enabling a wide range of applications including for the wireless industry (such as smartphone and wireless infrastructure, Wi-Fi, base-stations, GPS, and satellite communications) as well as for optical communications and optical storage.

The two firms will work together to develop specific enabling technology for nitride films deposited by RPCVD on both silicon wafers and on specially engineered substrates: cREO (rare earth oxide) on silicon.

"BluGlass' world-leading RPCVD technology is highly complementary to IQE's existing technology portfolio, and the collaboration is a key step in overcoming challenges inherent to epi-growth of cutting-edge materials," comments IQE Group's vice president Dr Rodney Pelzel.

"This arrangement comes on the heels of our announcement earlier this year of successful transfer of cREO epi capability [from Translucent Inc of Palo Alto, CA, USA] to IQE's North Carolina manufacturing site. This collaborative arrangement is a key step in furthering this technology," Pelzel adds.

"We are delighted to have formed a strategic partnership with IQE, one of the world's leading compound semiconductor foundries, supplying many of today's leading semiconductor manufacturers," says BluGlass' managing director Giles Bourne. "We have chosen to work with IQE, based on the enormous market potential and impact that the applications that we will be co-developing could have on the semiconductor industry in the future," he adds. "Their diverse product portfolio makes them a very compelling partner to be working with."

www.iqep.com
www.bluglass.com.au

EpiWorks breaks ground on production expansion

Capacity to quadruple over next three years

II-VI Inc's EpiWorks Division, which manufactures epitaxial wafers for optical components, wireless devices and high-speed communication applications, is breaking ground on a new production facility in Champaign, Illinois.

Due for completion by mid-2017, the expansion will enable a quadrupling of its capacity in Champaign over the next three years. In addition to substantial epiwafer production space, the new cleanroom will house a wafer characterization and test laboratory.

To operate the new facility, EpiWorks is recruiting experienced managers, engineers and technicians. The expansion supports the performance and volume requirements for several key components enabling multiple growing markets. These include indium phosphide (InP)- and gallium arsenide (GaAs)-based optoelectronic communication components for cloud computing and data-centers, vertical-cavity surface-emitting lasers (VCSELs) for 3D sensing and next-generation wide-bandgap devices for 5G wireless infrastructure.

"High-performance compound semiconductors are required to meet the performance needs of modern communication networks, sensors, smartphones, wireless communications networks, and datacenters. Our technology is being adopted in many applications, and we are ensuring that our capacity continues to meet customer demand now and in the future," says Giovanni Barbarossa, chief technology officer and president of the Laser Solutions Segment. "New capacity will support our RF and photonics businesses, and we will have more resources to research and develop new materials and products," he adds.

"Immediately after merging with II-VI in February, we ordered three new MOCVD production tools and filled our current cleanroom space," say EpiWorks' co-founders Quesnell Hartmann and David Ahmari. "These systems have already been installed, and we have now moved into the next phase of growth by expanding our cleanroom space, launching an aggressive hiring plan, and working to build the industry's most technologically advanced and efficient manufacturing line," they add.

"This company has a strong Illinois history, having been founded by University of Illinois alumni," says Illinois governor Bruce Rauner. "EpiWorks' success in Illinois is a testament to our state's research universities, the ingenuity of our workforce, and the innovative community in Champaign Urbana," he adds. "We hope to continue to be a partner with them to help grow their business within our borders and build upon this success."

www.epiworks.com

AXT's revenue grows 7% in third-quarter 2016, driven by stronger-than-expected demand for GaAs

InP inventory corrections in China suppress growth

For third-quarter 2016, AXT Inc of Fremont, CA, USA — which makes gallium arsenide (GaAs), indium phosphide (InP) and germanium (Ge) substrates and raw materials — has reported revenue of $21.9m (above the expected $20.5–21.5m). This is up 7% on $20.5m last quarter and up 19% on $18.4m a year ago, driven by stronger-than-expected demand for GaAs.

Of total revenue, 66% came from Asia Pacific, 23% from Europe, and 11% from North America. Only one customer generated over 10% of revenue, and the top five generated 38% (down from 42% last quarter), reflecting the ongoing diversification of both products and customers.

"The global build out of fiber-optical connections continue to be the leading driver of our InP sales," says CEO Morris Young. "Fiber-optic technology is helping to enable the fruition of applications such as cloud computing, the Internet-of-Things and video streaming. Worldwide fiber deployment has 100 million connections in 2015 and is expected to continue to grow for the long term." However, GPON and EPON markets in China are taking a pause to rebalance following two years of strong growth, notes Young. "This softness caused a modest decline in indium phosphide sales in Q3."

"Our raw material business remain under pricing pressure," says Young. Revenue from AXT's seven consolidated joint ventures was down $581,000. "But we are seeing price start to stabilize and in some cases improve," he notes. "Gallium price during the quarter seems to have stabilized and has ticked up a little bit, as has germanium pricing. This could lead to a more favorable pricing environment in quarters to come."

Gross margin has risen further, from 25.1% a year ago and 29.4% last quarter to 34.6% (the highest since Q1/2012), due to higher production volume, a favorable product mix (including InP substrate and other materials with high-end applications) and good progress in manufacturing efficiencies and yield improvements (especially in crystal growth).

Operating expenses have been cut further, from $5.3m a year ago and $5.1m last quarter to $4.9m. "Through the implementation of a number of programs, we are achieving improved deals for both ingots and wafer processing," says Young. "The benefit of these in-progress and other cost-reduction measures are becoming increasingly visible in our financial results."

Net income has recovered further, from breakeven a year ago and $1.2m ($0.03 per diluted share) last quarter to $2.2m ($0.07 per diluted share, above the expected $0.03-0.05 per diluted share).

Depreciation and amortization were steady at $1.2m. Capital expenditure (CapEx) was $0.5m (halved from $1m last quarter). After generating positive cash flow during Q3, cash, cash equivalents and investments rose by $2.4m from $45m to $47.3m.

For Q4/2016, revenue is expected to fall to $18.5–19.5m. InP revenue will rebound slightly, as increasing growth for fiber-to-the-home (FTTH) deployment and data-center connectivity will offset the continuing GPON- and EPON-related inventory adjustment in China. However, this will be outweighed by declines of $0.15m in germanium, $1m in GaAs (due mainly to temporary inventory adjustments by two major customers for semi-insulating GaAs following an unusually strong Q3, plus a slight $100,000–150,000 decline in semiconducting GaAs), and $1.5m in raw materials (following a strong Q3, which had included a sizable delivery to Japan of about 10 tons of gallium). Net income should be $0.02–0.04 per diluted share.

"In spite of these near-term factors that are expected in a down quarter in Q4, we do not see any fundamental changes in our key markets," notes chief financial officer Gary Fischer.

"Sales of semi-insulating GaAs has reached a relative stable level that provides a healthy base of profitable revenue," says Young. "Also, we are working with customers on certain investigations of new applications for the material that could provide future upside potential," he adds. "In the semiconducting GaAs market, we continue to participate selectively in high-end LED applications such as backlighting, signage and automotive," continues Young. "While the LED market remains highly competitive and fragmented, we are seeing relative stable demand that we expect to continue into 2017."

"Long term, we are closely watching the continued market development of VCSELs for 3D sensing applications, such as gaming, mobile phones, smart TVs, high-speed communications and high-power material processing. 3D sensing requires devices with relative high-precision functionality and consistent reliability," Young notes. This translates into the need for very low defect densities, i.e. very low etch-pit density (EPD). "Our VGF technology and proprietary processes allow us to offer industry-leading specifications that creates a significant competitive advantage for high-end VCSEL applications. This application could provide an attractive opportunity for our business if it is adopted into high-end smartphones, which could total 500–600 million units per year."

"We are focusing our resources on strategic product applications in InP, GaAs and Ge substrates that are showing promising market trends," Young says. "InP is a growth driver for our business in fiscal year 2017 and beyond, and we expect that GaAs will continue to provide a stable revenue base with upside potential from VCSELs and other investigational applications," adds Fischer.

www.axt.com

LayTec's 2000th tool delivered to Compound Semiconductor Centre

LayTec AG of Berlin, Germany says that it has delivered its 2000th in-situ metrology system since the firm's foundation in 1999. An EpiTT (with the figure 2000 in its serial number) has been shipped to Compound Semiconductor Centre (CSC) of Cardiff, Wales, UK — a joint venture formed in August 2015 between Cardiff-based epiwafer foundry and substrate maker IQE plc and Cardiff University.

CSC works on providing a complete capability value chain, from high-end R&D through product and process innovation to high value, large-scale manufacturing. "This EpiTT and other LayTec systems already installed in our labs provide unrivalled precision and sophisticated analysis algorithms, which is crucial for process optimization in semiconductor manufacturing environment," comments CSC director Dr Wyn Meredith.

"It is significant that our 2000th in-situ tool is delivered to a research institution with a strong connection to industry," says LayTec's founder & CEO Dr Thomas Zettler. "LayTec has always set a great value on cooperating with both industry and R&D," he adds. "We have equipped hundreds of customers worldwide with state-of-the-art metrology, mainly in the field of LED and laser production. In the last few years we also entered the PV, display and advanced silicon markets. Meanwhile, our product portfolio covers all areas of process monitoring: in-situ, in-line, lab-line and map-line metrology." Due to this market diversification, Zettler believes that LayTec can deliver the next thousand tools more quickly.

www.compoundsemiconductorcentre.com
www.laytec.de

IN BRIEF

LayTec adds staff to sales and customer support teams

LayTec is strengthening its team with the addition of Dennis Dachkovski as a sales manager, working closely with customers and distribution partners in Asia. Dachkovski has a scientific background as a graduate in physics as well as experience in process integration and thin-film characterization which he gained at Infineon Technologies.

Also, Benjamin Klessen has joined LayTec as a customer support engineer to provide service, training and installation of LayTec systems at customer sites worldwide. Klessen graduated in photonics (with a focus on optics and electronics) and has experience in the service and installation of optical inspection tools.

Veeco's MOCVD sales double as display backlighting demand stabilizes and LED industry recovers

Adjusted EBITDA turns positive; breakeven revenue lowered to $75m

For third-quarter 2016, epitaxial deposition and process equipment maker Veeco Instruments Inc of Plainview, NY, USA has reported revenue of $85.5m, down 39% on $140.7m a year ago but up 13% on $75.3m last quarter and slightly above the $70–85m guidance.

By region, the Americas comprised 22% of total revenue and Europe, Middle East & Africa (EMEA) 23%, while China fell from 44% last quarter to 25% as the rest of the world (including South-east Asia and Japan) rose to 30%, driven by strong sales of metal-organic chemical vapor deposition (MOCVD) systems.

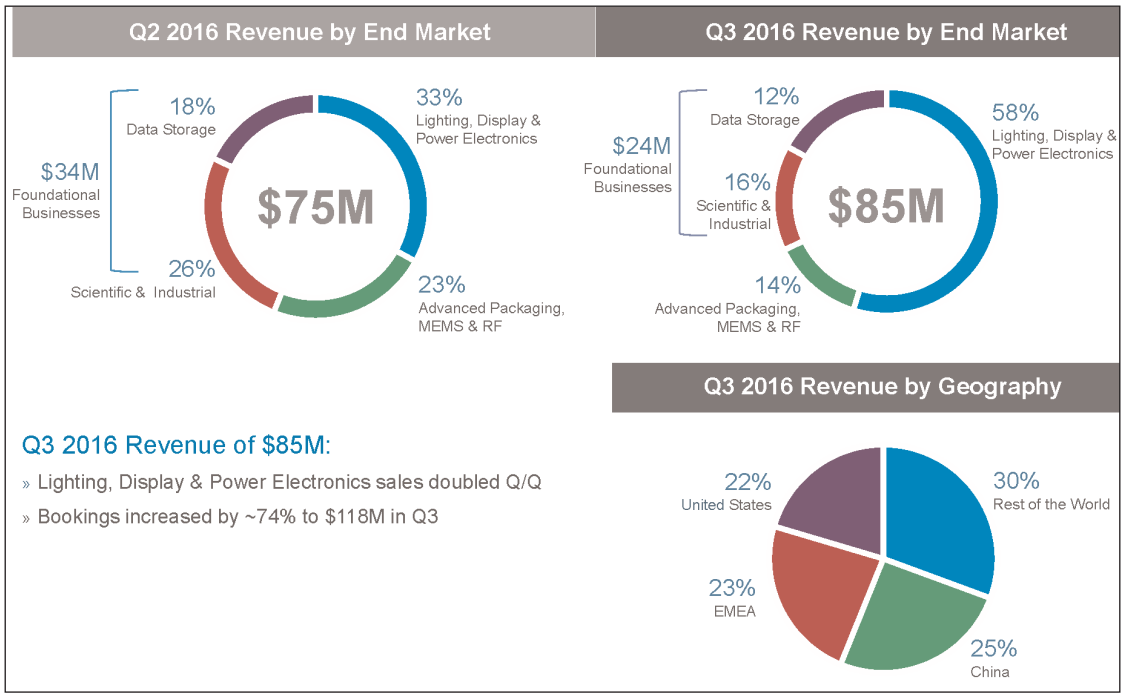
The Lighting, Display & Power Electronics segment — primarily MOCVD — has rebounded further, from 33% of total revenue last quarter to 58%, with revenue doubling quarter-on-quarter. "We are seeing a clear improvement in LED industry conditions and solid demand for our MOCVD products," says chairman & CEO John R. Peeler. "We continue to win LED lighting and display opportunities with our TurboDisc EPIK700 MOCVD system and expand our positions in [ROY] red, orange and yellow LEDs with our TurboDisc K475i As/P arsenic phosphide system," he adds. "We were able to support customers' accelerated shipment requests for a couple of MOCVD systems by effectively utilizing existing inventory," says chief financial officer Sam Maheshwari.

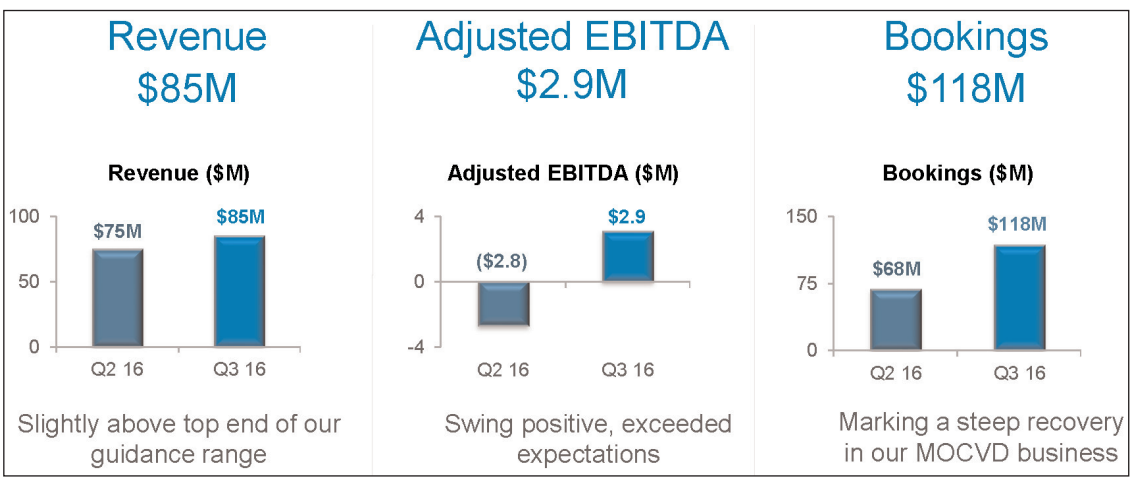
The Advanced Packaging, MEMS & RF segment comprised 14% of revenue, falling further from 23% last quarter. However, although sales in Advanced Packaging are down on last quarter, year-to-date sales already exceeded those of full-year 2015. "We have broadened our Precision Surface Processing [PSP] customer engagements in Advanced Packaging, and are now working with multiple OSATs [outsourced semiconductor assembly & test providers] and IDMs [integrated device manufacturers] to further penetrate this market," notes Maheshwari.

Veeco's Foundational Businesses fell from $34m (44% of revenue) last quarter to $24m (28% of revenue), with the Scientific & Industrial segment falling from 26% last quarter to 16% and the Data Storage segment falling from 18% to 12%.

On a non-GAAP basis (excluding charges of $57.8m, mostly an intangible non-cash ALD asset impairment of $56m plus restructuring charges of $1.8m requiring cash), gross margin was 40.3%, down on 42.4% last quarter but slightly above the midpoint of the 39–41% guidance range.

Operating expenses have been cut by $3.5m from last quarter's $38.1m to a lower-than-forecasted $34.6m. "We executed well against our cost-





reduction plans and accelerated OpEx savings by one quarter," notes Maheshwari.

Due to the higher sales volume and accelerated OpEx-related cost reductions, net loss was cut from $7.6m ($0.19 per diluted share) last quarter to $1.8m ($0.05 per diluted share, much better than the expected $0.26–0.10). Adjusted earnings before interest, taxes, depreciation and amortization (EBITDA) was $2.9m, an improvement from last quarter's loss of $2.8m and well above the guidance range of a loss of $6m to breakeven.

Veeco generated $7m in cash from operations, supported by an increase in customer deposits. Consistent with expectations for cash to stabilize in second-half 2016, cash and short-term investments rose by $6m to $337m.

Order bookings were $118m, up 73% on $68m last quarter. Growth was driven almost entirely by a sharp recovery in demand for Lighting, Display & Power Electronics business (MOCVD products). "Utilization rates have remained stable to slightly higher and we started to see customers making investments in MOCVD capacity," says Peeler. "We received multiple tool orders from both Epistar and HC SemiTek in support of their LED production plans," notes Maheshwari. "We successfully won new EPIK business by demonstrating the performance and cost of ownership advantages of EPIK versus a lower-cost competitor platform," he adds. "We secured follow-on orders for our recently launched K475i product, and we are seeing positive indications for additional MOCVD investment to occur in the near term." Quarter-end backlog rose by $32m to $177m.

For Q4/2016, Veeco expects revenue to rise to $85–100m. Gross margin is expected to fall slightly to 38–40%, including the impact of temporary inefficiencies due to duplicative labor and facility costs associated with manufacturing consolidation activities (moving manufacturing from three sites into the New Jersey facility; Veeco expects to begin seeing benefits from it by late Q1/2017, i.e. March). Operating expenses should remain relatively flat (savings from ALD cost reduction activities are expected to materialize from Q1/2017). The net result is expected to be between a loss of –$3m ($0.07 per share) and a profit of +$3m ($0.07 per share). Adjusted EBITDA is expected to be between breakeven and $6m.

"We remain focused on improving the company's through-cycle profitability," says Peeler. "We are executing against our cost-reduction initiatives [announced in early August], including our [more] recently announced plans to significantly reduce investments in atomic layer deposition (ALD) technology development," he adds. "We weighed the investments necessary to establish and grow a position in ALD with the potential and expected timing for returns and, although we continue to make progress in our development efforts for advanced semiconductor applications, the timing for potential revenue realization was delayed."

"In total, we now expect to lower the company's cost structure by $30m on an annualized basis [adding $10m cuts for ALD to the existing $20m from consolidation]. These actions are expected to lower our quarterly adjusted EBITDA breakeven level [from $75–80m] to approximately $75m in revenue, starting in the first quarter of 2017," Peeler concludes.

"Historically, Veeco's first quarter revenues have been seasonally lower than the fourth quarter [impacted by Chinese year, largely an MOCVD effect]," notes Maheshwari. "However, based on current visibility and outlook, first-quarter 2017 revenues are trending in the same range as Q4, largely on the back of the strength of the MOCVD industry," he adds. "The weaknesses and other seasonal declines from other businesses would be offset by the improved situation in MOCVD," continues Maheshwari. "We remain focused on achieving non-GAAP gross margin at or above 40%."

www.veeco.com

Almae orders Riber production MBE system to expand photonic component manufacturing capacity

Riber S.A. of Bezons, France, which manufactures molecular beam epitaxy (MBE) systems as well as evaporation sources and effusion cells, has received an order for a production system for delivery in 2017 to Almae Technologies, which was spun off in October 2015 from III-V Lab of Palaiseau, France (the joint laboratory between Nokia, Thales and France's Atomic Energy Agency CEA).

Almae is increasing its manufacturing capacity for advanced photonic components that are enabling the rapid increase of traffic in optical fiber networks for deploying fiber-to-the-home (FTTH), for consumer high-speed Internet access, and for 4G mobile networks.

"Almae has the ambition to become a world leader in advanced photonic solutions for the high-speed fiber optical networks which are at the heart of tomorrow's economy and society," says Almae's CEO Jean Louis Gentner. "Almae Technologies has developed an innovative process using gas-source MBE allowing our product performance to benefit from a differentiated competitive advantage and increasing our productivity in a very challenging market," he adds. "This acquisition is a very important step in the development of the industrial platform for our young company."

www.3-5lab.fr
www.riber.com

Aixtron returns to positive free cash flow in Q3, boosted by sales of AIX R6 system inventory

Full-year order intake guidance raised from €180–200m to €200–220m

For third-quarter 2016, deposition equipment maker Aixtron SE of Herzogenrath, near Aachen, Germany has reported revenue of €51.2m, down 6.2% on €54.6m a year ago but up 50% on €34.1m last quarter (due to a scheduled increase in systems supplied).

Equipment sales were hence €40.6m (79% of revenue), down just 1.7% on €41.3m a year ago and up 64% on €24.7m (just 73% of revenue) last quarter. Sales of spare parts & services were €10.6m (21% of revenue), down on €13.3m a year ago but up from €9.3m last quarter.

On a regional basis, 72% of revenue came from Asia (up from just 44% last quarter), just 7% from Europe (down from 33%), and 21% from the USA (down from 23%).

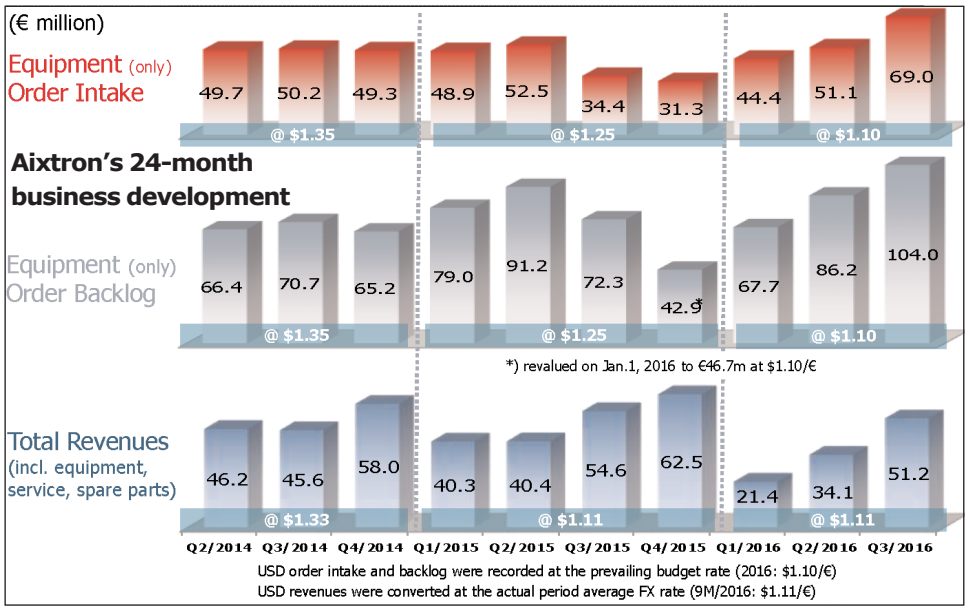
The majority of AIX R6 MOCVD system inventory (for GaN LEDs) — which amounted to €19.3m at the end of September — was sold in Q3 (and will be shipped in the coming months). Also, throughout Q3 there were strong shipments of Planetary reactor systems particularly for red, orange, yellow (ROY) LED optoelectronics and power electronics.

"We continue to be in a solid position in MOCVD outside GaN LEDs," notes president & CEO Martin Goetzeler. Also, Aixtron has completed one customer's qualification program for atomic layer deposition (ALD) tools for high-k oxide films; in Q3/2016 such silicon applications (including spares) were 25% of total revenue.

Gross margin has recovered further, from 20% last quarter to 33% (level with a year ago), due to a better product mix and higher sales volumes allowing for better utilization in production.

Operating expenses have risen from €18m last quarter to €20.4m, due mainly to currency impacts as well as increased R&D spending.

Earnings before interest, tax, depreciation and amortization (EBITDA) has improved from –€8.2m last quarter to –€0.4m (though still down on +€4.1m a year ago). The net result improved from –€11.1m (–€0.09 per diluted share) last quarter to –€3.8m (–€0.04 per diluted share).



Capital expenditure (CapEx) has rebounded from a low of €0.8m last quarter to €1.3m. Compared with –€20.7m last quarter (adjusted for acquisition effects), the positive free cash flow of €3m was due mainly to reduced operating losses and higher advance payments from customers (which rose from €24m at the end of 2015 to €41.3m at the end of this September, reflecting higher order backlog).

Cash & cash equivalents (including cash deposits with a maturity of more than 90 days) were €163.5m at the end of September, down from €209.4m at the end of 2015, due mainly to a negative net result of –€30.4m for the first nine months of 2016, payment of the second instalment of the agreed return of advance payments to China's largest LED maker San'an Optoelectronics Co Ltd, and an agreed milestone payment made in Q1/2016 for the purchase in April 2015 of PlasmaSi Inc of Fremont, CA, USA, which provides low-temperature silicon nitride plasma-enhanced chemical vapor deposition (PECVD) systems for the encapsulation of organic thin-films. However, cash and cash equivalents were up slightly from €161.3m at the end of June, due to Q3's lower operating losses and the higher advance payments received from customers. Aixtron has no financial debt.

The majority of AIX R6 MOCVD system inventory (for GaN LEDs) was sold in Q3

Increased demand for production systems for LED, telecom and opto-electronics applications (including low-margin sales of the AIX R6 inventory), as well as for the silicon industry, has driven growth in not only revenue but also orders. Total order intake in Q3/2016 was €69m, up 35% on €51.1m last quarter and doubling from €34.4m a year ago. Equipment order backlog has risen further, up by 21% from €86.2m last quarter to €104m. Total order intake as well as the respective equipment order backlog support management's expectation of revenue growth in Q4/2016.

"Despite a comparatively weak development in revenues in the first nine months of 2016, we have

CFIUS advises US President to prohibit Grand Chip's takeover of Aixtron

Grand Chip and Aixtron refuse request to abandon takeover, but aim to resolve US national security concerns

Aixtron says that the investigation period for the Committee on Foreign Investment in the United States (CFIUS) to review the tender offer by Grand Chip Investment GmbH (GCI) from a US national security perspective lapsed on 18 November.

CFIUS did not issue a close-out letter, but informed GCI and Aixtron that there are unresolved US national security concerns regarding the proposed transaction. It plans to recommend to the US President that the transaction be prohibited, based on its conclusion that there would be no reasonable way to mitigate the US national security risks perceived by CFIUS on the basis of the mitigation proposals submitted by the parties to date. As a consequence, CFIUS has recommended that the parties request withdrawal of their notice and abandon the entire transaction.

Both GCI and Aixtron have decided not to follow such recommendation, as a result of which the matter has been referred to the US President for decision in line with CFIUS statutes, under which the President must render his decision to block or allow the proposed transaction within 15 calendar days.

GCI and Aixtron say that they plan to continue to engage in further discussions to explore means of mitigation that may be amenable to CFIUS or the US President to resolve outstanding US national security concerns or to take alternative measures that could allow the parties to proceed with the transaction. GCI and Aixtron note that there are no assurances that CFIUS or the US President will entertain further dialogue with the parties or that they will be able to identify and agree to any mitigation or to take alternative measures that will allow the parties to proceed with the transaction.

www.aixtron.com

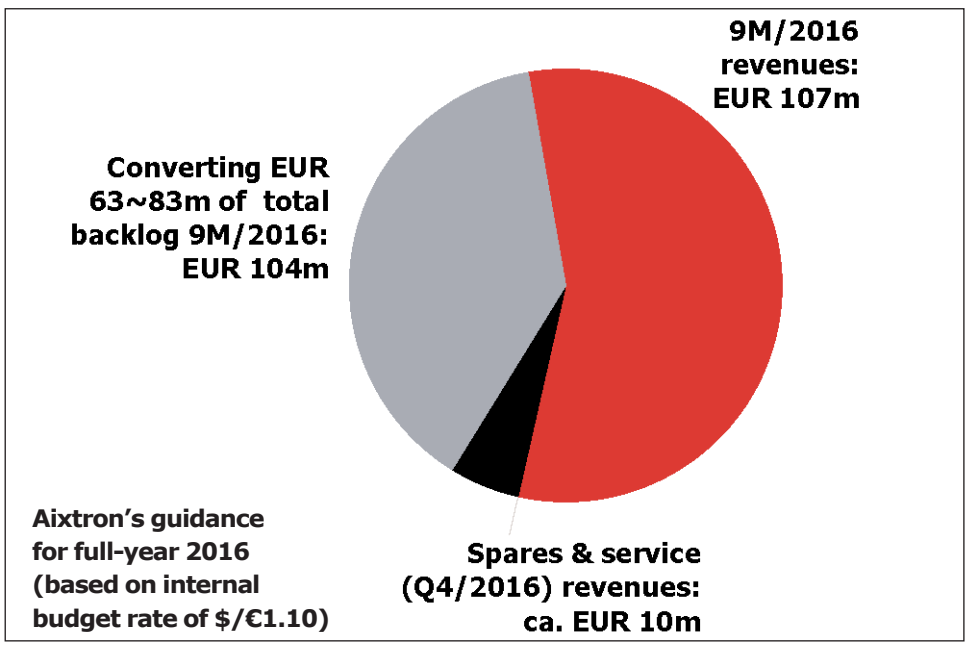
reiterated our 2016 full-year revenue guidance given in February, with slight adjustments for order intake and revenue," says Goetzeler. "This is due to solid order situation within recent months," he adds.

Based on €106.6m revenue accrued in the first nine months of 2016, plus expected spares & service revenue of about €10m in Q4/2016 and assuming that €63–83m of the €104m equipment order backlog will be converted into revenue in Q4/2016 (based on an internal budget rate of $/€1.10), for full-year 2016 Aixtron has narrowed its previous revenue guidance from €170–200m to €180–200m (compared with €197.8m in 2015). Order intake guidance for full-year 2016 has been raised from €180–200m to €200-220m (up from €167.1m in 2015), due mainly to the sale of AIX R6 equipment with surplus-level margins.

Depending on the successful completion of qualification processes, market entry efforts, as well as the achievement of revenue at the high end of the guidance range, management also expects another improvement in results for full-year 2016. Before transaction-related impacts, the firm's EBITDA, EBIT, net result and free cash flow should improve slightly from 2015 but remain negative, as expected revenue volumes continue to be too low to fully finance all of the products in the development pipeline.

Aixtron's management notes that, due to uncertainties in terms of investment requirements for certain product groups, potential restructuring costs or consequences from transactions (e.g. the takeover of Aixtron by China's Fujian Grand Chip Investment, for which the clearance certificate issued on 8 September by the German Federal Ministry of Economics and Energy was subsequently withdrawn in October), it is reviewing its 2017 EBITDA development.

www.aixtron.com



SPTS wins two Best Factory Awards and two Insider Made in Wales Awards

SPTS Technologies Ltd of Newport, Wales, UK (an Orbotech company that manufactures etch, PVD and CVD wafer processing solutions for the MEMS, advanced packaging, LED, high-speed RF on GaAs, and power management device markets) has recently won four business awards.

At this year's Best Factory Awards organized by Cranfield School of Management, SPTS was presented with the Innovation Award and the Export Award. Having met the qualification criteria set by the judging panel as well as a comprehensive factory audit, the Innovation Award recognizes SPTS for its level of innovation throughout the company. The Export Award notes the firm's proportion of export sales of 95%. The judges noted the multi-dimensional aspects of innovation at SPTS, which enables the firm to remain at the forefront of technical advances in semiconductor process technologies and to bring industry-leading products to its global markets. The judges also pointed to SPTS' lean manufacturing processes and commitment to continuous improvement which provides improved operational efficiencies and annual cost savings to the business.

Also, at the ceremony for the Insider 2016 Made in Wales Awards at Cardiff City Hall (which celebrate the best in manufacturing, design and product development from across Wales), SPTS received the Apprenticeship Scheme of the Year Award and was crowned the Large Manufacturer of the Year. The Made in Wales Awards also recognized SPTS Technologies' export sales by short listing it in the Exporter of the Year Award category.

The Export Award notes the firm's proportion of export sales of 95%

"It's the commitment to continuous improvement across the entire organization that has allowed us to grow our business, both operationally and profitably, year on year," says Kevin Crofton, president of SPTS and corporate VP at Orbotech. "The Best Factory Awards judging process was on par with some of our most demanding customer audits, and we are extremely proud to be recognized for manufacturing excellence by the team of assessors from Cranfield School of Management, the IEE and other independent institutions," he adds.

The Insider Made in Wales Apprenticeship Scheme of the Year Award "recognizes our commitment to identifying and attracting young people to our industry and company," Crofton continues. "Our apprenticeship program is one element of many programs that helps SPTS ensure our future with a skilled talent pool."

www.spts.com

Oxford Instruments' 2016 technical workshops return to IISc Bangalore

UK-based Oxford Instruments has held its 2016 technical workshops in India (22–23 November). Now in their fifth year (following previous workshops in Bangalore, Mumbai, Chennai, Kolkata and Mohali), this year's event 'Bringing the Nanoworld Together 2016' returned to the Indian Institute of Science (IISc) Bangalore, the location of the first workshop.

Showcasing nanotechnology tools and their use in multiple applications, the two-day seminar comprised over 24 talks from Indian and international speakers, as well as Oxford Instruments scientists. There were also technical poster sessions, providing participants with the chance to discuss research in detail, as well as networking opportunities.

The event was organized in two parallel sessions:

- Sessions on Nanoscale Plasma Processing cover multiple areas including the latest advances in etch and deposition technologies, graphene and 2D materials and their applications, ion beam technologies, and emerging applications including atomic-scale processing, quantum and BioMEMS.
- Sessions on NanoScience Cryofree research tools comprise an introduction to nanotechnology, innovations in ultra-low-temperature research, sensing individual photons with atomic membranes, the latest developments in cryogen-free high-magnetic-field and low-temperature sample environments for neutron scattering, the application relevance of key Cryofree tool innovations, and more.

The two-day seminar comprised over 24 talks

"We intend these educational seminars to improve participants' knowledge, and to keep them abreast of the latest technological advances in these research areas," says Frazer Anderson, strategic marketing & development director for Oxford Instruments Plasma Technology (OIPT). "The workshops provide ample opportunities for networking, debate and discussion around the rapidly evolving nanotechnology world."

www.oxford-instruments.com/btnt

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CORIAL introduces atomic-scale etching capability

Plasma etch and deposition equipment maker CORIAL S.A.S. of Bernin, France has announced atomic layer etching (ALE) capability on its ICP-RIE systems intended for advanced IC development.

"CORIAL has demonstrated atomic-scale precision etching of silicon with a rate of 1.675nm/min," says R&D manager Dr Andrei Uvarov. "It was enabled by COSMA Pulse, our unique software capable to control and pulse any process parameter (such as gas flow rate, RF and ICP power, working pressure, etc), with a minimum pulsation period of 50ms. COSMA Pulse can be easily installed on Corial 210IL 200mm etch systems allowing for ALE capability on our conventional ICP-RIE tools".

Conventional continuous etch processes no longer have the level of control that is needed when CDs approach the single-digit nm scale. To continue technology scaling in logic circuits and memory devices, atomic-level precision manufacturing is now required by chip makers and academics to provide control of surface structure at nanometer scale, ultra-high etch selectivity and low damage. In the past few years, ALE has emerged as a promising technology to address these manufacturing challenges.

"Corial 210IL etch system equipped with COSMA Pulse provides a level of precision required to pattern structures at the atomic scale," says Uvarov. "We expect fast adoption of COSMA Pulse by academics for research aiming at advanced devices manufacturing as CORIAL is the first company to offer larger functionalities — from continuous to pulsed processing — in one tool, and for a reasonable budget".

Key features for silicon atomic-scale etching are:

- reduced byproduct deposition on reactor walls to allow faster switching of process conditions;
- advanced tuning of RF pulsation to control ion energy;
- independent and fast pulsing of chlorine and argon flows during adsorption and desorption steps; and
- real-time process adjustment.

www.corial.net

BluGlass receives foundry order from new UK customer

BluGlass Ltd of Silverwater, Australia — which was spun off from the III-nitride department of Macquarie University in 2005 to develop a low-temperature process using remote plasma chemical vapor deposition (RPCVD) to grow materials including gallium nitride (GaN) and indium gallium nitride (InGaN) on glass substrates — has received what it describes as a significant order commitment from a new customer for about $600,000 of specialist epitaxy foundry development, to be delivered over the next 12 months.

The UK-based customer is developing gallium nitride (GaN) technology targeting LED and other applications. BluGlass recently fulfilled a small order for this customer, and has now secured this $600,000 order, which will be developing an innovative new project, says the firm.

"This single order from a new customer is the largest foundry order that the company has received to date," says BluGlass' managing director Giles Bourne. "The BluGlass foundry business continues to attract select customers and we are excited to be working with the innovators that will be leading the nitrides industry into the future," he adds.

www.bluglass.com.au

BluGlass institutional placement & shareholder share purchase plan

BluGlass has received commitments from both existing investors and new institutional investors for a placement of new fully paid ordinary shares to raise AUS$5m.

BluGlass is issuing 15.625 million shares at AUS$0.32 per share after the placement is settled. The issue price of AUS$0.32 per share represents a discount of 18.36% to the 5 day VWAP (volume weighted average price) share price to 27 October of AUS$0.392 per share.

Shareholders on BluGlass' register on 27 October with registered addresses in Australia and New Zealand will also be given the opportunity to apply for up to AUS$15,000 worth of shares (subject to any scale-back determined by BluGlass' directors) at AUS$0.32 per share (the same price as under the placement) without incurring brokerage or transaction costs, via a shareholder share purchase plan (SPP). BluGlass aims to raise AUS$2m under the SPP.

The purpose of the placement and SPP is to provide funds for;

- continuation of existing industry collaboration and evaluation agreements with Lumileds, HC SemiTek, and Veeco;
- capital expenditure for new equipment and resources to accelerate work with the existing industry partners as well as enabling the RPCVD technology to be applied to other applications;
- identification and engagement with potential future collaboration partners; and
- general working capital purposes.

Further details in relation to the proposed SPP are provided in the SPP Offer Booklet and Application Form sent to eligible shareholders.

Evatec establishes South East Asia operation

Evatec Ltd of Trübbach, Switzerland, which makes thin-film deposition and etch processing equipment for semiconductor, MEMS, optical and optoelectronic applications, says that, to support the expected strong business growth in South East Asia and provide better direct support to customers in this region, it has established a 'South East Asia hub' with offices in both Singapore and Malaysia.

The SEA region (including Singapore, Malaysia, Philippines, Thailand, Indonesia, and Vietnam) has a population of about 620 million people with a gross domestic product (GDP) of $2.65 trillion expected in 2016. Regional growth is projected to average 5.2% over 2016–2020, led by growth in Philippines and Vietnam, according to the OECD Economic Outlook 2016. The region's economy depends heavily on agriculture but manufacturing and services are becoming more important, notably manufacturing of textiles, electronic high-tech goods such as microprocessors and heavy industrial products such as automobiles.

Evatec's SEA activities will be led by Kevin Chen. Born in Taiwan, Chen joined Evatec in August as managing director of Evatec South East Asia. He has more than 15 years experience holding senior management positions in the capital equipment & materials industry for semiconductors, LED and solar manufacturing, with a proven sales track record in growing business and managing multi-cultural global organizations. He leads the team in the sales & marketing, field and application engineering, and back-office support functions.

"I am glad to have chance to build up the Evatec SEA team and work together with lots of local talents," says Chen. "Most of them have more than 20 years' experiences in high-tech or the semiconductor industry," he adds. "With the strong commitment from the Evatec SEA team and support from the team in Switzerland, we feel confident that we will grow our business here as expected".

www.evatecnet.com

Cambridge Nanotherm expands manufacturing capability for high-power LED designs

Cambridge Nanotherm Ltd of Haverhill, Suffolk, UK, producer of nanoceramic thermal management technology, says that it has built significant additional capability and capacity into its metal core printed-circuit board (MCPCB) manufacturing base to meet rising demand for its thermal management solutions. The firm has established partnerships with a wide network of PCB and thin-film manufacturers to offer a broad range of options in terms of circuitization, quality, volume and standards.

Cambridge Nanotherm's manufacturing capabilities span fast-turn-around prototyping, high-definition thin-film circuitization, speciality manufacturing, and high-volume mass production. Key industry and regulatory standards such as automotive standard ISO/TS 16949:2009 as well as industry-specific SGS standards can be applied.

The firm says that, from LED chip packaging to high-brightness modules, thermal management is becoming a limiting factor as customers demand ever brighter LED devices in ever smaller footprints. To meet these requirements, LED makers are being pushed into using more thermally effective substrates to ensure that LEDs stay cool enough to meet their advertised lifespan. Historically, that meant switching from cost-effective MCPCBs to expensive and difficult-to-work-with ceramics such as alumina and aluminium nitride. Cambridge Nanotherm offers an alternative.

For high-power LED applications, Nanotherm LC and Nanotherm DM technologies are enabling a new generation of products that rely on effective thermal management to operate successfully, says the firm. Its proprietary LC and DM technologies are available exclusively via this manufacturing process.

"Cambridge Nanotherm's MCPCBs offer designers a distinct thermal advantage," claims chief operating officer Andy Matthews. "Demand for our solutions has therefore been strong, and we're currently engaged with most of the top-ten LED manufacturers. As a result we've expanded our manufacturing routes to cater to a much broader variety of requirements," he adds. "We're working with some of the best PCB and thin-film circuitization companies so we can offer an exceptional range of options... We will continue to develop our manufacturing capabilities."

Nanotherm's patented ECO process involves converting the surface of the aluminium core of the MCPCB, which acts as a heat spreader, into an electrically insulating but thermally conductive Nanoceramic that offers outstanding thermal performance. Depending on the circuitization route that is chosen, composite thermal performance of the resulting MCPBC ranges from 115W/mK to 152W/mK.

Standard LC products are covered by UL recognition, speeding time to market for luminaires and modules. Nanotherm manages the entire process, from thermal design guidance and material choice to delivering the finished circuits, simplifying the manufacturing route for customers.

www.camnano.com

Rubicon's revenue doubles after patterned wafer customer draws down consignment inventory

Malaysia wafer plant and Batavia, IL crystal growth plant to be sold

For third-quarter 2016, Rubicon Technology Inc of Bensenville, IL, USA (which makes monocrystalline sapphire substrates and products for the LED, semiconductor and optical industries) has reported revenue of $7.1m, more than doubling from $3.5m last quarter and up 34% on $5.3m a year ago.

Revenue for wafer sales rebounded to $5.5m, tripling from $1.8m last quarter (and $2.1m a year ago). This was due mainly to increased orders from a key patterned wafer customer, which drew down all wafers in consignment inventory. Revenue from patterned sapphire substrates (PSS) was hence $4.5m, more than tripling from $1.35m both last quarter and a year ago. Polished wafer revenue was $0.99m, doubling from $0.49m last quarter and up 30% on $0.76m a year ago.

Revenue from sapphire core sales fell back from $0.69m last quarter to $0.42m (down from $1.82m a year ago), almost entirely from 4" cores. Revenue from 2" cores was just $3000, compared with $0.55m a year ago. Like last quarter, there was again no revenue 6" cores, compared with $40,000 a year ago.

R&D revenue fell again, from $0.27m a year ago and $0.11m last quarter to $0.08m.

Optical revenue rebounded slightly from $0.9m last quarter to $1.1m (roughly level on a year ago).

Results were impacted by the decision on 12 September for the firm's plant in Penang, Malaysia to cease PSS production in September, followed (after a transition period for the firm's key customer) by polished wafers at the end of November, and to shutter the facility by end-2016. Patterning equipment has been sold and buyers are sought for the real estate and remaining equipment. The plant was designed and equipped to produce primarily polished and patterned sapphire substrates for the LED market, and the decision to exit the LED market for the foreseeable future was made to focus on the optical and industrial sapphire market for the foreseeable future.

Rubicon hence has excess crystal growth capacity in the USA. So, it is consolidating operations into its leased space in Bensenville and Franklin Park, IL, involving vacating (by end-December) its largest plant in Batavia, IL (which it owns and may sell). Batavia is a special-purpose facility with enhancements to power and water cooling systems required for crystal growth production. "Our initial focus would be to seek a buyer that is interested in both the building and infrastructure," says Rubicon. It also seeks buyers for some of its crystal growth furnaces.

"We had been trying to stay in the LED substrate market by limiting our product offering to 6" wafers and working hard to reduce cost to make that product profitable," says the firm. "While we made significant progress on that front, the continual decline of prices has made the prospects of becoming profitable in the LED substrate market unlikely for the foreseeable future," it adds.

"There remains good margin opportunity in the optical and industrial segments," says CEO Bill Weissman. "The actions we are taking will improve our operating results, strengthen our cash position and allow us to grow in strategic markets that are better aligned with our strengths while offering stronger margin potential," he believes.

One-time charges in the quarter (related to exiting the LED market) included a $10.2m asset impairment for writing the Malaysia assets down to liquidation value, a write-down of $4m in excess raw material inventory, and $900,000 in accrued severance. The firm also recorded a write-down of $2.3m of excess 2" core inventory (which is sold primarily into the mobile device market) and severance of $180,000 for US staff reductions.

Although better than $48.2m ($1.84 per share) a year ago, net loss per share worsened again from $8.2m ($0.31 per share) last quarter to $24.8m ($0.94 per share). However, net cash used in operating activities has been cut, from $6.6m last quarter to just $0.5m. During the quarter, cash and short-term investments fell further, from $18m last quarter to $16.6m.

Once the Malaysia facility ceases production activities, wafer revenue will fall significantly, beginning in Q4/2016, notes Rubicon. Optical revenue over the past three years has been $4.5–7.1m annually.

Rubicon expects a "meaningful" improvement in cash flow once the changes are fully implemented. Crystal growth will be very limited in the near-term as Rubicon plans to use its existing crystal inventory to support optical orders. It also aims to outsource certain finishing steps to third parties in order to reduce staffing, equipment and footprint. Under this new operating model, staffing will fall to about 40 entering 2017, limiting fixed costs while retaining the knowledge base built up over the past 15 years.

"The optical and industrial sapphire markets are growing with new applications for sapphire emerging and, given our capabilities, we believe we are well positioned," says Weissman. "In the near term, our scaled-down operations and use of crystal inventory should allow us to significantly improve cash flow." The sale of assets should generate cash to provide more strategic opportunities to build stockholder value in, perhaps even outside of, the sapphire market, the firm believes. "We will continue to closely monitor the development of the optical and industrial sapphire markets and our new technologies, as well as the broader sapphire market," Weissman concludes.

www.rubicon-es2.com

Disco launches fully automatic polisher for CMP of difficult-to-process materials including sapphire

At SEMICON Japan 2016 at Tokyo Big Sight (14-16 December), Tokyo-based semiconductor manufacturing equipment maker Disco Corp is exhibiting the new DFP8141, a fully automatic single-spindle polisher that supports chemical mechanical polishing (CMP) of difficult-to-process materials including sapphire, silicon carbide (SiC), lithium tantalate ($LiTaO_3$), and lithium niobate ($LiNbO_3$).

Disco says the high-brightness LED market requires a polishing process for device performance improvement after backside grinding of the sapphire substrate on which the device has been formed. Due to the increased focus on energy saving, there has been increasing need to polish SiC for power devices (for which demand is growing) and lithium tantalate (LT) for surface acoustic wave (SAW) filters, as well as lithium niobate (LN). In response, Disco has developed the DFP8141, which offers processing solutions that were not available in the firm's product line-up until now.

Disco's new DFP8141 fully automatic polisher system.

The fully automatic specification allows the DFP8141 to complete CMP processing cassette-to-cassette. The systems also comes equipped with a cleaning station and performs wafer cleaning and drying after processing automatically.

The DFP814's design also allows for various specifications, including semi-automatic (with no transfer section) and in-line (for seamless processing with the DFG8830 grinder for difficult-to-process materials). In addition, the transfer system accepts three types of workpiece configurations: single wafer transfer, substrate transfer, and frame transfer. With a single spindle with two chuck tables (single-wafer processing), the DFP814 supports wafer diameters up to 8-inches.

Sales of the DFP8141 will begin in first-half 2017.

www.disco.co.jp

Monocrystal ships 5 millionth 4"-equivalent wafer

Monocrystal Inc of Stavropol, Russia (which makes large-diameter sapphire substrates and cores for LEDs, optical products and RFIC use) has shipped its 5 millionth 4-inch equivalent (FIE) sapphire wafer.

Large-diameter wafers have recently become a mainstream product, driven by LED makers benefitting from a 30% increase in metal-organic chemical vapor phase deposition (MOCVD) reactor throughput and higher binning yields. At the same time, says the firm, sapphire wafer shape and cleanness are crucial in achieving high epitaxial yields and getting the benefits of using large diameters.

Monocrystal's large-diameter substrates are used for high-brightness gallium nitride (GaN) LEDs. As well as having a crystal structure that benefits from low-stress ultra-large crystals, Monocrystal says that low thermal bow during the epitaxial process provides tight wavelength uniformity, leading to yields increasing by 2–3%, it is reckoned. Low internal stress results in zero breakage rates during nitride growth, improving equipment uptime, the firm adds. An ultra-clean wafer surface eliminates the need for a pre-cleaning step, saving $1 per wafer, it is claimed. Also, a low etch-pit density contributes to longer LED lifetime.

"Our landmark of 5 million FIE is the best testimonial that our large-diameter wafers help our customers reduce costs and strengthen their competiveness in the highly competitive LED market," says CEO Oleg Kachalov.

www.monocrystal.com

Kanematsu to distribute for SUSS MicroTec in Japan

SUSS MicroTec AG of Garching, Germany, which makes photomask aligners, laser processing systems and wafer bonders, has announced a strategic reseller partnership for Kanematsu PWS Ltd of Yokohama, Japan (a subsidiary of Tokyo-based Kanematsu Corp) to become the exclusive distributor of the entire SUSS product portfolio in Japan.

Effective 1 January, Kanematsu PWS Ltd will be responsible for all SUSS MicroTec related sales and service activities, supported by the SUSS Japan Business Development & Technical Sales Support team on site. The new partnership is aimed at enabling SUSS MicroTec to further expand its activities in Japan.

www.pwsj.co.jp/eng

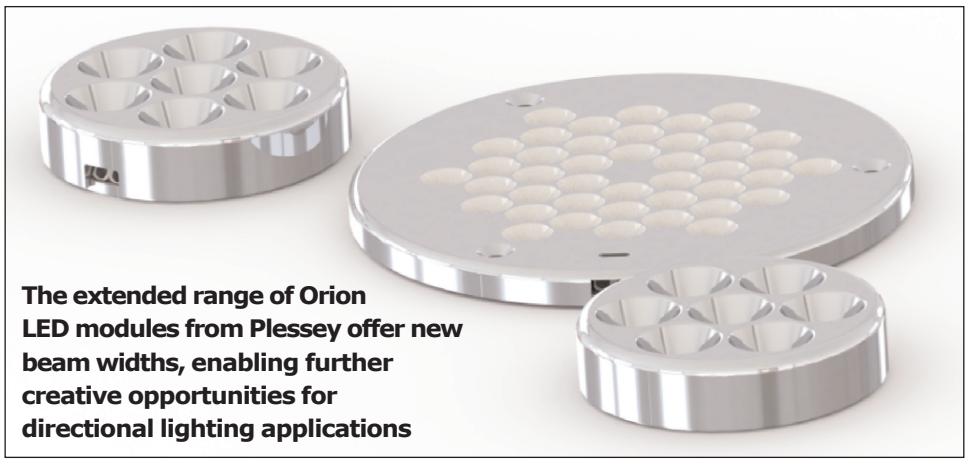
www.suss.com

Plessey extends beam-forming Orion LED module family with new beam widths

UK-based lighting and sensing product and component maker Plessey has extended its range of ultra-slim Orion LED modules based on its Stellar beam forming technology, with new beam angles opening the technology to a wider range of applications in industrial and architectural lighting design. Plessey showcased the new modules at LuxLive event in London, UK (23–24 November).

The Orion LED beam-forming modules deliver a compact 3000lm beam from a module that can be as little as 5.6mm thick (less than one-tenth the thickness of standard alternatives). The recently launched PLWS3000 25° FWHM (full width half maximum) beam-angle module has now been joined by modules with 15° and 50° beam angles. All modules in the family share a common 82mm diameter, allowing lighting designers to simply substitute modules to create a family of compact luminaires suitable for a wide range of lighting applications.

At the same time, Plessey has unveiled plans to launch Orion-Mini, a new 45mm-diameter version offering a 10° sub-1000lm beam in Spring 2017. The Orion-Mini will share the slim profile of the full-size module, but will be offered in a format suitable for design into small-form-factor downlights, spot-lights and architectural lights as a replacement for GU10, MR16 and similar lights.



The extended range of Orion LED modules from Plessey offer new beam widths, enabling further creative opportunities for directional lighting applications

With its slim line form, range of colour temperatures and improved thermal characteristics, Orion modules are designed to be used in a variety of directional lighting applications such as retail, track and architectural. Integrating the latest LED technology in conjunction with its Stellar beam-forming technology to provide an efficient, slim-line module provides a new design freedom not accessible with alternative chip-on-board (COB)-style modules, it is claimed. The thermal characteristics allow the heat-sink, and hence the overall luminaire, to be reduced in size.

"Plessey now offers Orion modules in a range of formats offering designers greater freedom," says Paul Drosihn, head of Modular Products. "Orion modules are revolutionizing the lighting market, giving scope for a radical rethinking of the way in which lighting from industrial high-bay to architectural luminaires is designed," he claims. "The Orion family with Stellar beam-forming technology provides an innovative approach to directional lighting applications, opening new opportunities for creativity in industrial and architectural design."

The Orion family is offered in three colour temperatures: warm white, neutral white and cool white. The modules have a luminous efficiency of more than 100 lm/W, feature improved light uniformity and thermal performance.

http://luxlive.co.uk
www.plesseysemiconductors.com/led-plessey-semiconductors.php

Plessey exhibits standard LED lighting module based on Stellar beam-forming technology

At the electronica 2016 trade fair in Munich, Germany (8–11 November), UK-based lighting and sensing product and component maker Plessey exhibited the first standard LED lighting module based on its Stellar beam-forming technology.

The Orion PLWS3000 series module delivers over 3000 lumens from a unit just 5.6mm thick and 82mm in diameter.

"The Orion module based on Stellar beam-forming technology represents the next phase in LED lighting with low cost, high efficiency and greater control of light," says Paul Drosihn, Plessey's head of Modular Products. "The greatly reduced form factor eliminates design constraints, providing lighting designers with a new level of design freedom."

The Orion module uses Plessey's Stellar beam-forming technology to provide a slim-line module that can be used in a variety of directional lighting applications. It is available in three colour temperatures: warm white, neutral white and cool white, with a luminous efficiency of more than 100lm/W. Key features include improved light uniformity and thermal performance.

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DISCOVER PROGRESS

Trace amounts of transition-metal impurities in GaN kill LED efficiency

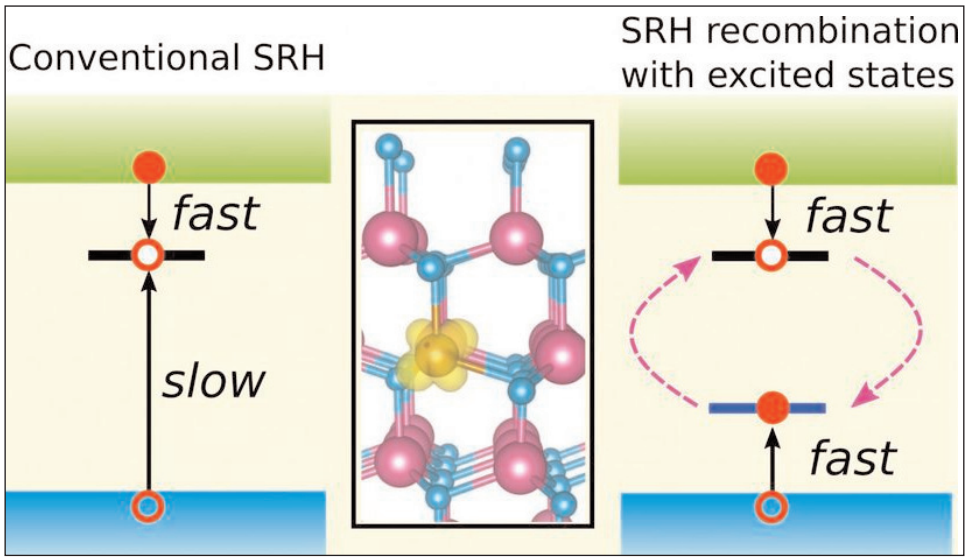
UCSB-led team finds that iron act as Shockley–Read–Hall non-radiative recombination centers in nitrides

Using first-principles calculations, University of California, Santa Barbara (UCSB) has demonstrated the mechanism by which transition-metal impurities — iron in particular — can act as non-radiative recombination centers in nitride semiconductors (Wickramaratne et al, 'Iron as a source of efficient Shockley–Read–Hall recombination in GaN', Appl. Phys. Lett. 109, 162107 (2016)). The work, which was funded by the US Department of Energy (DOE) Office of Science and by Marie Sklodowska-Curie Action of the European Union (EU), highlights that such impurities can have a detrimental impact on the efficiency of LEDs based on gallium nitride (GaN) or indium gallium nitride (InGaN).

For LEDs, high-purity material is essential to lighting technology, such as residential and commercial solid-state lighting, adaptive lighting for automobiles, and displays for mobile devices. Imperfections at the atomic scale can limit the performance of LEDs through Shockley–Read–Hall recombination. An LED's operation relies on the radiative recombination of electrons and holes, resulting in the emission of photons. Defects or impurities can act as a source of non-radiative recombination and prevent the emission of light, lowering LED efficiency.

UCSB, in collaboration with Rutgers University, the University of Vienna, the KTH Royal Institute of Technology in Sweden and the Center for Physical Sciences and Technology in Lithuania, has identified that iron, even at concentrations less than parts-per-million, can be highly detrimental.

Transition-metal impurities such as iron have long been known to act as 'killer centers', severely impacting devices based on traditional semiconductors such as silicon and gallium arsenide (GaAs). It is therefore surprising that little attention has been devoted to understanding the role of transition metals in recombination dynamics in GaN.



Shockley–Read–Hall recombination due to iron in GaN. Iron is a deep acceptor with a defect level (black line) close to the GaN conduction band (green). The charge density corresponding to this localized level is shown in the middle of the figure. Conventional SRH recombination (left) proceeds via electron capture from the conduction band into the defect level, but the overall rate would be limited by slow hole capture since the defect level is far from the valence band (blue). The presence of excited states enhances the hole capture rate (right) such that the overall SRH recombination process becomes very efficient.

"A naïve application of Shockley–Read–Hall theory, based on an inspection of defect levels within the bandgap, would lead one to conclude that iron in GaN would be harmless," says lead author Dr Darshana Wickramaratne. "However, our work shows that excited states of the impurity play a key role in turning it into a killer center."

The UCSB researchers identified a recombination pathway by which iron can lead to severe efficiency loss. Sophisticated first-principles calculations were essential to identify and understand the role of the excited states in the recombination process.

"Taking these excited states into account completely changes the picture," emphasizes team member Dr Audrius Alkauskas. "We strongly suspect that such excited states play a key role in other recombination phenomena, opening up new avenues for research."

The results highlight that strict control over growth and processing is needed to prevent the unintentional introduction of transition-metal impurities. Sources of iron contamination include the stainless-steel reactors used in some growth techniques for nitride semiconductors.

"Increasing the efficiency of light emission is a key goal for the solid-state lighting industry," says UCSB Materials professor Chris Van de Walle, who led the research team. "Our work focuses attention on the detrimental impact of transition metals and the importance of suppressing their incorporation."

http://scitation.aip.org/content/aip/journal/apl/109/16/10.1063/1.4964831
www.mrl.ucsb.edu/~vandewalle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www.chemistry.umicore.com

Nichia granted preliminary injunctions in Germany against Everlight white LED products

On 10 October and 28 October, Japan-based LED maker Nichia Corp filed a request for three preliminary injunctions in Germany at the Düsseldorf District Court alleging that the white LED products 334-15/X1C5-1QSA, 334-15/T2C2-1TVB and XI3535-KT577J1-03201-000P manufactured by Taiwan's Everlight Electronics Co Ltd and distributed in Germany infringe Nichia's YAG patent EP 936 682 (DE 697 02 929).

The Düsseldorf District Court has since (on 24 October and 7 November, respectively) admitted Nichia's arguments that the Everlight products infringe claim 1 of Nichia's YAG patent and granted the preliminary injunctions (File Nos. 4a O 104/16, 4a O 112/16 and 4a O 113/16).

Due to the particular urgency, the preliminary injunctions were granted ex parte (without the prior hearing of Everlight).

On 10 November, the preliminary injunctions were served on Everlight. Nichia notes that these are preliminary measures that can still be remedied by Everlight.

www.nichia.co.jp

Everlight highlights lighting and automotive LEDs and IR sensors at electronica

At the electronica 2016 trade fair in Munich, Germany (8–11 November), Taiwan-based Everlight Electronics Co Ltd showcased its newest infrared, automotive and lighting products (involving six half-hour product introductions daily).

A focus is Everlight's infrared portfolio of ambient light sensors (ALS), color sensors, infrared LEDs, photodiodes, photo-transistors, infrared receiver modules (IRM), photocouplers, phototriacs, solid-state relays (SSR), photo interrupters (ITR) and optical switches.

In particular, the development of ambient light sensors for wearables has created new opportunities regarding mobile data tracking as well as rapid detection for health analysis. The new ALS-PD50-42C operates at a green wavelength of 550nm with a sensing area of 8.1mm^2, and has a very low signal calculation failure rate and high current efficiency. A suitable application is heart rate signal detection in wearable electronics for the health and fitness industry.

Regarding increasing safety concerns worldwide, surveillance and security applications are becoming increasingly important. Light sensors such as the ALS-PDIC243-3C tell you if the light in the environment is sufficient. If it is not, IR LEDs like the HIR-C19D or HIR333C provide additional illumination to boost the capability of a camera to see at night or in dark surroundings.

Everlight's range of different color LEDs.

Everlight is also showcasing new solutions for color binning for interior and exterior automotive lighting applications along with other key automotive products. One example is white color binning for dashboard applications like switches, instrument clusters and displays. Everlight says that it follows binning standards and offer different binning methods to make it easy to apply LEDs in automotive applications. Also, in response to the design trend for personal in-car ambient lighting, Everlight provides multi-color solutions like RGBW and RGBY LEDs.

Regarding lighting LEDs, Everlight is putting special emphasis on its full-color LED portfolio, including multiple wavelengths to boost agriculture. The easiest way to achieve effective agricultural lighting is to provide either a spectrum of light that best replicates sunlight or the required spectrums/color combinations for specific functions. Color combinations vary depending on region, time, temperature, plant, plant cycle, production targets etc. Everlight says it has all the basic colors needed for replicating sunlight and activating specific functions for agricultural lighting. For any part of the spectrum where additional colors need to be added or additional light functions are needed, different color LEDs are available for customer selection and tuning. Other markets for full color LEDs (in addition to agricultural lighting) include architectural, stage and landscape lighting. The latest product from Everlight for these industries is an RGBW in one high-power LED.

Everlight is also showcasing UVA and UVC series LEDs, both featuring many applications ranging from curing of glues applied on industrial PCBs, light sources for exposure equipment, ink drying for printing systems, disinfection and sterilization, biological analysis and testing, water and air purification, money detector pens, cosmetic curing, to tanning machines.

www.everlight.com

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Arima Optoelectronics shifting from nitride blue LEDs to AlGaInP infrared LED chips

18 out of 40 MOCVD systems to be transferred to AlGaInP

LED epitaxial wafer and chip maker Arima Optoelectronics Corp (AOC) of Taoyuan, Taiwan has ceased production of nitride-based blue LED chips and shifted production to aluminum gallium indium phosphide (AlGaInP) LEDs in order to avoid price-price competition in the blue LED segment, reports Digitimes.

Arima has shut down 40 MOCVD systems used to produce blue LED epiwafers and chips, while 18 have been transferred to produce AlGaInP LED wafers and chips, the firm says.

Due to the high technological entry barrier, there are relatively few manufacturers of AlGaInP LED chips. The main competitors are Germany-based Osram Opto Semiconductors GmbH, China-based San'an Optoelectronics and Taiwan-based Epistar, Arima notes.

Arima is now focusing on infrared (IR)-emitting AlGaInP chips for applications such as iris recognition, automotive dashboards, brake lamps and direction indicators, plant-growth lighting, LED lighting and security surveillance. The firm has developed IR LED chips with emission wavelengths of 810nm, 850nm and 940nm.

Currently, China accounts for 56.6% of revenue from IR LED chips, Taiwan 19.2%, and South Korea 16.3%, Arima reckons.

www.digitimes.com/news/a20161117PD201.html

Cree files patent lawsuit against Emson's TacLight

LED chip, lamp and lighting fixture maker Cree Inc of Durham, NC, USA has filed a complaint with the US District Court for the District of Massachusetts alleging the infringement of its patented LED technology in the flashlights (e.g. Bell+Howell Taclight) of E. Mishan & Sons Inc (Emson).

As part of the complaint, Cree is seeking an award of enhanced damages, attorneys' fees and an injunction to prevent Emson from offering for sale and selling any products using "knock-off" LEDs.

"Cree will not tolerate and will aggressively defend against such blatant disregard of its intellectual property rights," says Dave Emerson, senior VP & general manager for Cree LEDs. "We have an obligation to our customers to ensure that the market offers products that include the high-quality LED components that customers have come to expect," he adds. "We are committed to protecting Cree's investment in research and development on behalf of our customers, shareholders and our licensing partners." Emerson notes.

www.emsoninc.com
www.cree.com

Cree extends IG parking luminaire series

Cree Inc of Durham, NC, USA has extended its range of IG Series LED parking structure luminaires to include a warmer color temperature and standard 0–10V dimming to offer better light with enhanced aesthetics and performance.

The result is more choices to meet demand for warm lighting. Featuring Cree's WaveMax Technology, the IG Series is said to deliver low-glare comfort and defeat shadows to provide enhanced safety and visibility while delivering high energy efficiency and fast payback.

"Parking structure operators are under constant pressure to lower operating costs while providing safe and visually appealing lighting," says David Elien, Cree's senior VP & general manager, commercial lighting. "With these new standard features, the high-performance IG LED parking structure luminaires not only outperform existing LED and metal halide solutions, but also offer a lower total cost of ownership."

The series offers enhanced performance and flexibility to meet code requirements with new, standard 0–10V dimming for IG parking structure luminaires that do not include a factory installed sensor, enabling easy integration with advanced control systems to maximize energy savings, says Cree. The increased functionality allows parking structure owners to integrate wireless or wired control systems for daylight harvesting, remote monitoring and occupancy sensor capabilities, further reducing energy usage and total cost of ownership.

Available in color temperatures of 3000K, 4000K and 5700K, the parking garage luminaires can deliver more than 80% energy savings and payback of less than two years compared with metal halide lighting, says Cree. Programmable motion controls further increase these savings and enable a simple way to customize settings for high- or low-occupancy applications.

The IG Series is backed by Cree's 10-year warranty and is available through Cree lighting sales channels throughout the USA and Canada.

http://lighting.cree.com/ig-series
www.cree.com/wavemax

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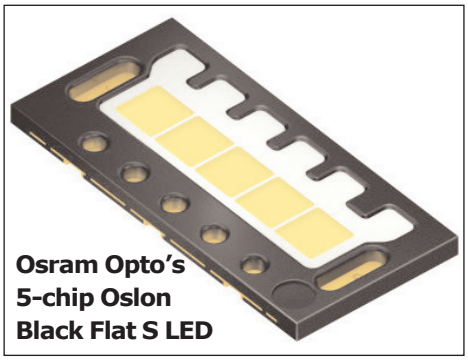
FerroTec

Osram adds surface-mountable Oslon Black Flat S multi-chip LEDs for ADB and matrix headlights

Osram Opto Semiconductors GmbH of Regensburg, Germany has launched the Oslon Black Flat S series, which is claimed to be the first surface mountable LEDs with up to five individually controllable chips.

Due also to the contrast ratio (of 1:65) provided by the package, they are predestined for use in ADB (adaptive driving beam) headlights, says the firm. Switchable light segments enable oncoming traffic and traffic further ahead on the road to be masked out, making driving more comfortable and safer. With improved thermal properties, the new high-power LEDs offer system benefits and are suitable as an entry-level ADB solution even for vehicles in the compact class, adds the firm. The 3.75mm x 5.7mm x 0.43mm 3-chip version in the Oslon Black Flat S series has been available since October, and the versions with four chips (in a 3.75mm x 6.9mm x 0.43mm package) and five chips (in a 3.75mm x 7.9mm x 0.43mm package) will be available from January 2017.

Osram Opto says that the Oslon Black Flat S series represents a significant expansion of its LED portfolio in this area of application. For



Osram Opto's 5-chip Oslon Black Flat S LED

the first time the light-emitting surface of the powerful new chips does not require a recess for contact with the bond wire and produces highly uniform light across its square format, making it easier to adapt the optics. The chips are individually controllable and offer very high contrast between neighboring chips which is 100% verifiable. These features enable oncoming traffic and traffic further ahead to be actively masked out with a high degree of contrast, says the firm. Drivers benefit from the optimum distribution of light on the road at all times.

"The Oslon Black Flat S series enables the benefits of adaptive matrix light to be offered not just on flagship models but also on cars in the entry-level and compact classes," says product manager Thomas Christl. In addition to glare-free high beam, other adaptive LED front lighting functions such as cornering light and city light can be implemented, without the need for any mechanical elements.

ADB solutions for the entry-level segment

Up to now, only the Osram Ostar Headlamp Pro had individually controllable chips. The Oslon Black Flat S series now adds this feature to the portfolio. In addition, the chips are surface mountable and are compatible with standard processes. In contrast to the Oslon Black Flat, the Oslon Black Flat S LEDs have an optimized and symmetrical contact surface design which further improves heat removal and cycle stability. This combination of thermal management and standard processing reduces system costs, says Osram. The higher possible current load of up to 1.5A provides sufficient light on the road from only three segments, and produces as much as 2000 lumen from the 5-chip version.

The new multi-chip LEDs were presented for the first time at electronica 2016 (8–11 November) in the Munich Exhibition Center.

www.osram.com/os/products

Essentia by Cree range gains 115lm/W LED Surface Wrap

Cree Inc of Durham, NC, USA has expanded its Essentia by Cree product portfolio with the new LED Surface Wrap, which delivers luminous efficacy of 115 lumens per watt (LPW).

"The new Essentia by Cree LED Surface Wrap is ideal for diverse commercial applications where customers are replacing traditional fluorescent fixtures in hallways, utility rooms and low ceiling areas," says David Elien, senior VP, lighting.

Traditional surface wrap fixtures with 2-foot and 4-foot fluorescent tubes are ubiquitous in both institutional and residential buildings, casting harsh, buzzing illumination that is familiar in corridors, stairwells and work areas, says the firm. The Essentia by Cree LED Surface Wrap provides clean white light with a low-profile arc lens design that mounts easily on ceilings or walls. The product comes standard with 0–10V dimming to 5% and is available with an emergency backup option. A field-installed occupancy sensor is also available to further enhance energy savings.

The Essentia by Cree LED Wrap's performance meets the DLC 3.1 Premium certification standard and qualifies for rebate incentives that can improve payback. The new wrap also meets California Title 24 and other stringent electrical codes requiring dimming control and emergency backup.

The Essentia by Cree lighting portfolio comes with a five-year limited warranty. The LED Surface Wrap is sold through Cree lighting sales channels throughout the USA.

http://lighting.cree.com/essentia-

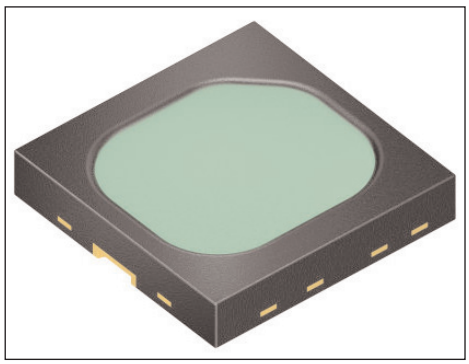
Osram presents first broadband infrared LED, paving way for smartphone-based food analytics by consumers

Osram Opto Semiconductors GmbH of Regensburg, Germany is using converter technology for infrared emitters for the first time, resulting in what it claims is the first broadband emitting infrared LED.

Emitting broadband infrared light in a wavelength range of 650–1050nm, the new SFH 4735 is mainly suitable as a light source for near-IR spectroscopy. Among the various applications nowadays is assessing the quality of food. Osram says that the new LED (which is 3.75mm x 3.75mm x 0.7mm and has spectral output of 60µW at 750nm and 30µW at 980nm) enables such sensor technology to move into the consumer sector, e.g. as an add-on for smartphones. The first mini spectrometers have already been showcased, and the new LED means that a compact light source is now available.

Measuring freshness with a smartphone

IR spectroscopy uses the characteristic absorption behavior of certain molecular compounds. If a defined spectrum is directed at a sample it is possible to determine the presence and quantity of certain ingredients from the wavelength distribution of the reflected light. This method is used in the food industry and in agriculture, among other sectors. For example, it is possible to measure the water, fat, carbohydrate, sugar or protein content of foodstuffs. This data provides an indication of freshness, quality or calorie content.



Osram Opto's SFH 4735 LED.

The new infrared LED opens this measurement technique up also to the consumer market. One option would be a compact sensor — like a USB stick — which would be used with an appropriate smartphone app to measure calories, freshness or nutritional content.

First converter for infrared emitters

The basis of the SFH 4735 is a blue chip (with a surface area of 1mm^2) fabricated in Osram Opto's UX:3 technology. Its light is converted into IR radiation with the aid of a phosphor converter developed specifically for this application. A residual blue component in the light helps users target the area they want to investigate. The emission spectrum of the SFH 4735 has a homogeneous spectral distribution in the infrared range. The chip is mounted in the proven and compact Oslon Black Flat package, which is characterized in particular by good thermal resistance.

Food analytics supplements bio monitoring

Compact units for spectroscopic chemical analyses open up a new range of applications in consumer electronics, notes the firm. Experts expect that it will be possible in the near future to integrate spectrometers directly in mobile devices. The new technology is a natural extension of bio monitoring, i.e. the trend for measuring various vital signs such as pulse rate and calorie consumption. A smartphone spectrometer will enable users to monitor the food they eat in a similar manner. Medicines can also be checked in the same way.

"Future applications are also of particular interest," says Udo Jansen, product marketing manager for Infrared. "It is conceivable that the emission range can be extended to include wavelengths up to 2000nm, in other words into the middle infrared spectral range. This will allow more precise and detailed measurements and will open up new options for everyday analyses of certain environmental parameters such as air quality."

www.osram.com

Osram presents prototype multi-channel laser for scanning LIDAR in self-driving cars

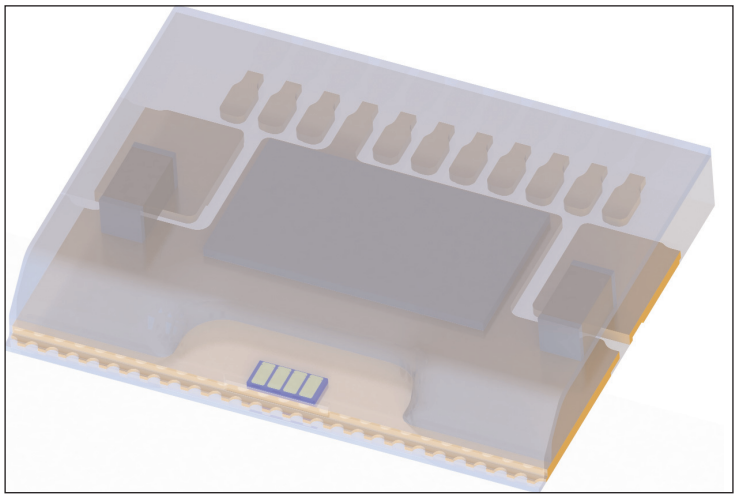
At the electronica 2016 trade fair in Munich, Germany (8–11 November), Osram Opto Semiconductors GmbH of Regensburg, Germany showcased a prototype four-channel laser that is said to take LIDAR (light detection and ranging) systems for autonomous or semi-autonomous driving a step closer.

With an extremely short pulse length and four parallel output channels, the prototype laser offers new options for detecting objects and a unique vertical detection zone, says Osram. This can be used for the first time in scanning LIDAR sensors based on micro-electro-mechanical systems (MEMS). Such solutions do not need a mechanism to re-direct the laser beam, so they are less susceptible to wear and tear. Together with Innoluce (an Infineon Technologies AG company and specialist in laser scanner technology) Osram says that it is showcasing what the future of LIDAR systems may look like.

LIDAR sensors are an essential element in future fully autonomous or semi-autonomous self-driving cars. Operating on the principle of time-of-flight measurement, a very short laser pulse is transmitted, hits an object, is reflected and detected by a sensor. From the time-of-flight of the laser beam it is possible to calculate the distance to the object. Scanning LIDAR systems scan the surroundings of the car horizontally with a laser beam across a certain angular segment and produce a high-resolution 3D map of the environment. In most cases, the laser beams in existing scanning LIDAR systems are deflected via mechanical moving mirrors. Some solutions make use of several laser diodes mounted one on top of the other to extend the vertical field of view.

Four-channel laser bar simplifies adjustment

Osram's four-channel LIDAR laser consists of a laser bar with four individually controllable laser diodes and a control circuit integrated in the module. The entire module is surface-mountable, which reduces assembly costs and the time needed for fine adjustment at the customer.



Osram Opto's four-channel LIDAR laser.

To create the laser bar, four laser diodes are produced next to each other in a single production step so they are precisely aligned to each other and can be individually controlled. "The new laser is a bar consisting of four laser diodes that are separated in the production process but are not individual diodes," says product manager Sebastian Bauer. "The result is a laser that emits four perfectly parallel beams," he adds. "Our customers no longer have to spend time laboriously adjusting the individual light sources."

Greater optical output, extremely short pulse length

For the new laser Osram has boosted the maximum optical output of its 905nm-wavelength nanostack pulse laser diodes by about 10W to 85W at 30A per channel.

The new laser is a bar consisting of four laser diodes that are separated in the production process but are not individual diodes

Also, the pulse length has been shortened from 20ns to less than 5ns. The short pulse length and the small duty cycle of 0.01% ensure that, even at such high outputs, the requirements of the relevant eye-safety standards are met. With an operating voltage of 24V the laser also meets the requirements for use in vehicles.

First laser for use with MEMS

Due to the short pulse lengths, the four-channel LIDAR laser for the first time enables a scanning LIDAR system to be produced in which the light beam is deflected via MEMS. The 2.7mm x 2.3mm MEMS chip is operated at up to 2kHz and has been developed by Innoluce B.V. of Nijmegen, The Netherlands (acquired by Germany's Infineon in October). The overall system covers a field of view of 120° horizontal and 20° vertical (with a resolution of 0.1° horizontal and 0.5° vertical). In daylight the range for detecting vehicles is at least 200m and for pedestrians 70m. The demonstrator presented at electronica will have slightly different properties.

Pulse laser diodes from Osram have been in use in cars for over 10 years, e.g. for time-of-flight (TOF) measurements in adaptive cruise control (ACC) systems and for emergency brake assist systems. This latest addition to the product portfolio aims to support the many new developments in sensors for self-driving cars. Samples of the new four-channel LIDAR laser will be available from early summer 2017, with market launch planned for 2018.

www.innoluce.com
www.osram.com

Analog Devices acquires laser beam-steering technology from Vescent Photonics

Non-mechanical technology enables robust integrated LIDAR for automotive safety applications

Analog Devices Inc (ADI) of Norwood, MA, USA (which designs and manufactures ICs for analog and digital signal processing applications) has acquired solid-state laser beam-steering technology from privately held company Vescent Photonics Inc of Golden, CO, USA (which was founded in 2002 to develop and manufacture technologies in waveguide, electro-optics, tunable lasers, and electronics for precision laser control).

Vescent's non-mechanical beam steering technology enables more robust integrated LIDAR (light imaging, detection and ranging) systems that overcome many of the major drawbacks associated with existing bulky mechanical offerings (such as reliability, size, and cost). ADI reckons that the acquisition strengthens its position as a major automotive safety system technology partner for next-generation (Advanced Driver Assistance Systems) and autonomous driving applications.

"From inertial MEMS sensors used in airbag and electronic stability control applications to 24GHz and 77GHz automotive radar, ADI solutions have helped save lives for over two decades," says Chris Jacobs, general manager of Automotive Safety at Analog Devices. "Now, this innovative technology will play an important role in making LIDAR systems more compact, more robust, and an affordable feature in every new car worldwide."

Existing ADAS systems must rely on a suite of sensor technologies that include cameras, radar and LIDAR to effectively provide advanced safety features such as forward collision warning, blind-spot detection, pedestrian detection, and autonomous driving functions. Cameras are used widely for object recognition while radar uses radio-frequency electromagnetic waves to measure distance. LIDAR uses laser beams to measure the distance and can also recognize objects. Scanning LIDAR systems can be used to detect objects on or near the roadway and fill the blind spots known to exist when using radar and cameras.

www.analog.com
www.vescent.com

Philips Photonics to double VCSEL capacity in Ulm

Expansion to be completed by end 2017

Philips Photonics of Ulm, Germany (a wholly owned business of Royal Philips of Eindhoven, The Netherlands) is doubling capacity at its laser diode facility to provide the key components for some of the latest developments in data communication, consumer sensing, and industrial thermal processing.

Since its establishment in 2000 as ULM Photonics GmbH and its acquisition by Philips in 2006, the facility in Ulm has grown significantly, with staffing rising from 50 in 2012 to 200 in 2016. The latest expansion, with a new production line featuring automation, reflects the potential of vertical-cavity surface-emitting lasers (VCSELs) in many applications, says the firm. Completion is planned for the end of 2017.

VCSEL diodes are key components in a growing number of consumer and industrial applications, including sensing of 3D objects in autonomous vehicles; PC 'mice'; industrial sensors and control functions; driver assist systems; ultra-fast data transmission in data centers and servers; and providing distance and gesture recognition in mobile phones.

"Over the past few years, we have invested steadily in research, product development and efficient manufacturing processes," says general manager Dr Joseph Pankert. "Today, our products are widely used in data centers, smartphones and a number of industrial applications," he adds. "The sharp rise in demand for VCSELs is a key factor in our capacity expansion at Ulm, and will enable us to respond to the needs of these rapidly growing markets."

Since its establishment in 2000 as ULM Photonics GmbH, the facility in Ulm has grown significantly, with staffing rising from 50 in 2012 to 200 in 2016

Semiconductor lasers have been developed and manufactured at the facility in Ulm since 2000. The firm has pioneered innovations such as VCSEL arrays (now widely used for time-of-flight and 3D depth imaging). In 2014, the company made the significant step to highly automated manufacturing with the launch of its existing 4" production facility, within the framework of the 'VIDAP' project, jointly sponsored by the German Federal Ministry of Education and Research (BMBF) and the European Union (EU).

www.photonics.philips.com

MACOM launches 25Gbps laser family for high-volume, cost-sensitive 100G optical markets

MACOM Technology Solutions Holdings Inc of Lowell, MA, USA (which makes semiconductors, components and subassemblies for analog RF, microwave, millimeter-wave and photonic applications) has announced volume production of its family of 25Gbps lasers for data-center, mobile infrastructure and fiber to the home (FTTH) applications.

Cloud data-center infrastructure is proliferating rapidly, driven by exponential data traffic growth and the hyperscale elasticity needed to accommodate surging cloud compute workloads and long-term capacity plans, says MACOM. Global demand for online multimedia and mobile data created almost 5 trillion gigabytes of data center traffic in 2015 alone. To meet this burgeoning demand, hyperscale data centers have leveraged inexpensive computing power connected by optical fiber and extremely high-speed, power-efficient lasers.

Leveraging etched facet technology (EFT) and its commercial-scale manufacturing capability, MACOM expects to capitalize on the 100G technology opportunity in Cloud data centers by replicating the significant cost structure reductions for lasers that it has previously achieved in passive optical networks (PON).

The 127/129/131/133D-25G-LCT11 and 1295/1300/1304/1309-25B-LCT11-S families of 25Gbps lasers serve CWDM and LAN-WDM data-center applications, respectively. The 131D-25I-LT5TC family of TO-packaged 25Gbps laser products service 5G-LTE and 100G PON applications. MACOM says that its TO package is a robust, high-speed design that enables the full utilization of laser bandwidth with efficient heat dissipation.

These families of products leverage MACOM's patented EFT technology which, when combined with its in-house wafer-scale indium phosphide (InP) manufacturing, is expected to provide a cost and capacity advantage previously unachievable by incumbent laser suppliers. Coupled with MACOM's driver MAOM-2304, the new laser family can offer a complete solution enabling data-center, mobile and FTTH needs to be addressed.

"In markets where EFT can bring disruptive economics to bear, we believe it will play a pivotal role in achieving the cost thresholds to enable mainstream deployment," says Dr Alex Behfar, senior VP & chief scientist, Photonic Solutions at MACOM. "We have already proven our ability to service high-volume cost-competitive markets such as PON, and with our 25Gbps laser family we believe we are well positioned to become a pre-eminent supplier of lasers into these high-volume markets."

www.macom.com/25GLasers

EC project COSMICC to develop silicon photonics-based transceivers for low-cost, high-speed datacoms

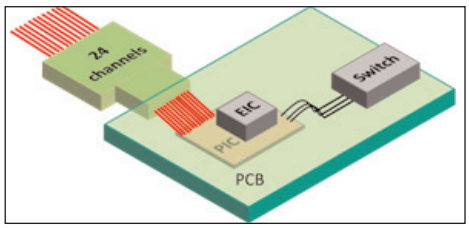
Leti-led Horizon 2020 project combines CMOS electronics and silicon photonics with high-throughput, fiber-attachment techniques for beyond 1Tb/s

The project COSMICC — funded by the European Union (EU) under its Horizon 2020 program H2020-ICT-2015 — has been launched to enable mass commercialization of silicon photonics-based transceivers to meet future data-transmission requirements in data centers and super computing systems.

COSMICC will combine CMOS electronics and silicon photonics with innovative high-throughput, fiber-attachment techniques. These scalable solutions aim to provide performance improvement an order of magnitude better than existing vertical-cavity surface-emitting laser (VCSEL) transceivers, and the COSMICC-developed technology will address future data-transmission needs with a target cost per bit that traditional wavelength-division multiplexing (WDM) transceivers cannot meet.

For example, the project partners are focusing on developing mid-board optical transceivers with data rates up to 2.4Tb/s with 200Gb/s per fiber using 12 fibers. The devices will consume less than 2pJ/bit, and cost about €0.2/Gb/s.

Coordinated by micro/nanotechnology R&D center CEA-Leti of Grenoble, France, the 11 project partners (from five countries) also include STMicroelectronics (France), STMicroelectronics (Italy), University Pavia (Italy), Finisar (Germany), Vario-Optics (Switzerland), Seagate (UK), University Paris-Sud (France), University of St. Andrews (UK), University Southampton (UK) and Ayming (France).



Schematic of COSMICC on-board optical transceiver at 2.4Tb/s (50Gbps/wavelength, 4 CWDM wavelengths per fiber, 12 fibers for Tx, 12 fibers for Rx).

"By enhancing an R&D photonic integration platform from project member STMicroelectronics, the partners in COSMICC aim to demonstrate the transceivers by 2019," says project leader Ségolène Olivier of Leti. "We also plan to establish a new value chain that will facilitate rapid adoption of the technologies developed by our members."

Several technological developments will be used to boost the photonic integration platform's high-data-rate performance, while also reducing power consumption.

A first improvement will be the introduction of a silicon nitride (SiN) layer that will allow the development of temperature-insensitive multiplex/demultiplex (mux/demux) devices for coarse WDM operation. In addition, the SiN layer will serve as an intermediate wave-guiding layer for optical input/output to and from the photonic chip.

Additional steps will enhance modulator performance to 50Gb/s, while making the transceivers more compact and reducing energy consumption. The partners will also evaluate capacitive modulators, slow-wave depletion modulators with 1D periodicity, and more advanced approaches. These include germanium-silicon (GeSi) electro-absorption modulators with tunable Si composition and photonic crystal electro-refraction modulators to make micron-scale devices. In addition, a hybrid III-V on Si laser will be integrated in the SOI/SiN platform in the more advanced transmitter circuits.

Project demonstrators will be tested in both laboratory and field environments.

www.h2020-cosmicc.com

NeoPhotonics reports record revenue of $103.3m in Q3, up 24% year on year

High-speed 100G-and-above revenue year-to-date up 38% year-on-year

For third-quarter 2016, 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 again reported record revenue, of $103.3m, up 4.2% on $99.1m last quarter and up 23.6% on $83.6m a year ago.

High Speed Products (100G-and-above) again rose to a new record, from 66% of total revenue last quarter to 67%, with "unprecedented" mid-term demand continuing to increase across all 100G product families (including coherent line-side products, client-side components and modules and multi-cast switches), according to president & CEO Tim Jenks.

Correspondingly, Network Products and Solutions (lower-speed transceivers, <100Gb/s) fell slightly again, from 34% of total revenue last quarter to 33%.

In particular, passive optical network (PON) revenue declined further, to $6.7m (although exceeding the expected $4m).

Of total revenue (compared with last quarter), 61% came from China (up from 60%) and 19% from the Americas (down from 20%), while Japan was 5% and the rest of the world was 15% (both level with quarter).

There were two 10%-or-greater customers, with Huawei Technologies (including Huawei affiliate HiSilicon Technologies) at 48% (up from 45% last quarter) and Ciena at 15% of total revenue (down from 16%). There were also four customers representing 5% or more of revenue, demonstrating the continued strength across all of the firm's largest customers.

However, at the end of the quarter (on 30 September), a distribution partner serving parts of the China market unexpectedly filed for bankruptcy reorganization in Hong Kong. As a result of the associated uncertainty with recent payments and receivables, NeoPhotonics reduced revenue in Q3 by $2.25m (mostly impacting high-margin, high-speed 100G products).

Impacted by the distributor reorganization charge of $2.25m in addition to the absorption of some mid-year higher volume-related price adjustments, PON under-recoveries and additional ramp-up costs, non-GAAP gross margin has fallen from 29.8% a year ago and 29.3% last quarter to 27.6% (well below the 29–31% guidance), in accord with the product mix of the greater-than-expected low-margin PON sales and $2.25m-lower high-margin high-speed sales (due to the distributor bankruptcy).

Operating expenses have risen from $21.8m last quarter to $24.7m (24% of sales), towards the upper end of the $23–25m guidance range due to new product R&D, principally for advanced coherent developments (raising R&D spending to 14% of sales).

Net income has fallen back from $4.6m ($0.11 per diluted share) a year ago and $6.9m ($0.15 per diluted share) last quarter to $2.9m ($0.06 per diluted share, below the guidance of $0.09–0.17). Nevertheless, this is still the firm's ninth consecutive non-GAAP profitable quarter. Adjusted EBITDA (earnings before interest, taxes, depreciation and amortization) has fallen back from $10.2m a year ago and $12m (12.1% of revenue) last quarter to $8.3m (8% of revenue).

Cash flow from operations was $4m, impacted by an increase in accounts receivable from shipments accelerating in the second half of the quarter. Also, as part of its production capacity expansion plan, capital expenditure (CapEx) was about $15m (making $30m year-to-date, in line with cash flow from operations of about $29m and EBITDA of $33m, and on track to be halfway through the 2-year expansion-related spending plan by year end).

During the quarter, cash and cash equivalents, short-term investments and restricted cash collectively hence fell by $10.6m, from $113.5m to $102.9m. However, total debt was cut by $0.9m to $44.5m.

Excluding the impact of the distribution partner's bankruptcy, Q3 revenue would have been $105.6m (near the top end of the $100–106m guidance range), including High Speed 100G-and-beyond product growth of 10% quarter-on-quarter and 53% year-on-year. Gross margin would have been 1.6 percentage points higher at 29.2% (just within the 29–31% guidance range) and earnings per share (EPS) would have been $0.05 higher at $0.11 per share (within the $0.09–0.17 guidance range). "Since the process is a reorganization, there may be opportunities for recovering a portion of this amount as the court makes decisions on creditors and the terms of the restructuring," notes chief financial officer Ray Wallin. "We have already made adjustments to our sales structure for the distributor situation such that our business will not see any additional impact from this," comments Jenks.

Reflecting markets and capital expansion plans, for fourth-quarter 2016 (including PON products) NeoPhotonics expects revenue of $109–115m, up 5.5–11% sequentially. Excluding PON, revenue should be $105–111m, up 8–15% from $97m in Q3. "Demand for leading-edge high-speed products plays directly into our core competencies, making us optimistic about our growth prospects going forward," says Jenks.

Due to the drop in low-margin PON revenue, gross margin should rebound to 30–33%. Operating expenses are expected to rise to $26–28m (including R&D spending remaining 14% of revenue). Nevertheless, earnings per share should rebound to $0.13–0.21. CapEx will rise sharply to $23m.

"To ensure NeoPhotonics has the capacity to serve the ever growing demand for our high-performance 100G products into 2017 and beyond, we are pursuing a 2-year capacity expansion program, the initial fruits of which helped drive our record shipment volumes in the third quarter," says Jenks. "We have been adding capacity for 100G-and-beyond products steadily through the year and we have made progress to eliminate bottlenecks in our supply chain. As a result, we are starting to see the benefits of the increasing output for ultra-narrow line-width tunable lasers as well as coherent receivers, EML lasers, 100G client modules and multicast switches," he adds.

"Capacity constraints continue to exist throughout the overall industry supply chain, which has an effect on our growth rate," Jenks continues. "As incremental industry bottlenecks are addressed, we expect the underlying market demand for 100G-and-beyond products will drive significant growth into 2017 and beyond. This will happen as 100G deployments continue to expand globally for both telecom and data-center applications and as the bulk of our new capacity comes online."

NeoPhotonics hence expects full-year revenue growth for 2016 to be about 22% (versus 10.9% in 2015), despite annual PON product revenue falling from nearly $45m to about $30m. "Our capacity additions provide volume increases of 50% or more in coherent products and EML lasers and more than doubling of volume in switches and 100G modules next year," says Jenks. Hence, 2017 should see a higher growth rate (most likely over 25%), despite the planned end-of-life for certain PON products by mid-2017.

"When our PON changes are complete, our results will no longer have to overcome headwinds from declining revenues from lower-speed products," says Jenks. "Rather, our full product portfolio will be focused on the highest-performance and highest-speed requirements, which are in the highest-growth market segments."

"We have also taken steps to accelerate some of our key R&D developments to intersect new market demand requirements for higher-speed 400G-and-beyond applications and for certain products used in coherent modules," notes Jenks. "We are continuing to launch products and capabilities in support of the industry need for speed at 200G, 400G and even 600G data rates." NeoPhotonics hence expects its R&D investment to exceed prior plans by 1–2% of revenue as it supports these additional programs, due to accelerating some programs "rather dramatically".

www.neophotonics.com

Oclaro revenue grows for fifth consecutive quarter, up 55% year-on-year, driven by 100G

Operating margin ahead of target, despite continuing capacity constraints for 100G and tunable products and tail-off in 40G

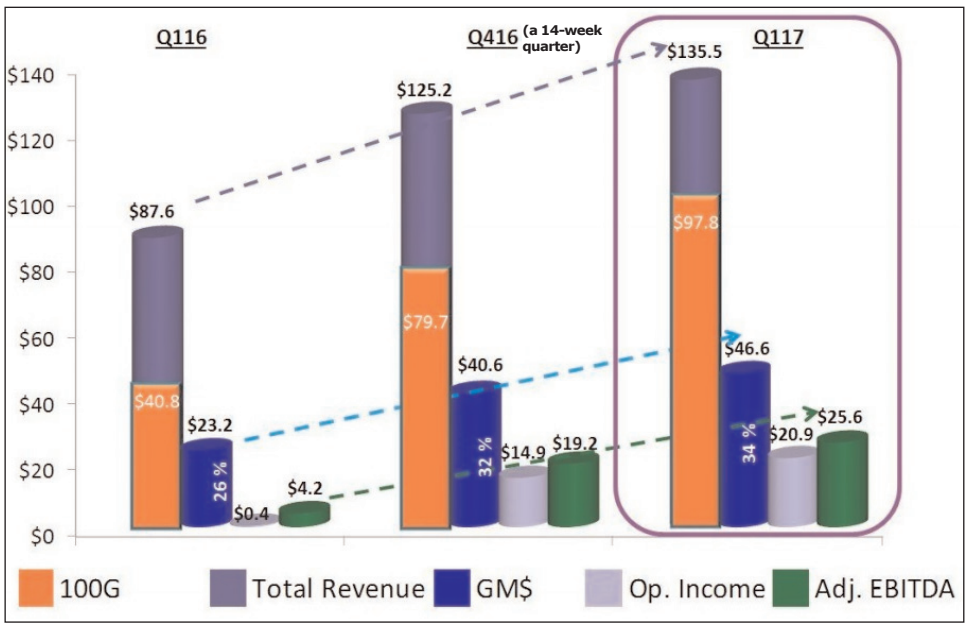
For its fiscal first-quarter 2017 (ended 1 October 2016), Oclaro Inc of San Jose, CA, USA (which provides components, modules and subsystems for optical communications) has reported a fifth consecutive quarter of 7%-or-greater sequential revenue growth, to another record of $135.5m (above the $126–134m guidance). This is up 8% on $125.2m last quarter (a 14-week quarter) and up 55% on $87.6m a year ago.

Growth was driven by 100G-and-beyond sales growing by about 20% for the fifth consecutive quarter, to $97.8m (72% of total revenue), up 23% on $79.7m (64% of revenue) last quarter and up 140% on $40.8m (47% of revenue) a year ago.

For 40G-and-lower speeds, revenue fell further, from $46.8m (53% of total revenue) a year ago and $45.5m (36% of revenue) last quarter to $37.7m (28% of revenue), driven mainly by the tapering down of $3m of 40G end-of-life products and the loss of the extra week of 10G sales compared with the 14-week fiscal Q4.

Client-side (datacom) sales were $68.4m, up 5% on $65.5m last quarter and up 44% on $47.5m a year ago. Line-side (telecom) sales were $67.1m, up 12% on $59.7m last quarter and up 68% on $40m a year ago. In particular, 100G revenue was approximately evenly split between the client-side and line-side markets.

By region, China comprised 43% of total revenue (roughly level with last quarter), Southeast Asia 23% (up from 16% last quarter, after revenue growth of 46%), the Americas 19% (down from 23%), and Europe 13% (down from 16%). However, demand in Southeast Asia is coming from contract manufacturers serving North American and European customers.



"The September quarter again demonstrated the continued strong performance of the company and the vitality of the global 100G market," says CEO Greg Dougherty. "We exceeded our guidance in all areas," he adds.

On a non-GAAP basis, gross margin has grown from 26.4% a year ago and 32.4% last quarter to a record 34.4% (above the forecasted 30–33%), due mainly to the 100G sales mix, economies of scale related to manufacturing overheads, and inventory management.

Operating expenses (OpEx) were $25.8m, level with last quarter but, due to the above-expected revenue, cut from 20.6% of sales to just 19% (beyond the targeted 20–21%), comprising 9.4% in R&D and 9.7% in SG&A (sales, general & administrative).

Growth was driven by 100G-and-beyond sales growing by about 20% for the fifth consecutive quarter, to $97.8m (72% of total revenue)

Operating income has grown from $0.4m a year ago and $14.9m last quarter to a record $20.9m (operating margin of 15.4% of sales), above the forecasted $12–16m.

Net income was $20m ($0.14 per diluted share), up from $14.4m ($0.11 per diluted share) last quarter, and the fourth consecutive quarter of positive earnings per share compared with a net loss of $1.6m ($0.01 per diluted share) a year ago. Adjusted EBITDA has grown from $4.2m a year ago and $19.2m last quarter to $25.6m.

Early in the quarter, Oclaro retired $65m of convertible debt, followed in September by raising a net $128.6m in capital through a stock offering. Overall, after capital expenditure (CapEx) of $14.2m and working capital in prepaid of $6.8m, total cash, cash equivalents and restricted cash rose by $132.7m from $96.6m to $229.3m.

"Based on the projected growth prospects for the data-center, China and metro markets, we expect customer demand for our highly differentiated 100G-and-beyond portfolio to remain strong in fiscal 2017," says chief financial officer ►

Pete Mangan.

For fiscal second-quarter 2017 (to end-December 2016), Oclaro expects revenue of $146–154m (up 8–14% quarter-to-quarter and nearly 60% year-to-year), driven mainly by continued growth in 100G. "We again expect to continue to see strong growth across all of our 100G products serving both the client- and the line-side markets," says Dougherty. "We continue to see very robust demand and we remain capacity constrained for essentially all 100G and tunable product line," he adds. Growth will be gated by capacity and not market demand. Oclaro expects 40G-and-below sales to decline further to about $35m, then to about $30m per quarter in fiscal second-half 2017 as 40G business winds down.

In fiscal Q2/2017, gross margin should be 33–36%, and operating income $22–26m (with operating margin rising to about 16% of sales). However, Oclaro's targets remain 35% gross margin and 15% operating margin. "We want to show that we can sustain that, and then move from there," notes Mangan.

We again expect to continue to see strong growth across all of our 100G products serving both the client- and line-side markets. We remain capacity constrained for essentially all 100G and tunable product line. Growth will be gated by capacity and not market demand

As Oclaro invests in R&D but continues to leverage SG&A, it expects OpEx to now remain 19–20% of sales, despite R&D rising to 10–11%, as SG&A is cut to 9% or less.

Regarding CapEx for fiscal 2017, Oclaro previously projected $55–65m, and now believes it will run to the high end of this range as it invests in additional capacity to grow revenue. This CapEx investment will result in a corresponding sequential increase in depreciation of $800,000–900,000 per quarter for the remainder of fiscal 2017.

www.oclaro.com

Lumentum launches module based on first uncooled 980nm DFB pump laser chip

Optical and photonic product maker Lumentum Holdings Inc of Milpitas, CA, USA has launched the T13 Series of 980nm pump laser modules, based on what is claimed to be an industry-first uncooled distributed feedback (DFB) 980nm pump laser chip. The T13 family of products combines a high-power DFB diode laser with additional components into an ultra-small form-factor coaxial package. Sample quantities are available now, with volume production in December.

"The T13 Series leverages the same TO-package demonstrated in numerous high-volume consumer applications and establishes the DFB's future role in compact, reliable 980nm pump lasers for optical amplification applications," says Jay Skidmore, VP R&D, High Power Lasers. "The DFB laser eliminates the external grating needed for conventional pump laser designs that opens a path towards much higher levels of integration," he adds. "Additional benefits include fiber length reduction, a decrease in the device's footprint, plus lower power requirements."

Lumentum's new T13 Series 980nm pump laser.

Operating up to 200mW, the T13 Series meets the telecoms industry's stringent requirements, including Telcordia GR-468-CORE for hermetic 980nm pump modules. The pump modules target single-channel and narrow-band amplifier applications for high-bit-rate transmission modules and CFPx transceivers.

The DFB laser eliminates the external grating needed for conventional pump laser designs that opens a path towards much higher levels of integration

"Introduction of the T13 Series pump is another example of Lumentum developing superior high-power laser technologies across our broad product portfolio to deliver best-in-class solutions," claims Doug Alteen, VP, product line management, Telecom. "The small pump laser package leverages the design and manufacturing of our high-volume 3D sensing lasers, which have proven to be highly reliable, with tens of millions of devices deployed."

Amongst Lumentum's portfolio of pump lasers for optical amplification, the 980nm Series of products supports erbium-doped fiber amplifiers (EDFAs) operating at power levels of 100–900mW. The 14xx nm and 15xx nm Series products (deployed in Raman amplification) offer operating powers up to 600mW in wavelengths covering the C-band and L-band. The new uncooled T13 Series pumps are derived from a 980nm pump platform and significantly reduce power consumption and enable operation in extreme physical environments, says Lumentum.

www.lumentum.com

Fraunhofer ISE and EVG set 30.2% efficiency record for silicon-based multi-junction solar cell

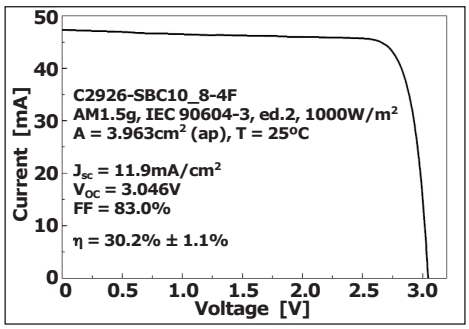
Direct wafer bonding of III-V cells exceeds theoretical limit of 29.4% for pure silicon cell

Researchers at the Fraunhofer Institute for Solar Energy Systems (ISE) in Freiburg, Germany together with EV Group of St Florian, Austria — a supplier of wafer bonding and lithography equipment for semiconductor, micro-electro-mechanical systems (MEMS), compound semiconductors, power devices and nanotechnology applications — have fabricated a silicon-based multi-junction solar cell with two contacts and a solar energy conversion efficiency exceeding the theoretical limit of silicon solar cells.

The researchers used a direct wafer bonding process to transfer a few microns of III-V semiconductor material to silicon. After plasma activation, the subcell surfaces are bonded together in vacuum by applying pressure. The atoms on the surface of the III-V subcell form bonds with the silicon atoms, creating a monolithic device.

The researchers say that the efficiency achieved presents a first-time result for this type of fully integrated Si-based multi-junction solar cell. The complexity of its inner structure is not evident from its outer appearance: the cell has a simple front and rear contact — just like a conventional silicon solar cell — and therefore can be integrated into photovoltaic modules in the same manner.

"We are working on methods to surpass the theoretical limits of silicon solar cells," says Dr Frank Dimroth, head of Fraunhofer ISE's III-V Epitaxy and Solar Cells department. "It is our long-standing experience with silicon and III-V technologies that has enabled us to reach this milestone." A conversion efficiency of 30.2% for the III-V/Si multi-junction solar cell of 4cm^2 was measured at Fraunhofer ISE's calibration laboratory. In comparison, the highest efficiency measured to date for a pure silicon solar cell is 26.3%, and the theoretical efficiency limit is 29.4%.



CV characteristic of GaInP/GaAs/Si solar cell.

The III-V/Si multi-junction solar cell consists of a sequence of subcells stacked on top of each other. Such tunnel diodes internally connect the three subcells made of gallium indium phosphide (GaInP), gallium arsenide (GaAs) and silicon (Si), which span the absorption range of the sun's spectrum. The GaInP top cell absorbs radiation between 300 and 670nm. The middle GaAs subcell absorbs radiation between 500 and 890nm and the bottom Si subcell between 650 and 1180nm, respectively. The III-V layers are first epitaxially deposited on a GaAs substrate and then bonded to a silicon solar cell structure. Subsequently, the GaAs substrate is removed, and a front and rear contact as well as an anti-reflection coating are applied.

"Key to the success was to find a manufacturing process for silicon solar cells that produces a smooth and highly doped surface which is suitable for wafer bonding as well as accounts for the different needs of silicon and the applied III-V semiconductors," says Dr Jan Benick, team leader at Fraunhofer ISE. "In developing the process, we relied on our decades of research experience in the development of highest-efficiency silicon solar cells," he adds.

"With this achievement, we have opened the door for further efficiency improvements for cells based on the long-proven silicon material," says ISE's director professor Eicke Weber, regarding breaking the "glass ceiling" of 30% efficiency with a fully integrated two-contact silicon-based solar cell.

"The III-V/Si multi-junction solar cell is an impressive demonstration of the possibilities of our ComBond cluster for resistance-free bonding of different semiconductors without the use of adhesives," says Markus Wimplinger, corporate technology development & IP director at EVG. "Since 2012, we have been working closely with Fraunhofer ISE on this development." The direct wafer-bonding process is already used in the microelectronics industry to manufacture computer chips.

On the way to the industrial manufacturing of III-V/Si multi-junction solar cells, the costs of the III-V epitaxy and the connecting technology with silicon must be reduced. There are still great challenges to overcome in this area, which Fraunhofer ISE aims to solve through future investigations. Its new Center for High Efficiency Solar Cells (currently being constructed in Freiburg) will provide facilities for developing next-generation III-V and silicon solar cell technologies. The ultimate objective is to make high-efficiency solar PV modules with efficiencies of over 30% possible in the future.

Dr Romain Cariou's research on this project at Fraunhofer ISE with the support of a Marie Curie Post-doctoral Fellowship. Funding was provided by the European Union project HISTORIC. The work at EVG was supported by the Austrian Ministry for Technology.

www.ise.fraunhofer.de
www.evgroup.com

Alta to provide cells for C-Astral's long-endurance UAVs

Alta Devices of Sunnyvale, CA, USA (a Hanergy company) says that its record-setting solar technology is to be used to significantly extend the endurance for the most sophisticated next-generation unmanned aerial vehicles (UAVs) of C-Astral Aerospace of Ajdovscina, Slovenia.

Alta designs and manufactures what is claimed to be the most efficient, thinnest, flexible solar technology in the world. In April, it announced another record of 31.6% solar efficiency for its newest cells.

Through the addition of Alta's solar technology, C-Astral's latest Bramor ppX-LRS (long-range solar) system can fly at least 2 hours longer, enabling highly efficient and precise global surveying and sensing capabilities in remote and urban areas.

One example application is mapping and surveying of long stretches of road from the sky — finishing the project in only a few days without disrupting traffic; if done from the ground, this kind of work would take 2–3 months of road closures. The beyond-line-of-sight capability of the UAV, together with its advanced gas detection and short-wave infrared (SWIR) sensors is also suited to pipeline monitoring, replacing manned aircraft systems and helicopters at a fraction of the cost. Alternatively, these aircraft can dramatically accelerate and reduce the cost of surveying major railway lines and power line infrastructure.

"From the time of our founding, we have known that solar technology is useful for extending flight times and have continuously pursued it," says C-Astral co-founder Marko Peljhan. "Alta's solar technology is the only mature option on the market that allows us to achieve extended flight times without compromising our high-performance aircraft design," he comments.

"There are very few companies with the deep expertise required to develop this type of aircraft," comments Alta Devices' chief marketing officer Rich Kapusta about C-Astral.

The new Bramor ppX airframe is made of Kevlar/Carbon/Vectran composite materials that provide a high level of survivability. Compared with a standard Bramor, the Alta-enhanced LRS version adds less than two ounces of weight, while increasing flight time to about 5.5 hours. This new system provides an all-electric, high productivity UAV for global surveying and remote sensing in remote areas (where access to fuel is an issue) and in urban areas (where pollution and noise must be contained). The Bramor ppX has an operational ceiling of 14,000 feet and is capable of operating in winds of up to 25 knots. Embedded autonomous flight procedures include an array of fail-safe options based on man-rated standards. It is equipped with a high-rate GNSS receiver and IMU precision data-logging electronics.

www.altadevices.com

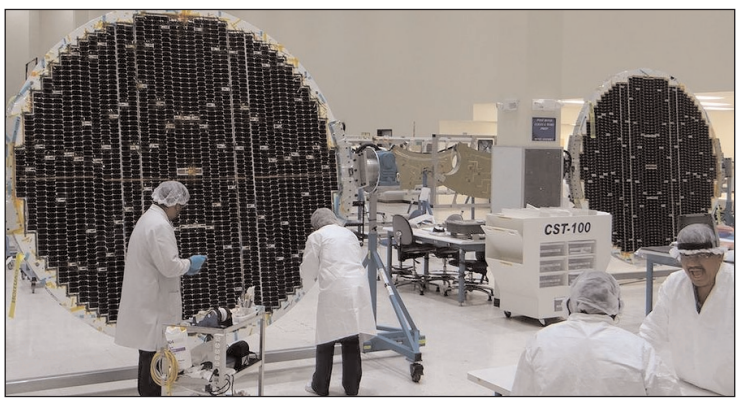
Spectrolab solar cells to power Boeing Starliner spacecraft to the International Space Station

Boeing subsidiary Spectrolab Inc of Sylmar, CA, USA (claimed to be the leading supplier of space solar cells) is to provide power aboard the Crew Space Transportation vehicle that is being developed by Boeing's Starliner program.

The Starliner is in development and is scheduled to begin crew transportation services to and from the International Space Station (ISS) in 2018 as part of NASA's Commercial Crew Program.

"The Starliner program needed a highly efficient, high-quality power solution," says John Mulholland, VP & program manager for Boeing's Commercial Crew program. "This is a perfect example of the benefits of 'One Boeing'," he adds.

The Starliner will use Spectrolab's XTJ solar cells, which are made of three distinct cell layers to capture different portions of the energy spectrum. They will hence efficiently convert solar energy into usable electricity aboard the Starliner, allowing astronauts to journey to the space station and back.



Spectrolab employees work to complete assembly of the Starliner solar panels in Sylmar.

"Spectrolab has put its 60 years of history into the design of these XTJ solar cells," says president Tony Mueller. The firm has previously provided solar cells to the ISS, the Mars rovers Spirit and Opportunity, NASA's Juno probe to Jupiter and over 700 other spacecraft. "It will be a momentous occasion when the Starliner launches for the first time," he adds.

www.spectrolab.com
www.boeing.com/space/crew-space-transportation-100-vehicle

First Solar accelerates Series 6 solar module production to 2018, after converting from Series 4 to Series 6 over 2017–2018 and cancelling Series 5

Drop in module pricing drives restructuring; 2016 guidance revised

First Solar Inc of Tempe, AZ, USA — which makes thin-film photovoltaic modules based on cadmium telluride (CdTe) as well as providing engineering, procurement & construction (EPC) services — has announced an acceleration of its roadmap for Series 6 production into 2018, with about 3GW of production expected in 2019. Over the course of 2017 and 2018, the existing production facilities will be converted to Series 6 production and the current Series 4 product will be phased out. As a result of the change in roadmap, the firm will cancel its Series 5 product.

"Following the completion of an internal review process to evaluate the best competitive response to address the current challenging market conditions, we have developed plans that will enable us to more quickly begin production of our Series 6 module," says CEO Mark Widmar. "Although the decision to accelerate our Series 6 roadmap requires a restructuring of our current operations, we expect the transition to Series 6 will enable us to maximize the intrinsic cost advantage of CdTe thin-film technology versus crystalline silicon," he adds. "Recent steep module pricing declines require us to evaluate all components of our cost structure and streamline our business model to best position the company for long-term success."

As a result of the transition from Series 4 to Series 6 production, First Solar will reduce its workforce at its manufacturing facilities both domestically and internationally. Additional reductions in administrative and other staff are also planned.

Resulting from the transition to Series 6 from Series 4 and other competitive factors, the firm expects to incur restructuring and asset impairment charges of $500–700m (including a cash impact of $70–100m), primarily in 2016, comprising the following:

- $475–585m, including asset impairments related to Series 4, Series 5 and stored manufacturing equipment, and charges for cancellation of open purchase orders (the cash impact is expected to be $50–70m);
- up to $80m for a non-cash impairment of goodwill;
- $10–15m in cash severance charges (primarily in 2016); and
- $15–20m of other charges (primarily in 2017).

These pre-tax restructuring and asset impairment charges are expected to have an offsetting tax benefit of $50–100m.

In addition, the firm expects to incur $220–250m of tax expense in 2016 associated with the distribution of $700–750m of cash to the USA from a foreign subsidiary. This distribution will provide liquidity for the restructuring of US operations and Series 6 investment. The cash tax impact related to this transfer is expected to be $8-10m.

Due to the restructuring and other related charges, the firm has updated its full-year 2016 GAAP guidance. Guidance is unchanged for net sales of $2.8–2.9bn and gross margin of 25.5–26% (although previously, in early November, net sales guidance was slashed from $3.8–4.0bn and gross margin guidance was raised from 18.5–19.0%). However, now, guidance for operating expenses has been raised from $480–500m to $965–1160m. Also, rather than operating income of $235–255m, First Solar now expects an operating loss of $210–445m. Likewise, rather than earnings per share of $3.75–3.90, it now expects a loss of $2.00–4.00. Guidance is unchanged for module shipments of 2.8–2.9GW (although this was previously reduced in early November from 2.9–3.0GW), operating cash flow of between –$100m and zero (previously reduced from $500–650m), capital expenditure of $225–275m (previously cut from $275–325m), and net cash balance of $1.4–1.5bn (previously reduced from $1.9–2.2bn).

Steep module pricing declines require us to evaluate all components of our cost structure and streamline our business model

In addition, 2016 non-GAAP guidance (excluding the impact of the current or previously announced restructuring actions) has been updated to reflect the sale of the entire remaining interest in the Stateline project: non-GAAP earnings per share guidance has now been raised from $4.30–4.50 to $4.60–4.80 (after already been increased in early November from $4.20–4.50).

Also, First Solar has now provided guidance for full-year 2017, including: net sales of just $2.5–2.6bn (70–75% solar power systems and 25–30% third-party module sales from module shipments of just 2.4–2.6GW), gross margin of 12.5–14.5%, operating expenses of $290-305m GAAP ($280–300m non-GAAP), operating income of $30–75m GAAP ($40–80m non-GAAP), earnings per share of between –$0.10 and $0.45 GAAP (breakeven to $0.50 non-GAAP), operating cash flow of $550–650m, capital expenditure of $525–625m (higher than 2016 expected levels due to the investment in Series 6 production equipment), and an ending net cash balance of $1.4–1.6bn.

www.firstsolar.com

First Solar's sales fall 26% in Q3, to $688m

Revised project sale timing leads to reduction in full-year revenue guidance, but margin forecast raised due to modules forming greater part of revenue mix

For third-quarter 2016, First Solar Inc of Tempe, AZ, USA — which makes thin-film photovoltaic modules based on cadmium telluride (CdTe) as well as providing engineering, procurement & construction (EPC) services — has reported net sales of $688m, down 26% on $934m last quarter due to the completion of multiple systems projects during the quarter, offset partially by higher module-only sales.

However, on a non-GAAP basis, earnings per share were $1.22, up from $0.87 last quarter due to lower restructuring charges and the foreign tax benefit.

During the quarter, cash and marketable securities rose from $1.7bn to $2.1bn, primarily due to borrowing under the firm's revolving credit facility. The short-term borrowing is a result of the ongoing construction of large-scale projects which have not yet been sold. Cash flow used in operations was $76m (roughly level with last quarter).

"In the third quarter our operational and financial results were solid," says CEO Mark Widmar. "Our entire fleet module efficiency for the past quarter was 16.5% and our lead line efficiency exited the quarter at 16.9%, demonstrating continued execution on our technology roadmap," he adds.

"Current market conditions are extremely challenging and require us to carefully assess our short- and long-term strategic response," notes Widmar. Based on Q3 results and the revised sale timing for the California Flats and Moapa projects (now expected to be sold in 2017), for full-year 2016 First Solar has slashed its guidance for net sales from $3.8–4.0bn to $2.8–2.9bn. However, the forecast for module shipments has been reduced only slightly, from 2.9–3.0GW to 2.8–2.9GW. Guidance for gross margin has therefore been raised from 18.5–19.0% to 25.5–26.0%. Guidance for non-GAAP operating expenses has been cut from $380–400m to $375–385m. Guidance has hence been increased for operating income from $310–370m to $340–370m, and for earnings per share from $4.20–4.50 to $4.30–4.50. Expectations for operating cash flow have been reduced from $500–650m to between –$100m and zero. Planned capital expenditure has been cut from $275–325m to $225–275m. Net cash balance (cash and marketable securities minus expected debt at the end of 2016) is now expected to be just $1.4–1.5bn rather than $1.9–2.2bn.

Our entire fleet module efficiency for the past quarter was 16.5% and our lead line efficiency exited the quarter at 16.9%, demonstrating continued execution on our technology roadmap

www.firstsolar.com

First Solar signs PPA with community choice aggregator MCE for 40MW$_{AC}$ first phase of Little Bear Solar Project

First Solar Inc of Tempe, AZ, USA — which makes thin-film photovoltaic modules based on cadmium telluride (CdTe) as well as providing engineering, procurement & construction (EPC) services — says that Californian community-based electricity provider MCE has entered into a power purchase agreement (PPA) for electricity generated from 40MW$_{AC}$ of First Solar's Little Bear Solar Project in Fresno County, CA. Designed to be built out eventually to 160MW$_{AC}$, the project should begin construction in 2019, with commissioning expected in 2020.

As a not-for-profit community choice aggregator (CCA) in California, MCE offers their customers locally controlled renewable energy options. The Little Bear PPA is First Solar's first with a CCA.

"MCE is at the forefront of community-based power, a trend that is growing not only in California but across the United States," comments Brian Kunz, First Solar's VP of project development, who describes MCE as "an early leader in this important energy segment… We look forward to expanding the relationship as MCE's customer base grows," he adds.

"MCE is dedicated to getting more renewable energy on the grid in California," says MCE's CEO Dawn Weisz. "By empowering communities and customers with green energy choices like Light Green 50% renewable and Deep Green 100% renewable, MCE is able to stimulate build-out of California solar projects, providing a competitive new marketplace for enterprising energy suppliers like First Solar."

MCE will initially purchase electricity from Little Bear's 40MW$_{AC}$ first phase, with an option to expand up to the project's full 160MW$_{AC}$ as its load increases through potential expansion.

www.mcecleanenergy.org

Stion's frameless module chosen for BIPV carbon-neutral apartments in The Netherlands

Stion Corp of San Jose, CA, USA says that its frameless CIGS (copper indium gallium selenium) photovoltaic module is being incorporated into the design of the most recent project of Dutch firm NBA (NewBestArchitecten). Two five-storey residential apartment buildings, each with 48 individual units, will all be carbon neutral, including the elevator and the common room. The houses are also equipped with high-efficiency water heat pumps and a heat recovery system (all solar-powered).

While most carbon-neutral homes include solar modules, "what is unique about this project is that the solar modules are integrated into the building, so that you would not know the buildings have solar unless we told you," says NBA architect Harold van de Ven.

According to Stion, building-integrated photovoltaics (BIPV) has been on the radar for many architects but few have actually developed projects using an integrated solar module. Many BIPV manufacturers are trying to figure out how to deposit thin layers of photovoltaic materials on glass that nevertheless still allows sunlight through, but this is still prohibitively expensive, says the firm. Instead, NBA installed the panels vertically as a façade that will encase the entire building, except for areas with traditional windows that allow for natural sunlight.

While panels are typically installed on a south-facing roof, increased efficiencies are enabling east-west installations. Stion says that its CIGS solar modules are suitable for installations that need to eke out every watt of power, as they generate increased energy compared with crystalline silicon due to:

- what is claimed to be an industry-best temperature coefficient of –0.26%/ºC that reduces energy production loss when temperatures increase;
- increased energy generation over time due to CIGS having no light-induced degradation (LID) or potential-induced degradation (PID); and
- increased production in shaded environments.

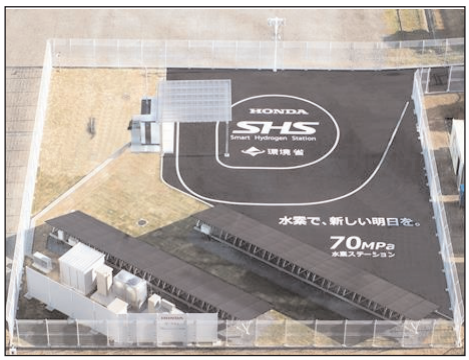
Stion notes that east-west facing arrays also have the benefit of extending the time period over the day during which energy is produced. "Rather than a large spike in production during the peak hours of the day, we smooth and extend the energy generation profile by installing the modules in east–west," comments Henrico van de Boomen, owner of EigenEnergie.net (the largest CIGS distributor in Europe). Also, east–west installations minimize the amount of electricity needed to be net-metered, which can be beneficial for policies that reimburse less for net-metered energy.

www.stion.com
www.EigenEnergie.net

Solar Frontier provides CIS PV panels for demonstration test of Honda's hydrogen production station

Tokyo-based Solar Frontier has provided a total of 20kW of its CIS (copper indium selenium) thin-film photovoltaic (PV) solar panels for Honda Motor Company's 70MPa Smart Hydrogen Station (SHS), for which demonstration testing began on 24 October in Tokyo. This marks the first time that Solar Frontier has supplied its solar panels for fuel-cell-powered automobile projects.

The demonstration test is being performed by Honda under the Japanese Ministry of the Environment's Low Carbon Technology Research and Development Program, with the aim of verifying the operational effect of the 70MPa SHS, which produces solar power-derived hydrogen. To examine the CO_2 reduction effect under real-world city conditions and its practical utility as a transplantable power-generating facility, the test is putting the 70MPa SHS in operation with the Clarity Fuel Cell (Honda's new fuel-cell-powered vehicle) and the Power Exporter 9000 (Honda's V2L-compatible portable external power output device).



Solar Frontier's CIS thin-film solar modules installed on the 70MPa Smart Hydrogen Station.

The 70MPa Smart Hydrogen Station uses Power Creator, a high-differential-pressure electrolyzer system developed by Honda that generates high-pressure hydrogen gas without the use of a mechanical compressor. Solar Frontier's CIS thin-film solar panels act as the source of power in the Power Creator.

"The ultimate in eco cars are fuel-cell-powered automobiles that emit zero CO_2 or exhaust gas, instead generating power through hydrogen and using that electricity to run," comments Solar Frontier's director & executive officer Shinji Kato.

www.solar-frontier.com

Berkeley sets efficiency record for perovskite solar cell

Two types of perovskite separated by boron nitride layer

Solar cells made from inexpensive perovskite material can more efficiently turn sunlight into electricity using a new technique to sandwich two types of perovskite into a single photovoltaic cell.

Perovskite solar cells are made of a mix of organic molecules and inorganic elements that together capture light and convert it into electricity. However, perovskite photovoltaic devices can be made more easily and cheaply than silicon and on a flexible rather than rigid substrate. The first perovskite solar cells could go on the market next year, and some have been reported to capture 20% of the sun's energy.

University of California, Berkeley (UCB) and Lawrence Berkeley National Laboratory (LBNL) have reported a new design that already achieves an average steady-state efficiency of 18.4%, with a high of 21.7% and a peak efficiency of 26% (Etgen et al, Nature Materials, DOI: 10.1038/nmat4795).

"We have set the record now for different parameters of perovskite solar cells, including the efficiency," says senior author Alex Zettl, a UC Berkeley professor of physics, senior faculty member at Berkeley Lab and member of the Kavli Energy Nanosciences Institute. "The efficiency is higher than any other perovskite cell — 21.7% — which is a phenomenal number, considering we are at the beginning of optimizing this," he adds.

"This has a great potential to be the cheapest photovoltaic on the market, plugging into any home solar system," notes UC Berkeley physics graduate student Onur Ergen (lead author of the paper).

The efficiency is also better than the 10-20% efficiency of polycrystalline silicon solar cells used to power most electronic devices and homes. Even the purest silicon solar cells, which are extremely expensive to produce, peaked at about 25% efficiency more than a decade ago.

The achievement is due to a new method for combining two perovskite photovoltaic materials — each tuned to absorb a different wavelength of sunlight — into one graded-bandgap solar cell that absorbs almost the entire spectrum of visible light. Previous attempts to merge two perovskite materials have failed because the materials degrade each other's electronic performance.

"This is realizing a graded-bandgap solar cell in a relatively easy-to-control and easy-to-manipulate system," says Zettl. "It combines two very valuable features — the graded bandgap, a known approach, with perovskite, a relatively new but known material with surprisingly high efficiencies — to get the best of both worlds."

Full-spectrum solar cells

As a semiconductor material like silicon, perovskites conduct electricity only if the electrons can absorb enough energy — e.g. from a photon of light — to raise them over the forbidden energy bandgap. These materials preferentially absorb light of specific wavelengths (corresponding to the bandgap energy) but inefficiently at other wavelengths.

"In this case, we are swiping the entire solar spectrum from infrared through the entire visible spectrum," Ergen says. "Our theoretical efficiency calculations should be much, much higher and easier to reach than for single-bandgap solar cells because we can maximize coverage of the solar spectrum."

The key to mating the two materials into a tandem solar cell is a single-atom-thick layer of hexagonal boron nitride, separating the perovskite layers from each other. In this case, the perovskite materials are made of the organic molecules methyl and ammonia, but one contains the metals tin and iodine while the other contains lead and iodine doped with bromine. The former is tuned to preferentially absorb light with an energy of 1eV (infrared) while the latter absorbs photons of energy 2eV (amber color).

The monolayer of boron nitride allows the two perovskite materials to work together and make electricity from light across the whole range of colors between 1eV and 2eV.

The perovskite/boron nitride sandwich is placed atop a lightweight aerogel of graphene that promotes the growth of finer-grained perovskite crystals, serves as a moisture barrier and helps to stabilize charge transport though the solar cell, Zettl says. Moisture makes perovskite fall apart.

The whole structure is capped at the bottom with a gold electrode and at the top by a gallium nitride (GaN) layer that collects the electrons generated within the cell. The active layer of the thin-film solar cell is about 400nm thick.

"Our architecture is a bit like building a quality automobile roadway," Zettl says. "The graphene aerogel acts like the firm, crushed rock bottom layer or foundation, the two perovskite layers are like finer gravel and sand layers deposited on top of that, with the hexagonal boron nitride layer acting like a thin-sheet membrane between the gravel and sand that keeps the sand from diffusing into or mixing too much with the finer gravel. The gallium nitride layer serves as the top asphalt layer."

It is possible to add more layers of perovskite separated by hexagonal boron nitride, although this may not be necessary, given the broad-spectrum efficiency already obtained, reckon the researchers.

"People have had this idea of easy-to-make, roll-to-roll photovoltaics, where you pull plastic off a roll, spray on the solar material, and roll it back up," Zettl says. "With this new material, we are in the regime of roll-to-roll mass production; it's really almost like spray painting."

The work was supported by the US Department of Energy, the National Science Foundation, and the Office of Naval Research.

www.nature.com/nmat/journal/vaop/ncurrent/full/nmat4795.html
www.research.physics.berkeley.edu

Three-prong attack to improve quaternary solar cell MBE

Researchers claim double conversion efficiency over previous work, giving comparable performance to organometallic vapor phase epitaxy.

Researchers based in USA and Spain say they have doubled the AM1.5G conversion efficiency of ~2.0eV aluminium indium gallium phosphide (AlGaInP) solar cells grown by molecular beam epitaxy (MBE) compared with previous work [J. Faucher et al, Appl. Phys. Lett., vol109, p172105, 2016].

The team from Yale University in the USA, Universidad Rey Juan Carlos in Spain, and University of Illinois at Urbana-Champaign in the USA see applications in multi-junction devices for high-efficiency space vehicle power and concentrator photovoltaics. Combined in 5–6 junction structures it is hoped that conversion efficiencies greater than 50% could be achieved. Existing 3–4 junction devices with more than 44% efficiency seem to be reaching the limit for such designs.

The team used three approaches to improve performance: the introduction of AlGaInP-AlInP grading near the window and back surface field (BSF) regions; optimization of the growth process and device design; and post-growth annealing.

Aluminium-containing solar cell layers suffer from oxygen-related defects, sapping performance. AlGaInP devices grown by MBE have previously had poor performance compared with material grown by organometallic vapor phase epitaxy (OMVPE). The researchers have managed to improve the performance of MBE-grown structures to a level comparable to OMVPE.

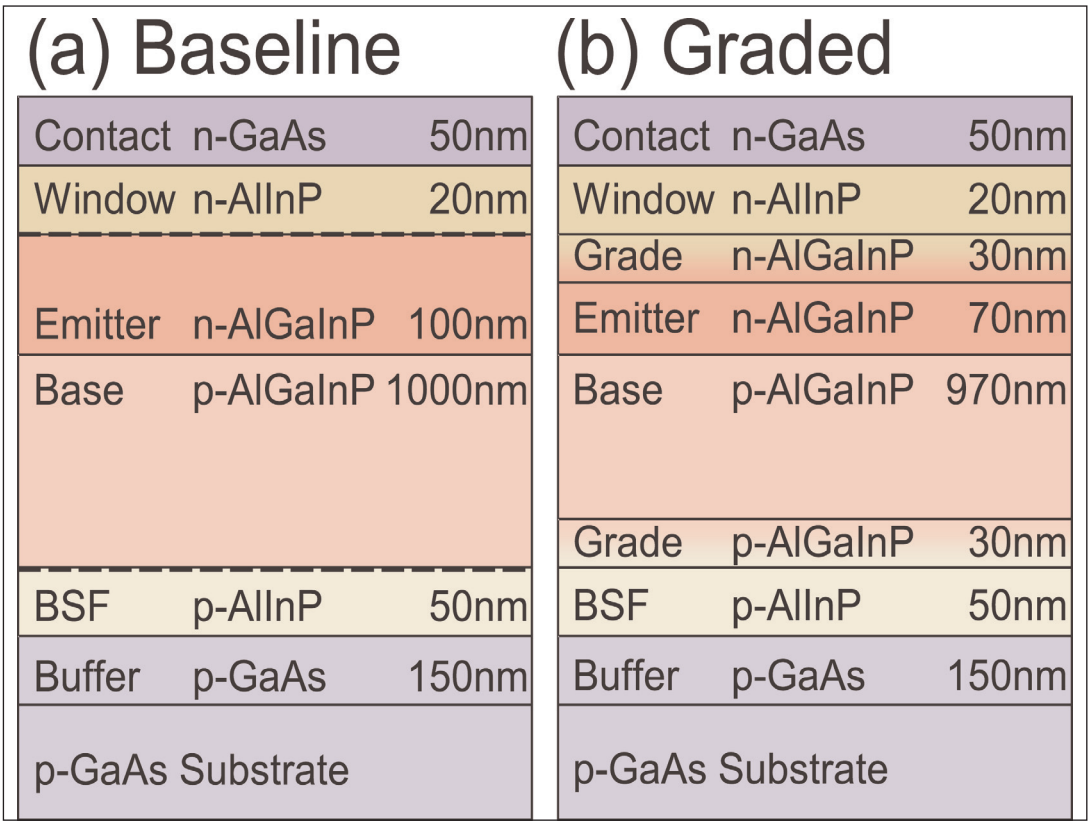


Figure 1. Layer structures for (a) baseline AlGaInP solar cells with abrupt heterojunctions denoted by black dashed lines and (b) cells with AlGaInP compositionally graded heterojunctions.

Combined in 5–6 junction structures it is hoped that conversion efficiencies greater than 50% could be achieved. Existing 3–4 junction devices with more than 44% efficiency seem to be reaching the limit for such designs

The MBE (Figure 1) was performed on gallium arsenide (GaAs) to give cells responsive to photons of ~2.0eV energy. The AlGaInP and AlInP layers were initially grown at 460°C. The AlInP had 50% Al content and the AlGaInP 10% Al. Two structures were produced: one with sharp transitions between the different Al composition (comparison baseline), and the other graded.

Compositional grading was achieved by varying the Al and Ga fluxes, seeking to provide a monotonic change in bandgap and minimal lattice mismatch. The researchers also hoped that by avoiding pauses between AlGaInP and AlInP the incorporation of oxygen and other trap states in the transition region would be reduced. Transmission electron microscopy (TEM) did not show any dislocations in the transition region. However, high-angle annular dark field images did show slight phase separation of the cell ternary and quaternary materials. The team comments that this is common for such alloys grown by MBE.

The internal quantum efficiency peak of the graded structure was measured at 74%. The bandgap-voltage offset — the difference between the bandgap-voltage and open-circuit voltages ($W_{OC} = E_g/q - V_{OC}$) — was 616mV. The IQE of the baseline structure peaked around 60%. The bandgap-voltage offset was the same as for the graded structure.

Further optimization of the growth process involved varying growth rates, V/III ratios, and substrate temperature with a view to increasing carrier diffusion lengths. With 490°C temperature the electron diffusion length was doubled to around 910nm, according to simulations. At the same time, peak IQE increased to 80% and W_{OC} was reduced to 602mV. The performance was relatively insensitive to growth rate and V/III ratio variations.

Short-circuit current (J_{sc}) was increased by 1.16x by reducing photon absorption in the upper layers through decreasing the combined grade and emitter thickness to 70nm. At the same time, W_{OC} was further reduced to 573mV. The base layer was increased to 1.5μm to reduce transmission losses.

The researchers suggest that changing the n-type silicon doping to selenium might further improve performance. In OMVPE, such a change has led to improvements in IQE, short-circuit current, and open-circuit voltage.

A final strategy to improve performance was an anneal immediately after the MBE growth. A 670°C 5-minute thermal process reduced dark current by a factor of about 4 (Figure 2). The researchers estimate the electron diffusion length to be more than 2000nm. The IQE peak increased to 95%. Short-circuit current also increased to 9.0mA/cm^2. The bandgap-voltage offset was 520mV.

The team comments: "Most of the J_{sc} increase with annealing arises from improvements in long-wavelength IQE, implying significantly improved material quality in the p-type base."

The fill-factor increased to ~0.85, giving a conversion efficiency of 10.9%. ■

http://dx.doi.org/10.1063/1.4965979

Author: Mike Cooke

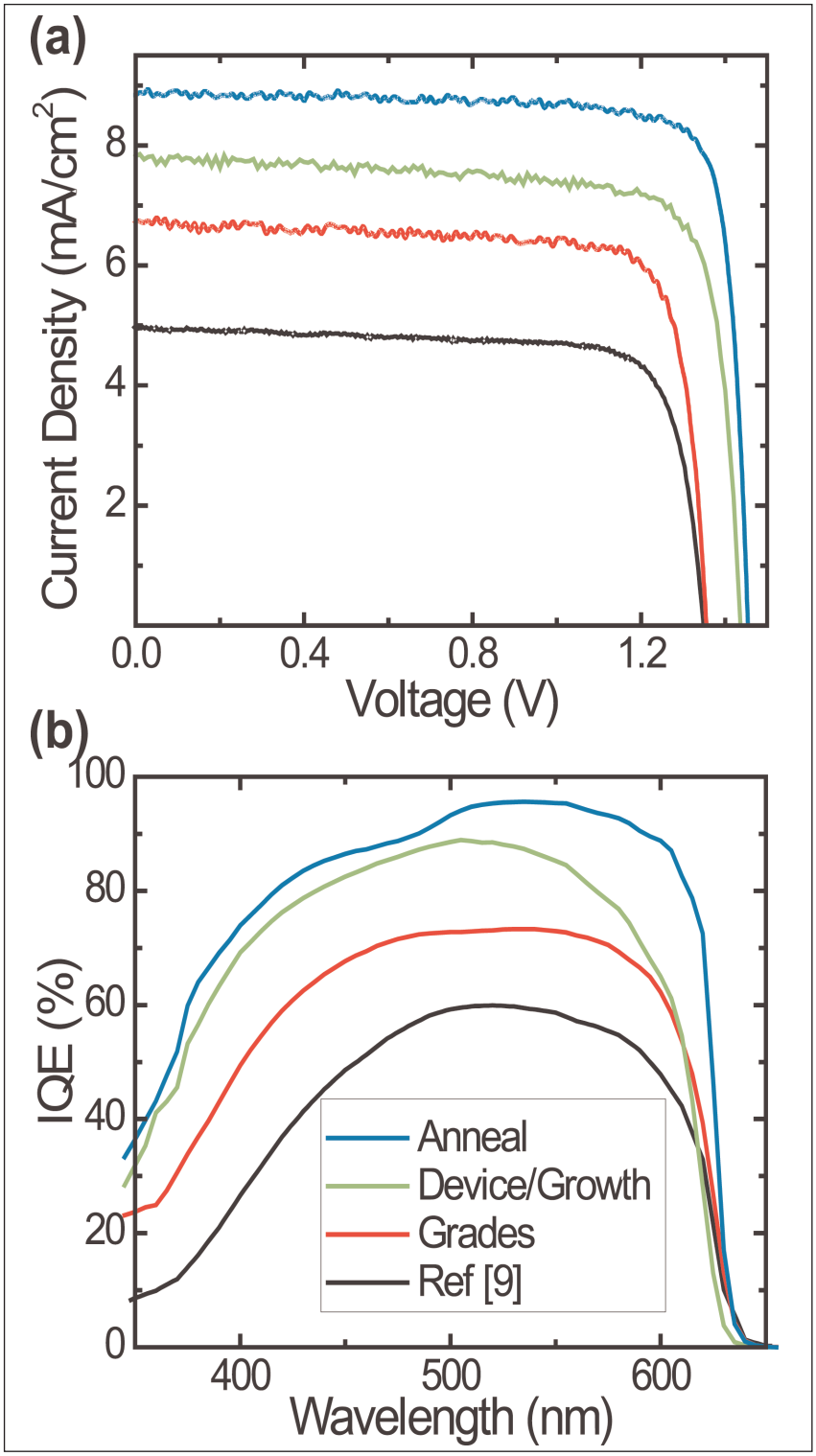


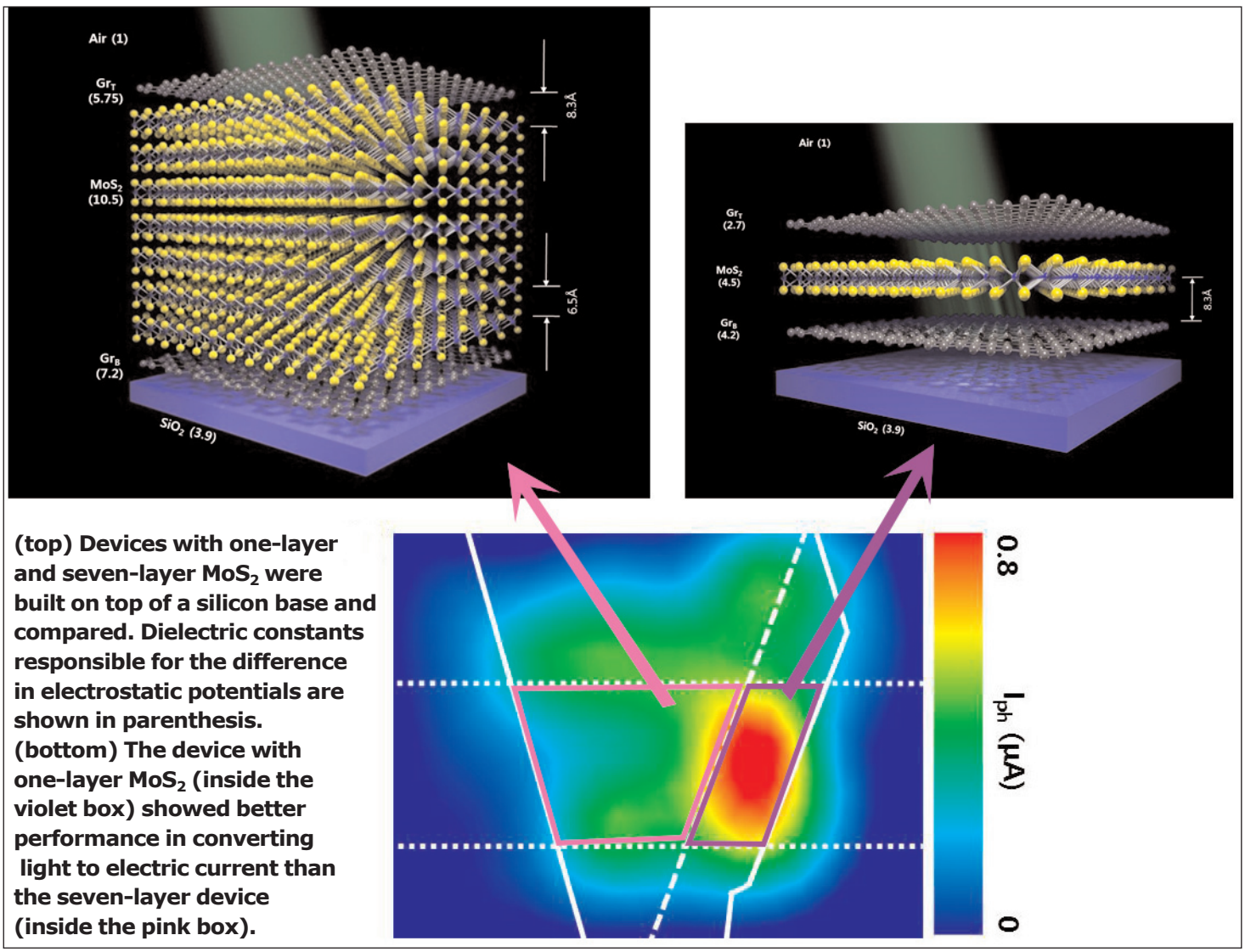
Figure 2. (a) Current–voltage characteristics under AM1.5G illumination and (b) IQE showing improvements over previously reported MBE-grown AlGaInP cells (black) by incorporating AlGaInP grades (red), growth window and device structure optimization (green), and post-growth annealing (blue).

South Korea's Institute for Basic Science develops thinnest photodetector

MoS_2 sandwiched by graphene enables 1.3nm-thick monolayer device to achieve higher photoresponsitivity than seven-layer device.

By using 2D technology comprising molybdenum disulfide (MoS_2) sandwiched in graphene, South Korea's Institute for Basic Science (IBS) Center for Integrated Nanostructure Physics at Sungkyunkwan University (SKKU) has developed what is reckoned to be the world's thinnest photodetector (Woo Jong Yu et al, 'Unusually efficient photocurrent extraction in monolayer van der Waals heterostructure by tunneling through discretized barriers', Nature Communications (2016); DOI: 10.1038/ncomms13278). With a thickness of just 1.3nm (10 times smaller than existing standard silicon diodes) the device could be used in the Internet of Things, smart devices, wearable electronics and photoelectronics.

Graphene is conductive, thin (just one atom thick), transparent and flexible. However, since it does not behave as a semiconductor, its application in the electronics industry is limited. So, to increase graphene's usability, IBS has sandwiched a layer of the 2D semiconductor MoS_2 between two graphene sheets and put it over a silicon base. They initially thought that the resulting device was too thin to generate an electric



(top) Devices with one-layer and seven-layer MoS_2 were built on top of a silicon base and compared. Dielectric constants responsible for the difference in electrostatic potentials are shown in parenthesis. (bottom) The device with one-layer MoS_2 (inside the violet box) showed better performance in converting light to electric current than the seven-layer device (inside the pink box).

current but, unexpectedly, it did. "A device with one layer of MoS_2 is too thin to generate a conventional p–n junction, where positive (p) charges and negative (n) charges are separated and can create an internal electric field. However, when we shine light on it, we observed high photocurrent," says Yu Woo Jong, first author of this study. "Since it cannot be a classical p-n junction, we thought to investigate it further."

To understand what they found, the researchers compared devices with one and seven layers of MoS_2 and tested how well they behave as a photodetector, i.e. how they are able to convert light into an electric current. They found that the device with one layer of MoS_2 absorbs less light than the device with seven layers, but it has higher photoresponsitivity. "Usually the photocurrent is proportional to the photoabsorbance; that is, if the device absorbs more light, it should generate more electricity, but in this case, even if the one-layer MoS_2 device has smaller absorbance than the seven-layer MoS_2, it produces seven times more photocurrent," says Yu.

The monolayer is thinner and therefore more sensitive to the surrounding environment. The bottom SiO_2 layer increases the energy barrier, while the air on top reduces it, thus electrons in the monolayer device have a higher probability of tunneling from the MoS_2 layer to the top graphene (GrT). The energy barrier at the GrT/MoS_2 junction is lower than the one at the GrB/MoS_2, so the excited electrons transfer preferentially to the GrT layer and create an electric current. Conversely, in the multi-layer MoS_2 device, the energy barriers between GrT/MoS_2 and GrB/MoS_2 are symmetric, therefore the electrons have the same probability to go either side and thus reduce the generated current.

For these reasons, up to 65% of photons absorbed by the thinner device are used to generate a current. Instead, the same measurement (quantum efficiency) is only 7% for the seven-layer MoS_2 apparatus.

"This device is transparent, flexible and requires less power than the current 3D silicon semiconductors. If future research is successful, it will accelerate the development of 2D photoelectric devices," Yu believes. ■

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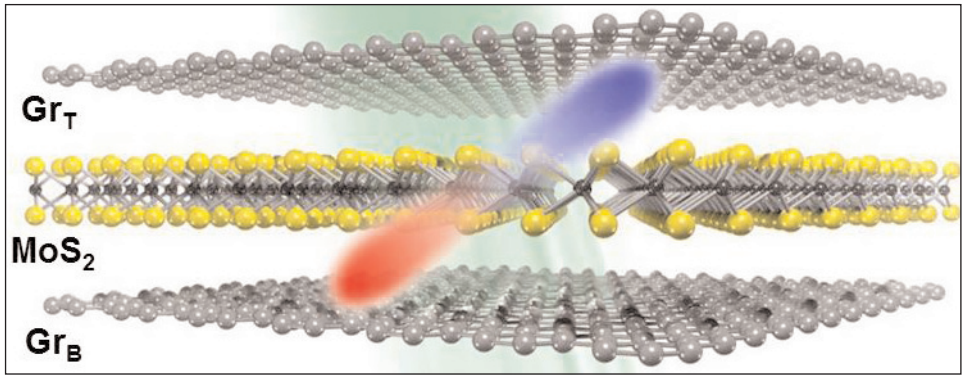
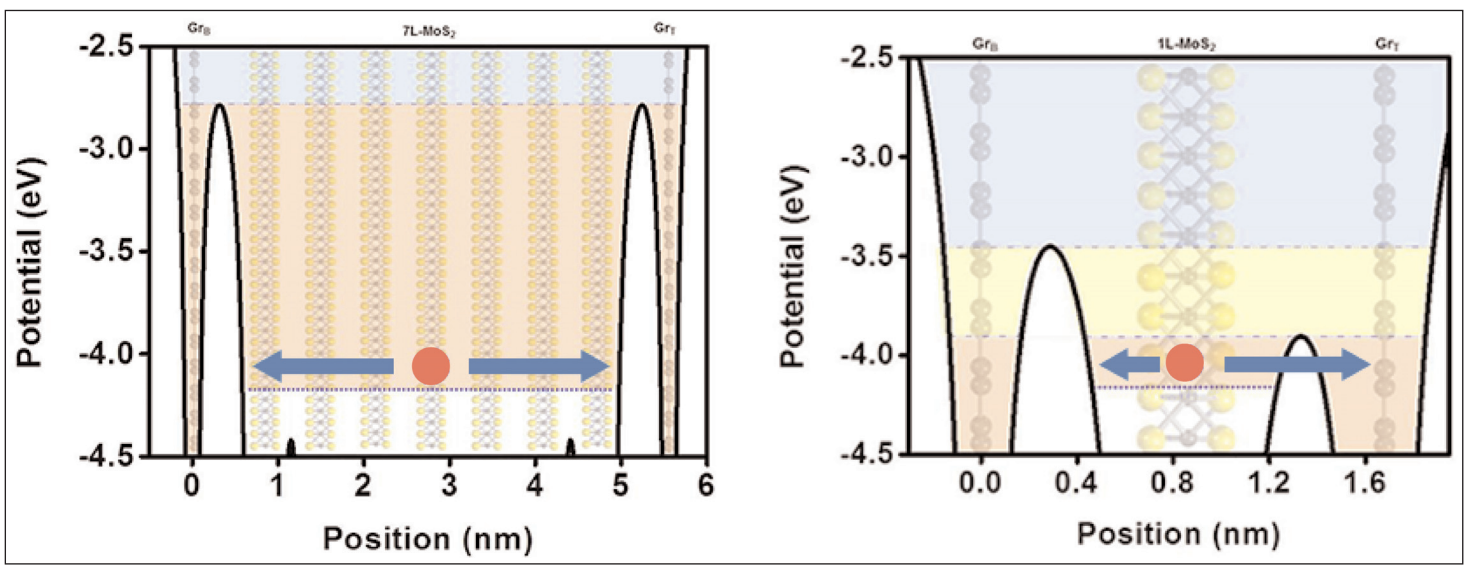


Device with MoS_2 layer sandwiched between top (GrT) and bottom (GrB) graphene layers. Light (green ray) is absorbed and converted into electric current. When light is absorbed by the device, electrons (blue) jump into a higher energy state and holes (red) are generated in the MoS_2 layer. Motion of holes and electrons created by the difference in electronic potential between the GrT-MoS_2 and the GrB-MoS_2 junctions generates the electric current.



How the device with one-layer MoS_2 generates more photocurrent than the seven-layer MoS_2 one. In the one-layer device MoS_2 (right), the electron (red circle) has a higher probability to tunnel from the MoS_2 layer to the GrT because the energy barrier (white arch) is smaller in that junction. In the seven-layers MoS_2 device (left) instead, the energy barrier between MoS_2/GrT and MoS_2/GrB is the same so electrons do not have a preferred direction flow. More energy is generated in the one-layer MoS_2 device because more electrons flow in the same direction.

Indium phosphide on silicon template for optoelectronics

Researchers use wafer bonding to create platform for 1.2μm-wavelength laser diode growth and fabrication.

Sophia University in Japan has developed a wafer bonding process that produces a thin layer of indium phosphide (InP) on silicon (Si) template that was used for the production of ~1.2μm-wavelength laser diodes (LDs) by metal-organic vapor phase epitaxy (MOVPE) [Keiichi Matsumoto et al, Jpn. J. Appl. Phys., vol55, p112201, 2016].

The team comments: "Although the growth of active materials on an InP/Si substrate was carried out by Morral et al in 2003, the optical property of the as-grown structure was unsatisfactory, and the integration of optical devices has never been demonstrated to our knowledge."

The researchers hope to overcome the limitations of monolithic integration of III-V materials and hybrid bonding of III-V devices onto silicon platforms. Monolithic integration suffers from the generation of anti-phase domains and large lattice mismatches (~8% for InP on Si) giving crystal dislocations and residual strain. Hybrid integration needs high-precision alignment, which is difficult to achieve at low cost.

The Sophia team believes its integration technique could provide the needed light source for optical interconnections on silicon platforms. Silicon photonics waveguides need light with wavelengths longer than 1.1μm.

The researchers prepared a 2-inch-diameter 1μm-thick InP layer on a silicon wafer through hydrophilic bonding. The process (Figure 1) involved low-pressure MOVPE of gallium indium arsenide (GaInAs) and InP layers on an InP substrate. The buried GaInAs layer functioned as an etch-stop for removal of the original InP substrate.

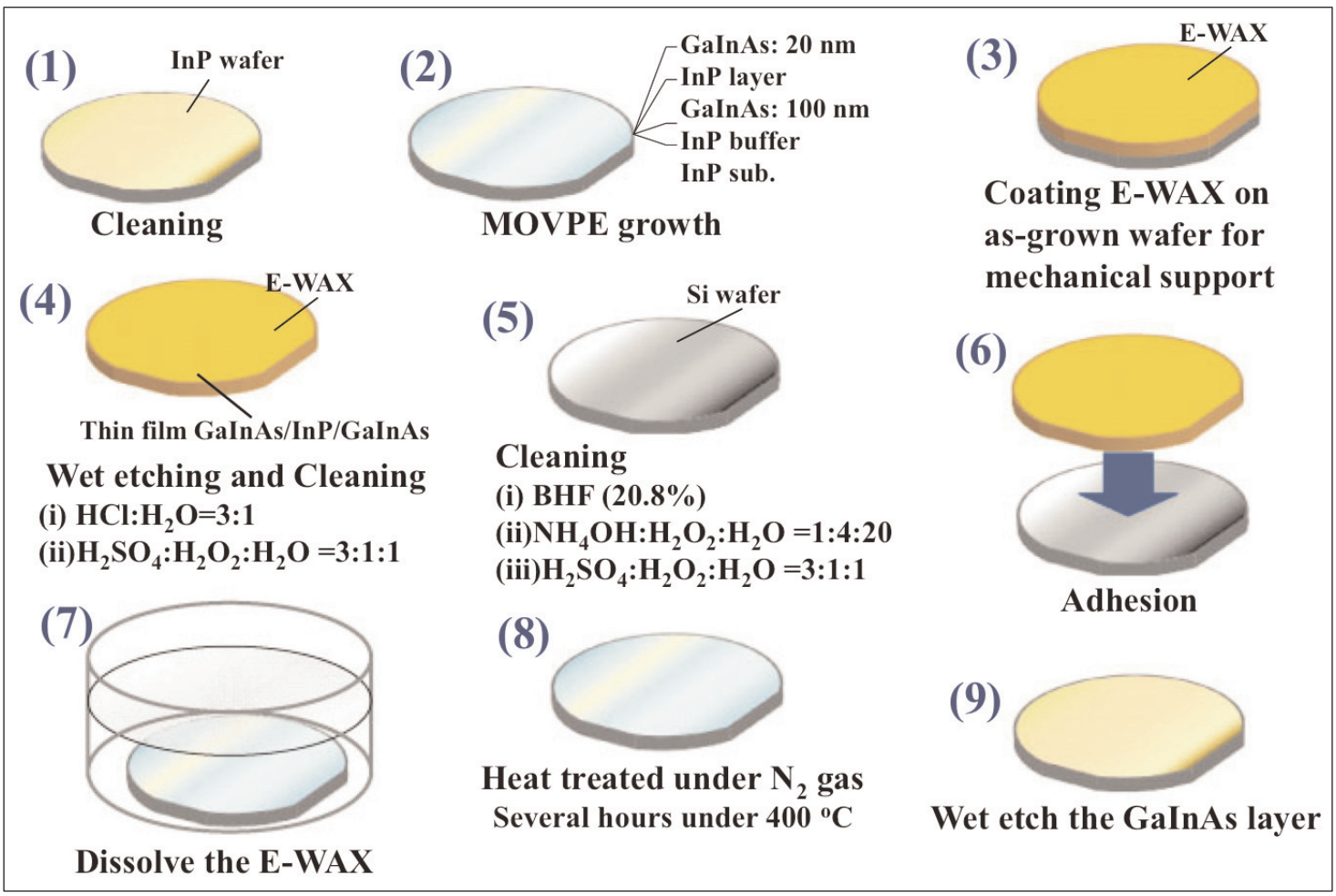


Figure 1. Schematic of InP/Si fabrication process.

The team found that ramping the temperature over a period of 45 hours before the final anneal at 400°C decreased the void occupancy rate from more than 3.9% (15-minute ramp) to less than 0.1%. The long ramp time is thought to encourage gas diffusion from the Si/InP interface, avoiding the build up of high internal pressures that create voids. "Thus, we successfully fabricated a void-free 2-inch InP/Si substrate without forming any outgassing channels," the team writes.

The annealing was found to provide an ohmic contact between the InP and Si, compared with the Schottky contact of unannealed samples. Annealing at a higher temperature of 630°C was found to reduce the interface resistance. The 630°C temperature is typical of what is used in MOVPE growth of GaInAs.

The specific resistance of the 630°C interface was between 0.06Ω-cm^2 and 0.28Ω-cm^2, compared with the range 0.06–0.38Ω-cm^2 for 400°C. The current density was 2A/cm^2. The researchers claim that the 630°C value is almost the same as for a silicon reference.

Photoluminescence from multiple quantum wells of low-pressure MOVPE GaInAs was almost the same on InP/Si and pure InP substrates in terms of intensity, peak position and full-width at half maximum. X-ray analysis further suggested no degradation of crystal quality from using InP/Si, according to the team.

Finally, the team produced double-heterostructure laser diodes (LDs) with a $Ga_{0.25}In_{0.75}As_{0.45}P_{0.55}$ active region (Figure 2). The laser diode wafer was lapped down to 100μm thickness and cleaved into Fabry–Perot bars. The electrodes were gold-zinc on the p-AlGaAs contact layer and gold-aluminium on the n-Si underside.

Contact	p-GaInAs	50nm
Cladding	p-InP	1μm
Active	GaInAsP	170nm
Buffer	n-InP	330nm
Bonded template	n-InP	1μm
Bonded substrate	n-Si	

Figure 2. Laser diode layer structure.

The cavity length was 340μm and the width was 70μm.

Under 10kHz 100ns pulses, the threshold current density was 6.4–8.4kA/cm^2 at room temperature (Figure 3). A similar device produced on pure InP had a much lower threshold of 3.7kA/cm^2.

The researchers comment: "This may be mainly due to heating and less carrier injection owing to an unstable heterointerface. Thus, further investigation of the different characteristics between the laser diodes on the InP/Si substrate and that on an InP substrate is still required and we hope to report improved laser diode operation in the future." ■

http://doi.org/10.7567/JJAP.55.112201

Author: Mike Cooke

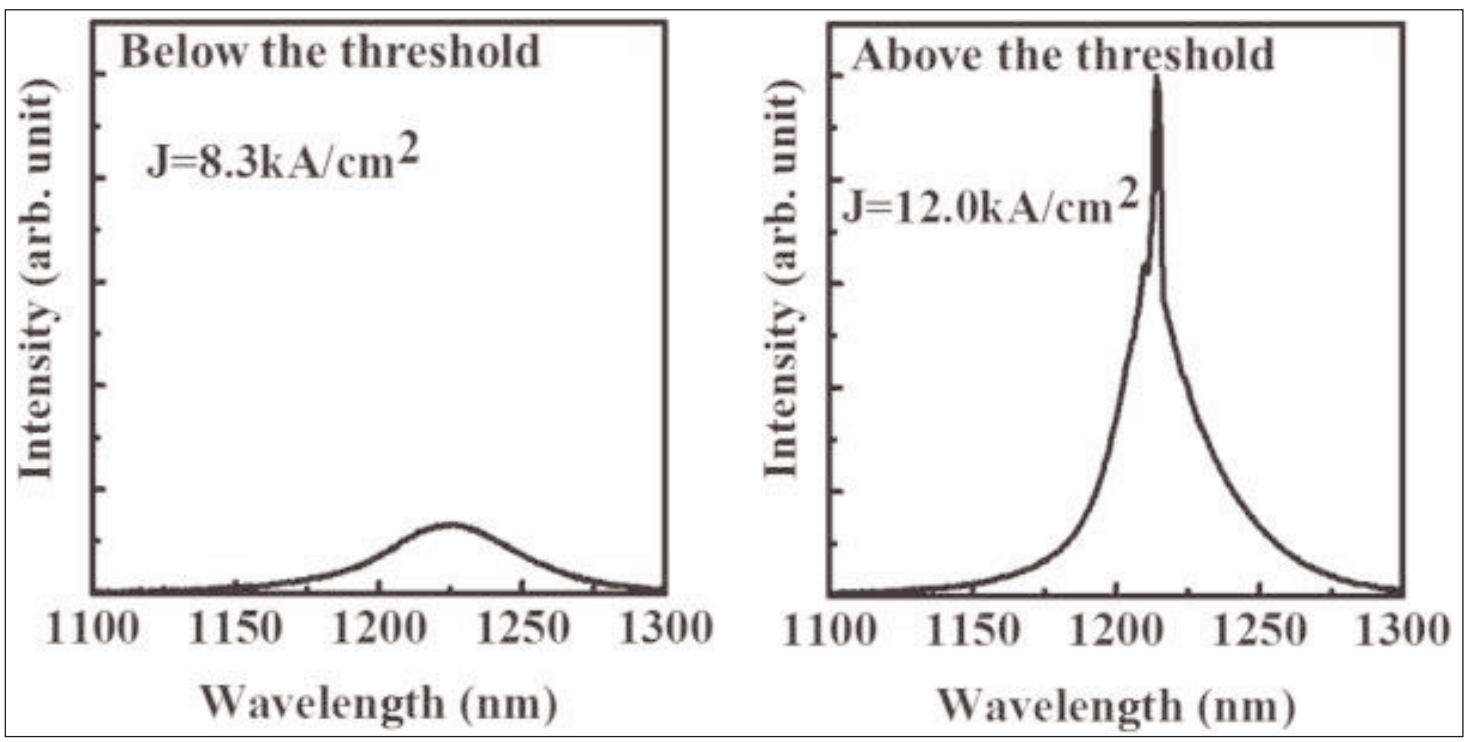


Figure 3. Comparison of laser diode spectra below (left) and above (right) threshold current density.

Extending interband cascade VCSEL wavelengths to 3.4µm

Electrically pumped device demonstrates pulsed threshold current density as low as 390A/cm^2.

The US Naval Research Laboratory and Sotera Defense Solutions in the USA have increased the wavelength of interband cascade vertical-cavity surface-emitting lasers (ICVCSELs) to 3.4µm, which "extends considerably the previous longest wavelength of 3.0µm for an electrically pumped vertical-cavity surface-emitting laser operating at room temperature," [W. W. Bewley et al, Appl. Phys. Lett., vol109, p151108, 2016].

The researchers add: "While threshold current densities as low as 390A/cm^2 at 25°C are several times higher than those of the best ICL edge emitters, they are nonetheless an order of magnitude lower than for the longest-wavelength (λ ~ 3.0µm) GaSb-based ICVCSEL with type-I quantum wells demonstrated to date."

Existing mid-wave infrared (mid-IR) interband cascade lasers use long-lived interband transitions in type-II antimonide quantum wells to generate photons. Electrons are regenerated between cascade stages, as in the more complex quantum cascade lasers that use intersubband transitions.

Edge-emitting interband cascade lasers have achieved threshold currents of 100A/cm^2 at an applied voltage of 4.5V in continuous-wave (cw) operation. Continuous-wave operation can be maintained up to 118°C. Wall-plug efficiencies of 18% have been reported for devices emitting in the 3µm to 6µm range.

ICVCSELs have achieved 3µm wavelengths, but with a high threshold of ~5kA/cm^2 at 25°C in pulsed mode.

The ~13µm epitaxial structure for the ICVCSEL (Figure 1) was grown by molecular beam epitaxy (MBE) on n-type gallium antimonide (n-GaSb) (100) crystal orientation substrate.

The bottom mirror consisted of 22.5 pairs of n-GaSb and aluminium arsenide antimonide (n-$AlAs_{0.08}Sb_{0.92}$) quarter-wavelength layers, grown at 500°C. The n-type doping was supplied by tellurium. The doping levels in the mirror structure increased toward the layer interfaces to reduce voltage drops. Superlattices consisting of 20-period 1nm/1nm n-GaSb/n-AlAs were used for transition between the quarter-wavelength layers. The growth was monitored with a custom near-IR laser interferometer to ensure layer uniformity. The mirror

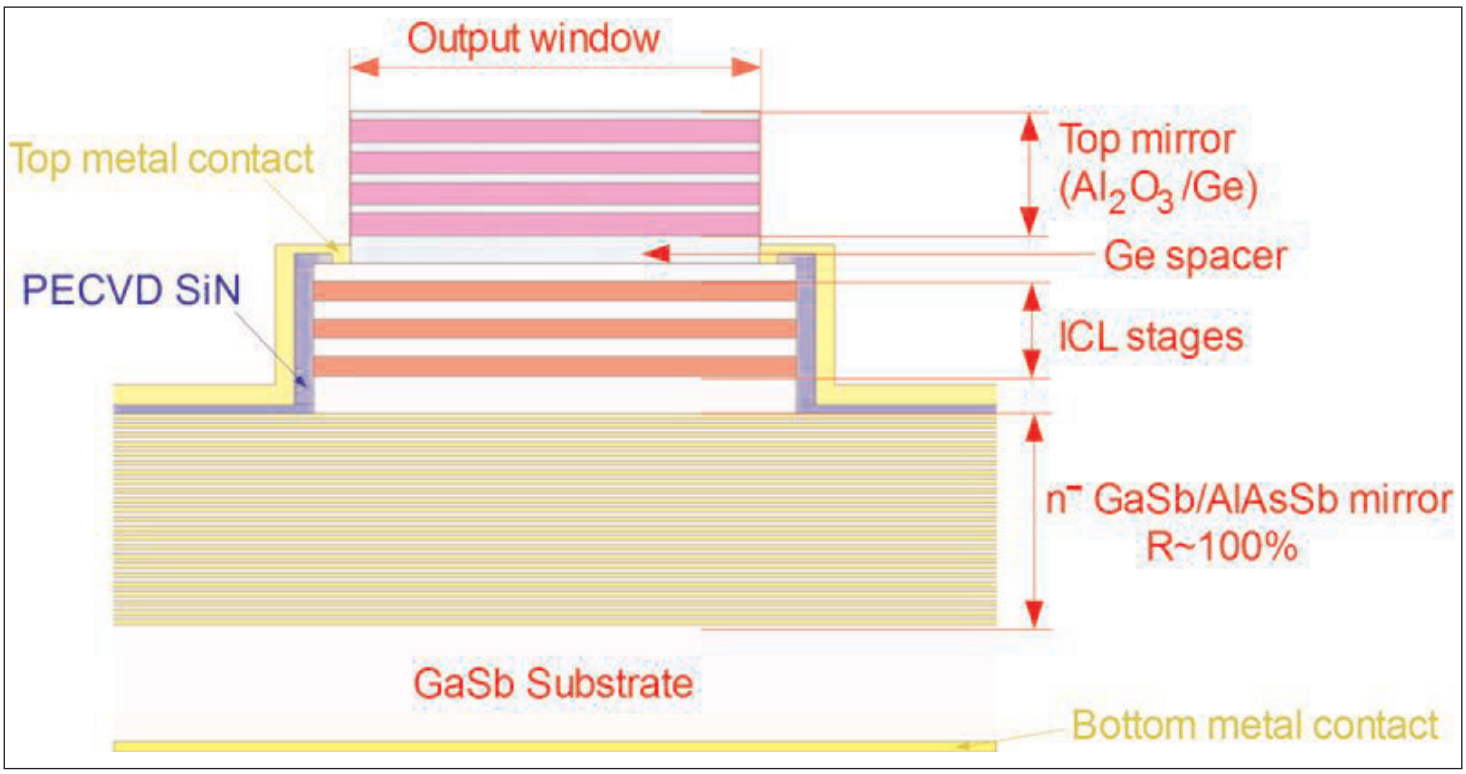


Figure 1. Schematic of ICVCSEL structure.

was designed to have a reflectivity of 99.5%.

The mirror was separated from the active region by an n^--GaSb spacer and 440°C 20nm chirped InAs/AlSb superlattice. These layers reduced the conduction band offset to a suitable level for electron injection into the active region.

The active region consisted of three groups containing five stages. The groups were separated by n^--GaSb spacers. The groups were place approximately at antinodes of the resonant cavity.

The semiconductor structuring was completed with a 90nm InAs/AlSb superlattice and 100nm n^+-$InAs_{0.91}Sb_{0.09}$ cap.

Fabrication consisted of dry etching circular mesas to a depth below all the active stages. plasma-enhanced chemical vapor deposition (PECVD) of 250nm silicon nitride, dry etch-back to expose the top contact window of the device, silicon dioxide sputtered and lifted-off to fill pin holes in the silicon nitride, formation of annular titanium/platinum/gold top contact on outer rim of mesa, deposition of chromium/tin/platinium/gold bottom contact on the back-side of the n-GaSb substrate, and deposition of four quarter-wavelength layers of germanium and aluminium oxide for the top mirror.

The top mirror coating extended over the mesa's sidewall. The top mirror reflectivity was estimated to be 99.3%. However, only 0.05% of the incident light was transmitted to the outside world. The researchers say that the source of parasitic absorption has not been definitively identified.

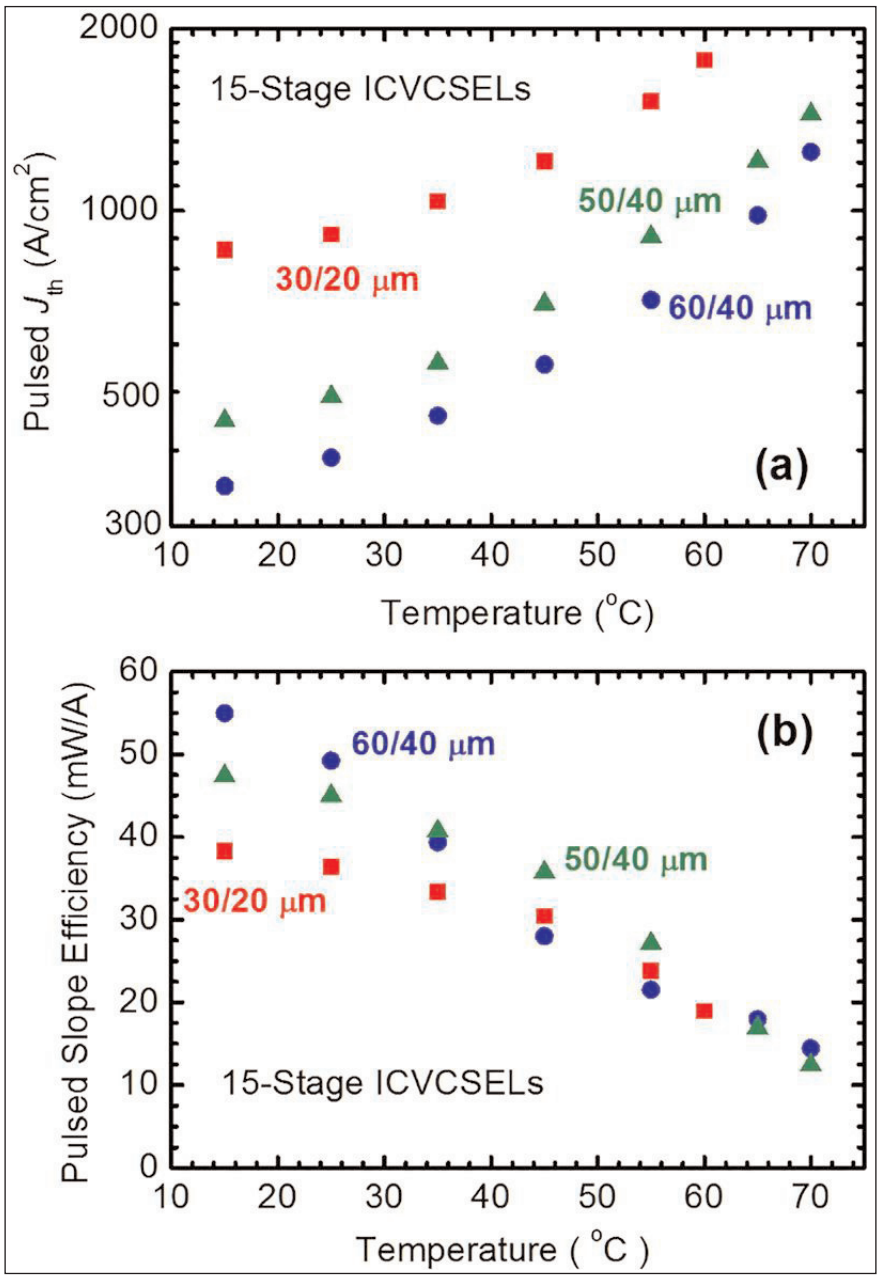


Figure 2. Threshold current densities (top) and slope efficiencies (bottom) versus operating temperature for three ICVCSELs.

Operation consisted of 150ns pulses at 100Hz repetition. Estimated threshold currents varied with mesa diameter. With 60μm-diameter (D, 40μm-diameter emission aperture, d) devices the threshold was 390A/cm^2. Smaller 30μm-diameter (20μm aperture) mesas increased the threshold to 920A/cm^2. "The former value is only 2–3 times higher than the typical pulsed results for state-of-the-art edge-emitting ICLs at RT," the team writes. Smaller devices with mesa diameters of 20μm and 10μm did not lase at all.

A 50μm-diameter (40μm aperture) ICVCSEL operated up to 70°C. However, the maximum output power of the device was only 0.54mW.

While the 50μm-diameter device shows peaks separated by 1.5nm in wavelength, the smaller 30μm ICVCSEL gives a single-mode emission.

The slope efficiency at 25°C ranged between 49mW/A for 60μm mesa (40μm aperture) ICVCSELs to 36mW/A for 30μm mesa (20μm aperture) ICVCSELs. The efficiency declines at increasing temperature. The researchers plan to improve the slope efficiency by refining their processing methodology. The team mainly blames high parasitic losses in the mirrors and, possibly, current spreading above threshold.

They conclude: "While the thermal impedance of the present structure is most likely too high to allow continuous-wave (cw) operation, it should be achievable with improved heat dissipation, e.g. in an epitaxial-side-down geometry. Once uniform lasing can be obtained within a smaller mesa diameter (e.g. D ~ 20μm), emission in a single spectral mode should be attainable at drive powers less than 10mW." ■

http://dx.doi.org/10.1063/1.4964840

Author: Mike Cooke

China: the future of world trade and the semiconductor industry

Mike Cooke looks at recent political developments in the light of frustrated Chinese attempts to take over western semiconductor companies.

There is a specter haunting world trade — the specter of protectionism. The fear is that this will solidify into trade war, such as devastated the world economy following the 1929 Wall Street crash. And trade war can easily morph beyond metaphorical aggression.

With the US Electoral College win of president-elect Donald Trump and the development of his transition team, the saber-rattling has already begun. At the center of the claims and counter-claims is the position of trade with China. Three of Trump's seven stated election policies on trade mention China by name [www.donaldjtrump.com/policies/trade]:

"5. Instruct the Treasury Secretary to label China a currency manipulator.

"6. Instruct the US Trade Representative to bring trade cases against China, both in this country and at the World Trade Organization. China's unfair subsidy behavior is prohibited by the terms of its entrance to the WTO.

"7. Use every lawful presidential power to remedy trade disputes if China does not stop its illegal activities, including its theft of American trade secrets — including the application of tariffs consistent with Section 201 and 301 of the Trade Act of 1974 and Section 232 of the Trade Expansion Act of 1962."

In addition, according to Trump [Tweet, 6 November 2012, www.twitter.com/realdonaldtrump/status/265895292191248385], "The concept of global warming was created by and for the Chinese in order to make US manufacturing non-competitive."

In some ways, Trump's rhetoric makes explicit the concerns that have been simmering through Sino–US relations for the past several years at various House and Senate committees and in the executive branch of the US federal government.

Days after the US election, China promised 'tit-for-tat' responses to any moves to impose tariffs on its exports to the USA. "A batch of Boeing orders will be replaced by Airbus," suggested an 'op-ed' in China's Global Times, owned by the Chinese Communist Party's People's Daily. "US auto and iPhone sales in China will suffer a setback, and US soybean and maize imports will be halted. China can also limit the number of Chinese students studying in the US." [www.globaltimes.cn/content/1017696.shtml]

On the other hand, Trump is expected to focus more on deal-making and less on issues such as human rights, in line with his 'America First' priority. Scrapping of the Trans-Pacific Partnership (TPP) trade deal would probably also be welcome in Beijing.

What has this to do with the semiconductor business? Recently, there has been a spate of merger and acquisition activities with Chinese investors seeking to take over US and European companies. Along with concerns about the loss of national control and pride in these entities come considerations regarding defense and security, Trump's "theft of American trade secrets" among them. Further, the dividing line between "Chinese investors", as individuals and corporate entities, and the Chinese government is unclear to say the least. Commercial success often leads to and from close ties with national governments, in China, the USA, and elsewhere.

As the preceding text shows, the US situation is uppermost in many minds in the preparations for the new presidency. But not all the moves have been along the US–China axis. The German Federal Ministry of Economics and Energy reopened review proceedings in October on a "cleared" deal regarding an offer made in May by China's Fujian Grand Chip Investment Fund LP (via German subsidiary Grand Chip Investment GmbH, GCI) to take over Germany's Aixtron SE, a leading producer of metal-organic chemical vapor deposition systems. [www.semiconductor-today.com/news_items/2016/oct/aixtron_241016.shtml]

The German federal government is concerned that Aixtron's security-related know-how, including technology used in defense industries, could be revealed through the takeover. By late October, GCI had received tenders for about 65% of Aixtron shares, meeting the 50.1% threshold needed for the deal.

It's not just the German government that's concerned. The Committee on Foreign Investment in the United States (CFIUS) has informed Aixtron–GCI that it has unresolved US national security concerns regarding the proposed transaction. CFIUS is further recommending that US President Obama should prohibit the transaction and Aixtron–GCI withdraw their notice, abandoning the deal.

Aixtron–GCI have decided not to follow the CFIUS recommendation and, at the time of writing, were

awaiting the President's decision (due in early December).

The companies comment: "GCI and Aixtron plan to continue to actively engage in further discussions to explore means of mitigation that may be amenable to CFIUS or the US President to resolve outstanding US national security concerns or to take other alternative measures that could allow the parties to proceed with the transaction. There are no assurances that CFIUS or the US President will entertain further dialogue with the parties or that the parties will be able to identify and agree to any mitigation or to take alternative measures that will allow the parties to proceed with the transaction."

Another Chinese company with an interest in buying a German company is San'an Optoelectronics Co Ltd, which has had preliminary discussions about acquisition or partnership with laser and LED manufacturer Osram, although no agreements have been reached or proposed, let alone signed [www.reuters.com/finance/stocks/600703.SS/key-developments/article/3451194, www.ledinside.com/news/2016/10/sanan_opto_refutes_plans_of_acquiring_osram]. Reuters estimated that such a deal would be worth about €7.2bn. However, San'an stressed in early October that only one joint meeting had taken place on the issue. An acquisition could take place in stages, initially of the Osram Opto business, with automotive and specialty lighting being reserved for subsequent deals.

"Chinese investors have been approaching Osram for some time regarding acquisition talks," according to Roger Chu, director of research at market analyst LEDinside. "If San'an Opto intends to acquire Osram, though, it will probably require funding from the Chinese government."

GCI and Aixtron plan to continue to actively engage in further discussions

Fuelling the market rumor mill has been reports of dissatisfaction with Osram by its largest 17% shareholder, Siemens. In particular, Siemens is apparently unhappy with Osram's €3bn investment plans for the period up to 2020 that involve setting up a new €1bn 6-inch fab in Malaysia for general lighting and white LEDs, along with €2bn R&D funding targeted at work in areas such as smart city applications, wireless lighting control, laser and organic LED technology.

For its part, Siemens was rumored to be looking to sell its Osram shares to China's Go Scale Capital in September [www.ledinside.com/news/2016/10/government_policy_undertones_in_chinese_investors_interests_in_acquiring_osram]. Previously, in January, Go Scale Capital was frustrated by CFIUS intervention in its attempts to acquire US-based LED maker Philips Lumileds for $3.3bn.

San'an claims that it is the largest and earliest-established industrial production base for top-quality full-color ultra-high-brightness LED epitaxial wafers and chips in China. San'an also produces compound solar cells and III-V compound semiconductor devices for microwave integrated circuits and power electronics based on 6-inch gallium nitride facilities. On the optoelectronics side, the company is promoting LED intelligent lighting communication (LiFi), car networking systems and opto-electronic intelligent monitoring products. Production cleanrooms have ratings from level 100 to level 10,000. The company claims annual production of 24 million epitaxial wafers and 300 billion chips, accounting for more than 58% of domestic production capacity, giving it the first place in the China market.

San'an Opto subsidiary Xiamen San'an Integrated Circuit was also reported in March as offering to acquire Taiwan-based power electronics & opto chip foundry GCS Holdings Inc, including its California-based subsidiary Global Communication Semiconductors LLC (GCS, www.gcsincorp.com) for $226m. This move was rejected by CFIUS in early August.

In response, GCS agreed to set up a China-based joint-venture 6-inch facility for radio frequency, power and fiber optic integrated circuits with Xiamen San'an Integrated Circuit Co Ltd, to be named Xiamen Global Advanced Semiconductor, according to Taipei Times. According to information on the Taiwan Stock Exchange Market Observation Post System (in Chinese, 10 November, translated by google), the expressed purposes of the move are to expand operation scales, enhance profitability and strengthen competitiveness by combining production capacity and technical superiority of both companies. The joint venture also involves Xiamen City, Fujian Province. The registered capital is given as $4m with 49% ($1.96m) coming from GCS. Xiamen San'an Integrated Circuit Co Ltd is to make up the remaining $2.04m in cash (51%). GCS Holdings Inc, the Cayman Islands-registered and Taiwan-listed owner of GCS LLC, put its assets at TWD2.7bn (~ $80m) in its 31 March financial report.

GCS produces photodetectors and vertical-cavity surface emitting lasers (VCSELs) based on indium gallium arsenide technology. Wafer foundry services include gallium arsenide and gallium nitride radio frequency electronics, indium phosphide heterojunction bipolar transistors, gallium nitride power devices, and optoelectronics. Its production capacity is presently based on 4-inch wafers. One motivation for working with San'an was to expand into 6-inch production.

As is usual in such cases, mergers and acquisition activity strengthened share prices in the target companies, which then fall as the deals met with government obstructions. An interesting connection between the San'an group of manoeuvres and the attempted GCI–Aixtron deal was San'an failing to qualify an Aixtron's AIX R6 metal-organic chemical vapor deposition system as part of a multi-system order in early 2016. In addition to truncating the order, Aixtron's shares fell in value, putting the business under pressure. ■

Seeking source of green gap in InGaN light-emitting diodes

Findings exclude inferior InGaN material quality from the list of potential causes.

Researchers based in Germany and Russia have used temperature-dependent measurements to explore the source of the green gap in indium gallium nitride (InGaN) light-emitting diode (LED) efficiency [Felix Nippert et al, Appl. Phys. Lett., vol109, p161103, 2016].

The team from Technische Universität Berlin in Germany, STR Group–Soft-Impact Ltd in Russia, and Osram Opto Semiconductors in Germany used 'state-of-the-art' devices produced using metal-organic chemical vapor deposition (MOCVD) on c-plane sapphire and packaged using Osram's commercial Golden Dragon+ process.

Two types of LED were studied with different emission wavelengths: blue 445nm and green 530nm. "Our findings exclude inferior InGaN material quality from the list of potential causes for the green gap," the team says.

The active regions consisted of five and seven InGaN multiple quantum wells (MQWs) for 445nm and 530nm, respectively. The barriers between the wells were GaN. The structure included an aluminium gallium nitride (AlGaN) electron-blocking layer before the magnesium-doped GaN p-contact.

The recombination was categorized according to the ABC model where the linear term in the carrier density (A) is associated with the Shockley-Read-Hall (SRH) process through defect states, the quadratic term (B) with photon production, and the cubic term (C) with Auger three-particle interactions.

The researchers used small-signal time-resolved photoluminescence (SSTRPL) to probe external quantum efficiency (EQE) and differential carrier lifetime (DLT) as a function of operating current. Determination of the DLT allowed extraction of the SRH A coefficient and of the sheet radiative, B_{2D}, and Auger, C_{2D}, coefficients.

The team notes that its measurements below 150K deviated from the ABC model with the internal quantum efficiency (IQE) being higher than predicted. It is found that below this temperature the recombination coefficients are dependent on the injection level. They therefore restricted themselves to temperatures where the ABC model held with constant coefficients.

DLTs were found to decrease with increasing current injection (Figure 1). The IQE for the green devices was much lower than that of the blue LEDs. Also, the green IQE degraded faster with temperature.

Despite the different IQE behaviors, extracted SRH recombination was almost the same for the two device types (Figure 2). The researchers comment: "Usually,

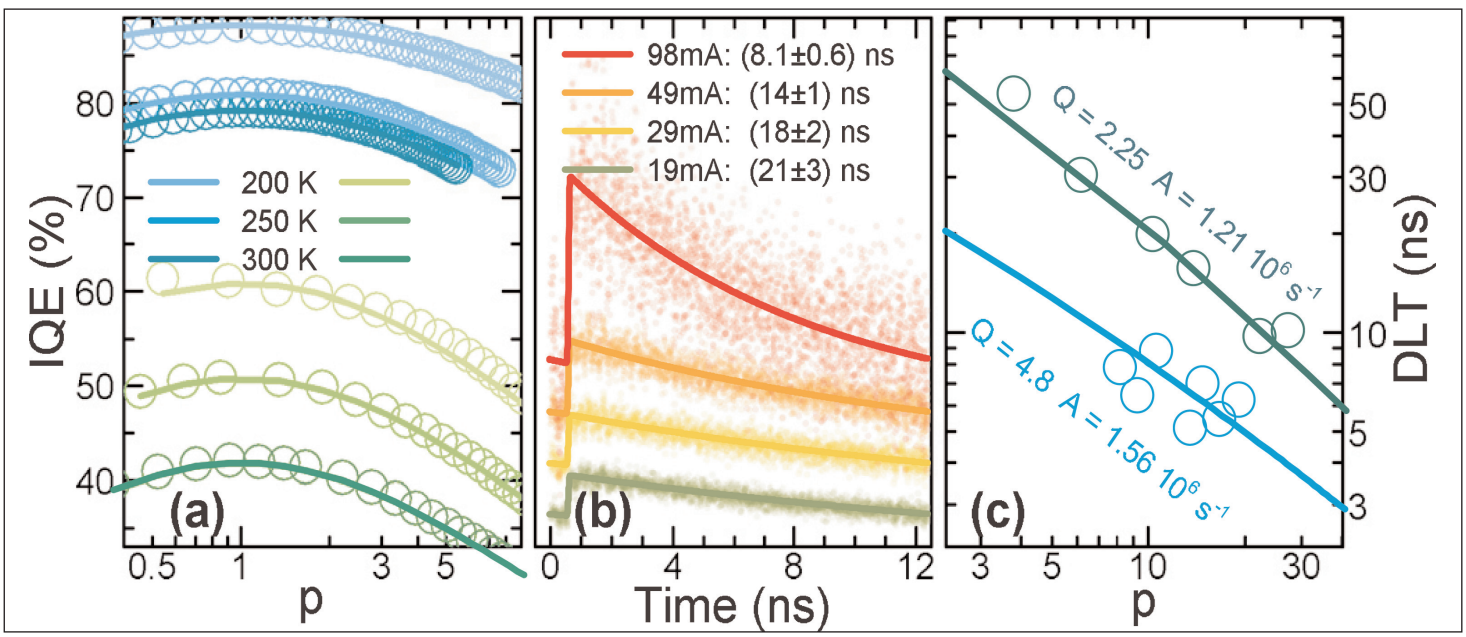


Figure 1. (a) IQE as function of normalized optical output power (p = 1 at maximum EQE) for blue and green MQW LEDs at different temperatures. Circles correspond to data points, while solid lines are fits based on ABC model. (b) SSTRPL traces for green devices at 300K at various currents. Circles correspond to data points and solid lines show mono-exponential fits. (c) Example evaluation of SRH-RC A. Blue (green) points are measured DLTs of blue (green) MQW LED at 300K. Solid lines depict fits to data.

the green gap is explained by a rise in the point/structural defect density in the InGaN QWs with high indium content — an enhanced SRH recombination — or by a decreased overlap between electron and hole wavefunctions due to the [quantum-confined Stark effect] QCSE, lowering the radiative recombination. Naturally, also a combination of both factors seems plausible at first glance. In contrast, we have obtained almost identical SRH RCs A for our blue (445nm) and green (530nm) LEDs over the whole temperature range (see Fig. 2(a)).”

The difference in performance was revealed by the reduced sheet radiative and Auger recombination of the green LEDs (Figures 2(b), (c)). There is some uncertainty due to possible differences in contribution of the quantum wells. In general, InGaN quantum well structures under electroluminescence tend to have higher emission from wells near the p-type hole-injection end as opposed to the n-contact layer.

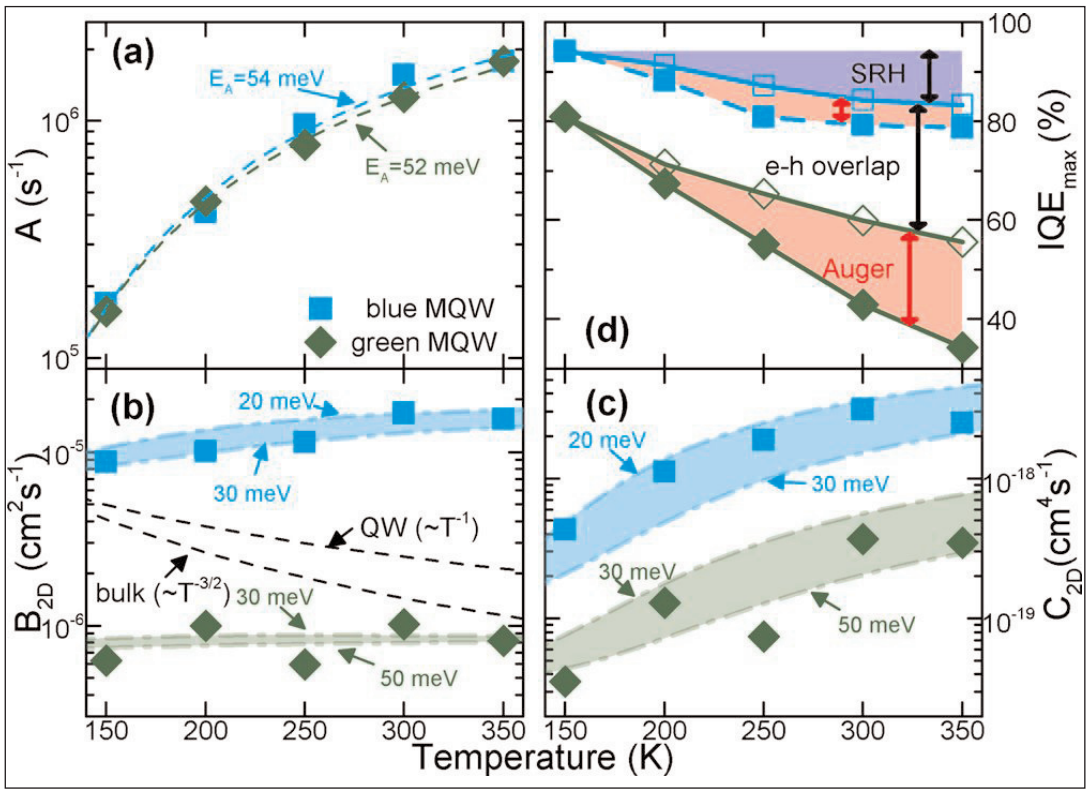


Figure 2. Temperature dependence of RCs corresponding to (a) SRH, (b) radiative and (c) Auger recombination. Blue squares (green diamonds) refer to blue-emitting (green-emitting) MQW LEDs. Shaded areas: theoretical estimates made for certain ranges of hole localization energy. (d) Temperature dependence of IQE. Open symbols: values derived assuming that B_{2D} & C_{2D} do not vary with temperature above 150K. Shaded areas: impact of several mechanisms to IQE reduction. Dashed lines in panel (a), (b): fits of activation energy EA of SRH recombination, and expected temperature dependence of B in bulk and QW material, respectively.

The researchers believe that the differences in B and C recombination is attributable to reduced electron–hole overlap for the green compared with the blue devices. The radiative and Auger recombination coefficients (RCs) were also seen to increase with temperature, T. The researchers comment: “While the rise of the Auger RCs with T does not conflict qualitatively with available models considering phonon-assisted processes, a corresponding rise of the radiative RCs (blue LED) or an almost constant behaviour (green LED) is anomalous, as either a proportionality to $T^{-3/2}$ (bulk materials), to T^{-1} (QWs), or no temperature dependence (quantum dots) is expected in semiconductors (compare with dashed lines in Fig. 2(b)).”

The researchers do not think the reduction in overlap can be explained exclusively by the quantum-confined Stark effect that arises from electric fields between increased polarization charges at quantum well interfaces, enhanced by the higher indium content of InGaN alloys needed for longer-wavelength green light emission. Rather, they propose a model where the recombination occurs between delocalized electrons and localized holes.

Localization occurs because of the higher effective mass of the holes. “We consider that a few neighboring indium atoms may provide effective carrier localization in InGaN,” the researchers comment. The radiative recombination was assumed to result from hydrogen-like hole wavefunctions. Increasing temperature increases the effective localization radius, which increases the recombination. The hole localization has a similar effect on Auger recombination involving two delocalized electrons and a localized hole.

The team blames about half the decrease in IQE in green quantum wells at the usual LED operating temperature of 350K on decreased electron–hole overlap. Additional losses come from the temperature dependence of the radiative and Auger processes. In particular, while the radiative process increases only weakly with temperature, non-radiative Auger recombination increases steeply, becoming a significant contributor to the green gap.

The team writes: “Any rise in charge carrier localization enhances the electron–phonon coupling, favoring phonon-assisted Auger processes and their impact on the IQE reduction.” ■

http://dx.doi.org/10.1063/1.4965298

Author: Mike Cooke

Photo-electro-chemical lift-off of free-standing gallium nitride

Batch process causes no damage and is compatible with growth substrate, enabling reuse and process cost reduction.

University of California Santa Barbara (UCSB) in the USA has used photo-electro-chemical (PEC) etch to lift-off c-plane free-standing gallium nitride (GaN) from light-emitting diode (LED) structures as part of a thin-film flip-chip fabrication process [David Hwang et al, Optics Express, vol. 24, p22875, 2016].

The team sees PEC lift-off as an alternative to laser-based techniques. "PEC lift-off causes no damage to the devices, is a batch process as all LEDs are undercut at the same time, is compatible with free-standing GaN substrates, and enables substrate reuse," the researchers write. By contrast, laser lift-off of sapphire growth substrates is a slow chip-by-chip process and has the potential to cause cracking of the LEDs, reducing yield. The laser technique cannot be used for LEDs on free-standing GaN or silicon carbide growth substrates.

Flip-chip orientations for LED fabrication give high light extraction, improved heat extraction, and decreased current crowding. LED performance degrades where there is increased temperature and/or current density.

Using free-standing growth substrates can improve performance by reducing dislocation densities in the light-emitting material, increasing efficiency. However, free-standing GaN substrates are extremely expensive, and reuse should reduce potential production costs. For ultraviolet LEDs, GaN material absorbs the radiation generated and must be removed.

The free-standing c-plane GaN used by UCSB was supplied by Sciocs Company Ltd. The epitaxial structure was grown by metal-organic chemical vapor deposition (Figure 1).

The sacrificial layer consisted of a 6-period multiple quantum well (MQW) of 2.5nm InGaN separated by

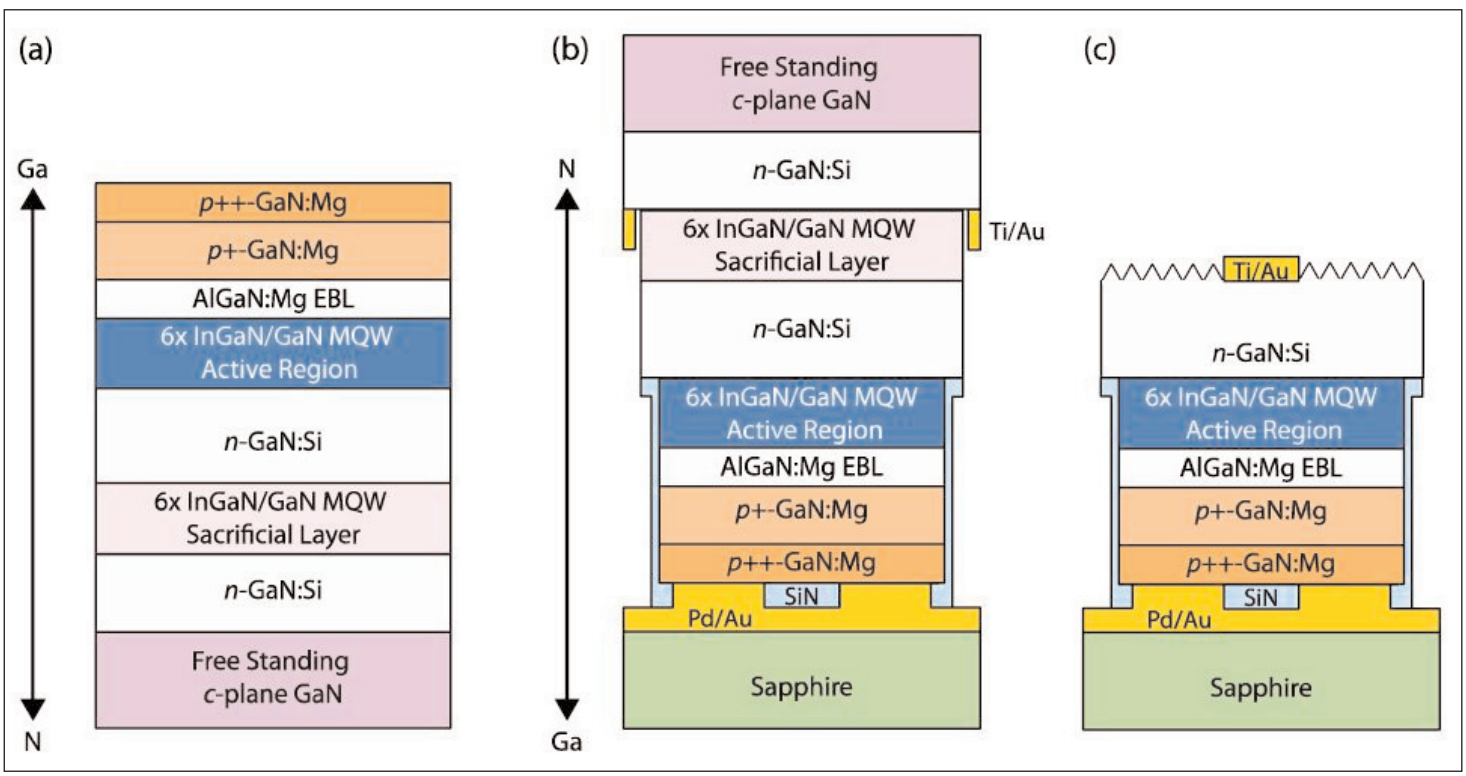


Figure 1. Cross-sectional schematic of (a) as-grown epitaxial structure, (b) partially processed sample after wafer-bonding and before PEC etching, and (c) completely processed sample with p-GaN down and N-face of n-GaN up.

7nm GaN barriers, grown on 1.5μm n-GaN. The structure had a 430nm wavelength photoluminescence peak.

The LED part of the structure contained a 3μm n-GaN contact, another 6x(2.5nm/7nm) MQW with emission at 440nm, a 10nm p-AlGaN electron-blocking layer (EBL), a 110nm p^+-GaN contact, and a 20nm p^{++}-GaN contact.

Fabrication began with plasma mesa etch down to the n-GaN contact layer above the sacrificial MQW. The sidewalls of the mesa were covered by plasma-enhanced chemical vapor deposition (PECVD) of silicon nitride that protected the LED structure during the photo-electro-chemical etch. Palladium/gold metals were electron-beam evaporated onto the p-GaN contact. The top gold also provided a bonding pad for the flip-chip assembly process.

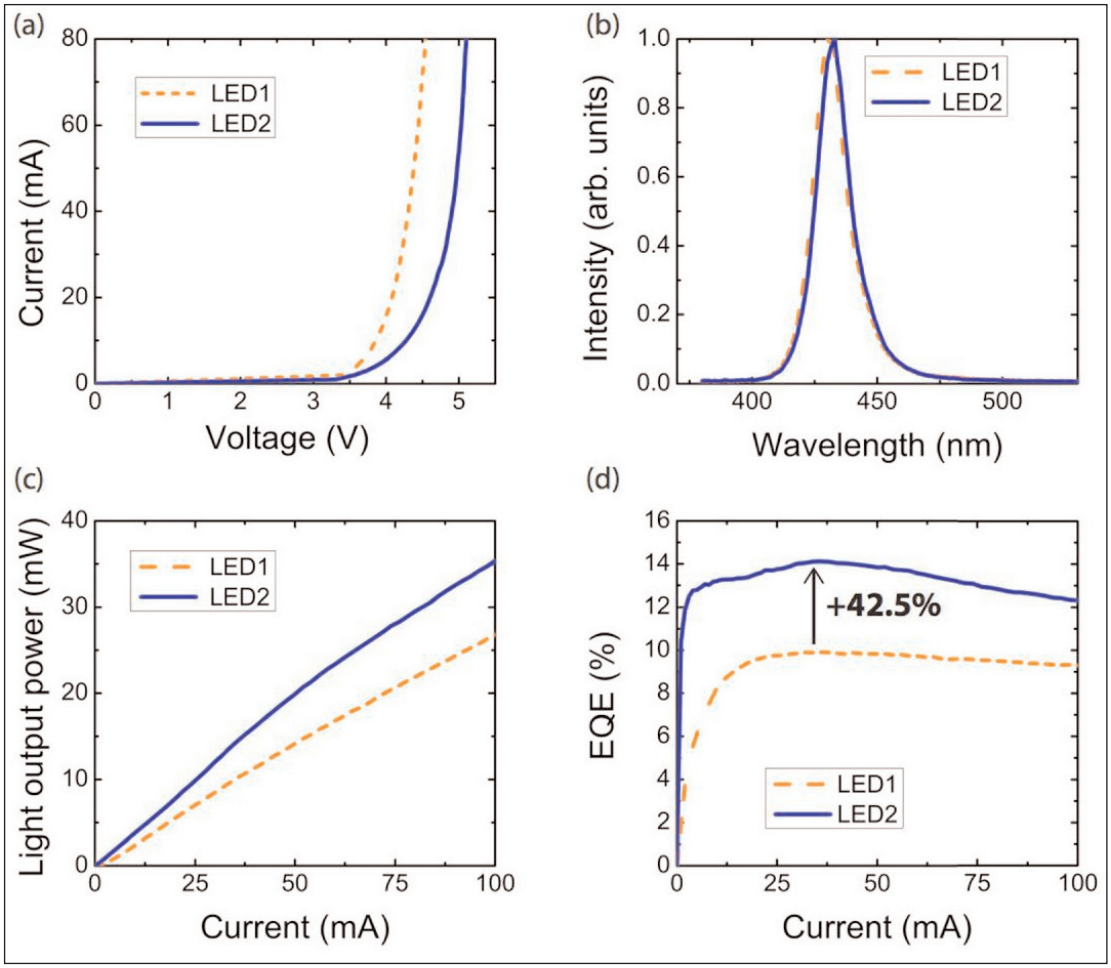


Figure 2. (a) Current–voltage curve for LEDs 1 and 2 after flip-chip processing: 1mA of current corresponds to current density of 1A/cm^2. (b) Electroluminescence spectra showing peak wavelength. (c) Dependence of light output power on current. (d) Dependence of EQE on current.

The sacrificial region was prepared by another plasma etch to expose the sidewalls of the respective MQW structure outside the area defined by the 0.1mm^2 LED mesa. A titanium/gold electrode was deposited on the 1.5μm n-GaN as a cathode for the photo-electro-chemical etch.

The structure was flipped and bonded onto sapphire coated with titanium/gold. Then the photo-electro-chemical etch was carried out with backside illumination and potassium hydroxide solution for five hours. The light source was an array of 405nm LEDs. After the free-standing GaN substrate was removed, the n-electrode of titanium/gold was deposited.

The PEC etch proceeds by the holes from electron-hole photo-generation reacting with the potassium hydroxide solution, oxidizing the sacrificial MQW. The titanium/gold electrode extracted the excess electrons into the solution.

Some of the resulting devices were further etched in potassium hydroxide solution without illumination to further roughen the emission surface, improving light extraction efficiency. Without the extra etch there was still some unintentional roughening from the PEC lift-off etch.

The devices were packaged by dicing, mounting on silver headers, wire-bonding, and encapsulating in 1.4-refractive index silicone.

An LED without extra surface roughening (LED 1) had a 3.5V turn-on, while an LED with roughening (LED 2) had a higher turn-on. The researchers believe this was due to variations in growth across the wafer. The LED 2, however, had much improved light output — 14.6mW output power and 14.1% external quantum efficiency (EQE) at 36A/cm^2 current density, compared with 10.3mW and 9.9% for LED 1 (Figure 2). "Roughening resulted in a 42% improvement in output power and EQE," the team writes. The 432nm emission peaks of the devices were similar with full-width at half maximum (FWHM) of 15nm.

In absolute terms there needs to be improvement in output power and EQE. The team suggests that this could be addressed through growth optimizations, incorporating a reflective silver-based p-contact to improve extraction efficiency, and a high-thermal-conductivity silicon carbide submount to improve heat extraction. ■

http://dx.doi.org/10.1364/OE.24.022875

Author: Mike Cooke

Low-resistance tunnel junction boosts InGaN nanowire LED performance

Turn-on voltage reduced to 2.9V by inserting aluminium layer between heavily doped regions, reducing tunneling width.

McGill University in Canada has developed an indium gallium nitride (InGaN) nanowire light-emitting diode (LED) that incorporates "for the first time" a tunnel junction with a thin aluminium (Al) layer inserted between heavily doped (n^{++}/p^{++}) gallium nitride sections [S. M. Sadaf et al, Nano Lett. 2016, vol16, p1076, 2016]. The LED demonstrated reduced 2.9V turn-on voltage and enhanced output power compared with devices using tunnel junctions with no aluminium interlayer or without a tunnel junction.

The researchers comment: "This unique Al tunnel junction overcomes some of the critical issues related to conventional GaN-based tunnel junction designs, including stress relaxation, wide depletion region, and light absorption, and holds tremendous promise for realizing low-resistivity, high-brightness III-nitride nanowire LEDs in the visible and deep ultraviolet spectral range. Moreover, the demonstration of monolithic integration of metal and semiconductor nanowire heterojunctions provides a seamless platform for realizing a broad range of multi-functional nanoscale electronic and photonic devices."

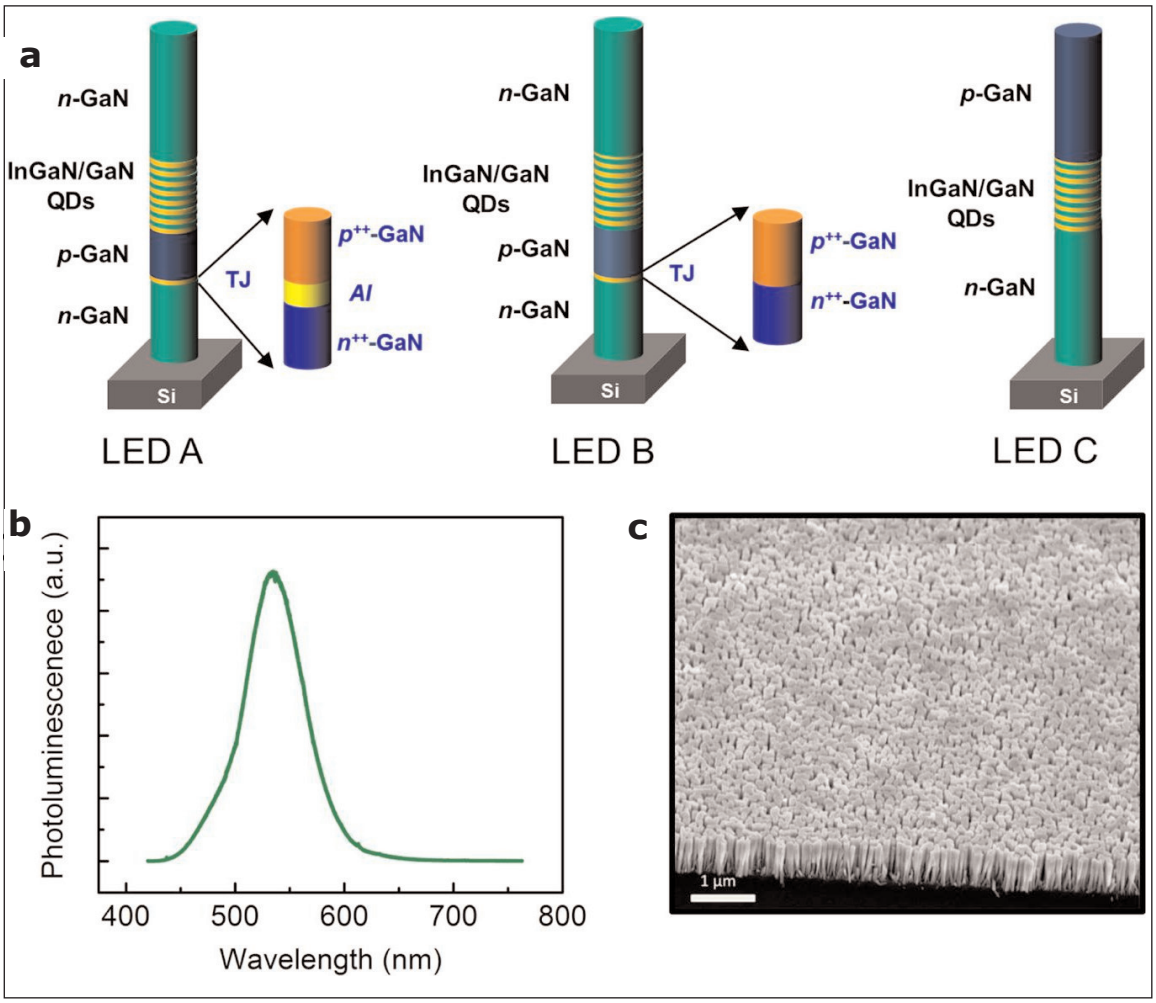


Figure 1. (a) Schematic of LEDs with Al tunnel junction dot-in-a-wire (LED A), n^{++}-GaN/p^{++}-GaN tunnel junction (LED B), conventional nanowire without tunnel junction (LED C). (b) Photoluminescence of LED A at room temperature. (c) Scanning electron microscope image of LED A at 45° angle.

Efficient tunnel junctions are difficult to achieve in wide-bandgap materials such as GaN. The high doping needed is particularly challenging for p-type conduction where the high activation energy of magnesium in GaN leads to low acceptor ionization efficiency. A large depletion width results across which it is difficult to tunnel.

Aluminium has a 4.08eV work function consistent with an ohmic contact with n-GaN. Defects at Al/p^{++}-GaN interfaces "result in deep energy levels,

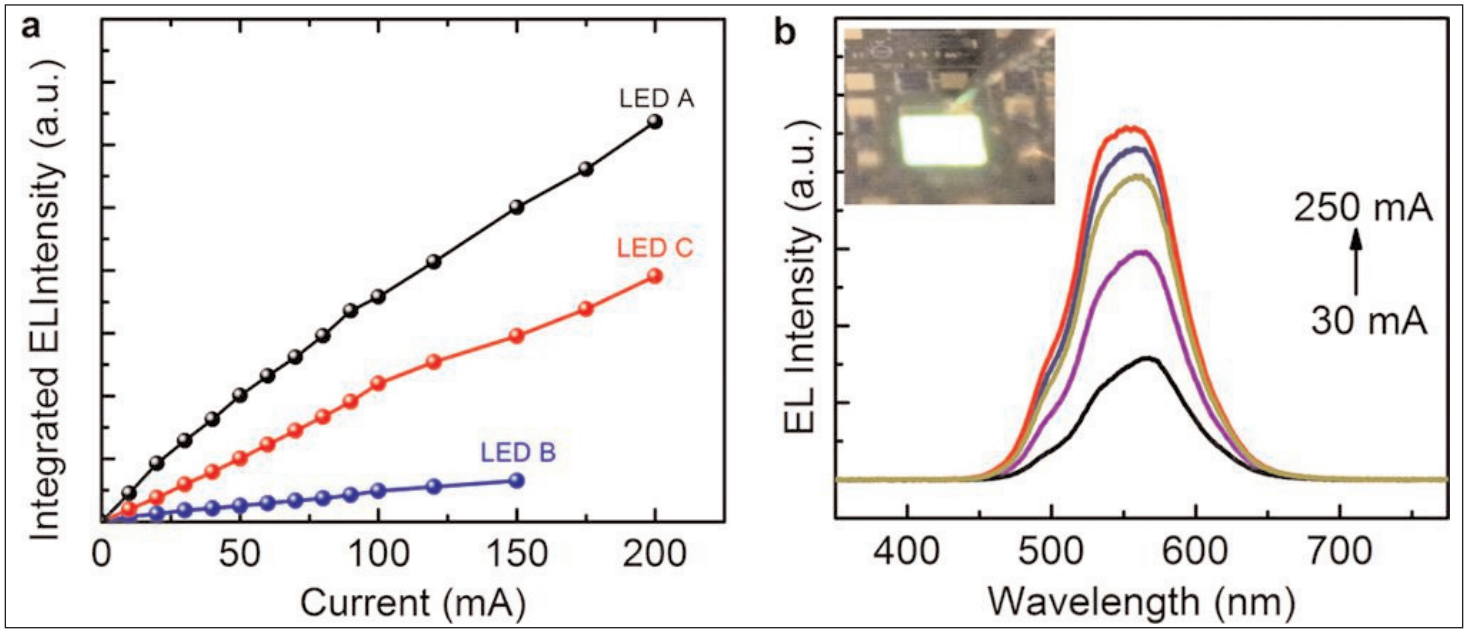


Figure 2. (a) Light output–voltage characteristics of LEDs. (b) Electroluminescence (EL) spectra of LED A under pulsed biasing. Inset optical micrograph of LED A showing strong green light emission.

which can significantly enhance carrier transport from p-GaN to Al in a similar manner to conventional trap-assisted tunneling," the researchers say. The quasi-ohmic characteristics of the Al/p^{++}-GaN junction should reduce the tunneling width significantly. The Al interlayer can also reflect generated light, enhancing extraction.

Three types of vertical nanowire structure were produced by plasma-assisted molecular beam epitaxy (PAMBE) on n-silicon (111) substrate (Figure 1). The new structure — LED A — incorporated a tunnel junction with 7nm n^{++}-GaN, 2nm Al, and 10nm p^{++}-GaN. LED B used a traditional tunnel junction without the aluminium interlayer. LED C was a device without tunnel junction.

The p- and n-type regions of the devices were grown at 750°C and 780°C, respectively. The Al layer of the tunnel junction was deposited at 450°C and was capped with Ga. The p^{++}-GaN for the tunnel junction was grown at 650°C. These temperatures were derived from series of optimization experiments. The optimized conditions achieved an Al layer that was free of voids or agglomeration.

The active regions of the devices consisted of 10 layers of strain-induced self-organized 3nm InGaN quantum dots and 3nm GaN barriers. The dots were p-doped to enhance hole injection and transport. There were no AlGaN electron-blocking layers.

Photoluminescence from the three structures was "nearly identical", according to the team, with a single peak at 534nm from the quantum dot layer. Variations in indium composition led to inhomogeneous broadening of the peak. Electron microscopy gave a density of the nanowires of the order of $10^{10}/cm^2$. The diameters ranged between 40nm and 100nm.

Electron microscope and x-ray analysis suggested that the aluminium layer did not introduce performance-killing defects such as stacking faults or threading dislocations into the LED structure.

Device fabrication consisted of deposition and planarization of a polyimide resist layer, contact metallization and thermal annealing. The contacts with n-type layers were titanium/gold. The p-type contact for LED C was nickel/gold. The contacts were made to the top of the nanowires and the back-side of the silicon substrate. A 120nm indium tin oxide (ITO) transparent conducting layer was added for current spreading. The device area was 0.5mmx.0.5mm with 30% nanowire filling factor.

LED A showed a sharper turn-on of current beyond 2.9V, compared with the other devices. The specific resistance at 400mA was $4x10^{-3}\Omega$-cm^2. These values compare with a 5.5V turn-on and $5x10^{-2}\Omega$-cm^2 specific resistance for LED B with standard tunnel junction. The standard nanowire LED C without tunnel junction had an intermediate current-voltage performance.

The researchers estimate that the contribution of the Al-based tunnel junction to the series specific resistance is $1x10^{-3}\Omega$-cm^2 or lower.

Similarly, the light output under 10% duty-cycle pulsed operation from LED A was improved over that from LEDs B or C (Figure 2). The pulsed operation was designed to avoid the junction heating that occurs under continuous wave conditions. "The significantly improved light intensity is largely due to the efficient tunnel injection of holes into the active region," the team comments. The researchers also report that there was no shift in the spectrum with increasing current.

The team hopes that core-shell nanowire structures could lead to high-power operation by reducing non-radiative surface recombination. ■

http://dx.doi.org/10.1021/acs.nanolett.5b04215

Author: Mike Cooke

Integrating gallium nitride LED with silicon drive transistor

Researchers wafer bond silicon-on-insulator layers to GaN-on-sapphire LED substrate and fabricate MOSFETs.

Toyohashi University of Technology in Japan has developed a wafer bonding technique to combine silicon metal-oxide-semiconductor field-effect transistor (MOSFET) electronics with gallium nitride (GaN) micro-light-emitting diodes (μLEDs) [Kazuaki Tsuchiyama et al, Appl. Phys. Express, vol9, p104101, 2016]. The researchers also see prospects for the integration of silicon electronics with high-voltage/high-frequency GaN transistors.

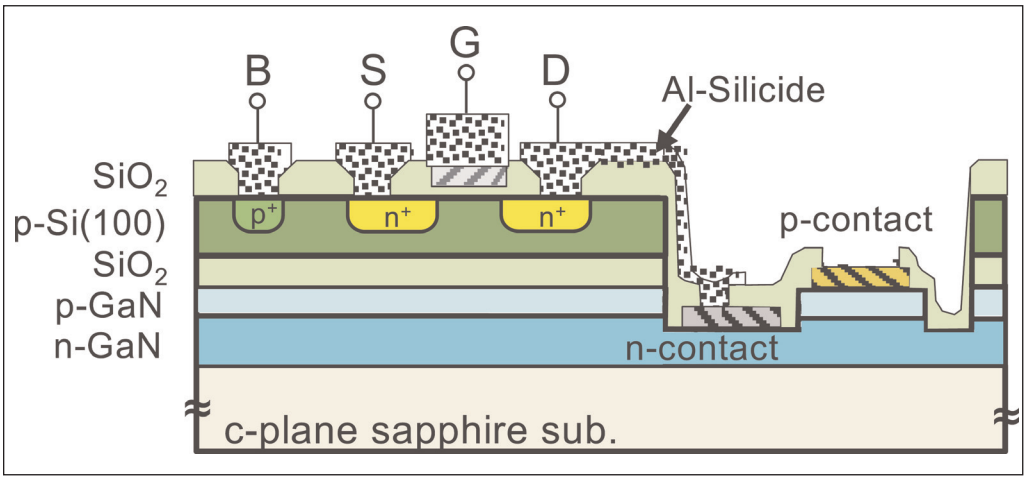


Figure 1. Schematic cross section of GaN-μLED driver circuit consisting of silicon n-MOSFET and GaN-μLED.

The electronics were fabricated in a 340nm silicon layer on 400nm buried silicon dioxide (SiO_2, BOX) electrical insulator on a GaN LED wafer (Figure 1). The researchers comment: "With such a structure, the thermal decomposition of the GaN layer and the contamination of the Si layer under a high-temperature process can be prevented because the GaN layer is capped with the top-Si layer during the Si device process."

The layer thicknesses were also chosen to avoid cracking, since thicker layers tend to crack due to mismatches in thermal expansion coefficients.

The transistor structure was fabricated before selective etch that removed silicon materials from the region where LEDs were planned. Finally, metal wiring, including the gate electrode, was deposited to form the n-MOSFET drive circuit and μLED combination.

The team comments: "This structure and process flow had high compatibility with a traditional Si planar process, and thus the utilization of a Si CMOS process line was possible."

The $Si/SiO_2/GaN$ structure was created using surface-activated bonding of silicon-on-insulator (SOI) and GaN-LED on sapphire wafers. The buried oxide came from low-pressure chemical vapor deposition of silicon dioxide on the GaN-LED wafer. The silicon handle of the SOI wafer was removed by grinding and dry etch.

The doping of the MOSFET regions was achieved by ion implant with a plasma-enhanced chemical vapor deposition (PECVD) layer of SiO_2. The n-type source and drain regions (S/D) were achieved with phosphorus doping and the p^+ body contact (B) with boron. The gate insulator was SiO_2 from a high-temperature (900°C) wet oxidation. The high temperature also annealed and activated the doping implants.

The LEDs consisted of mesa structures with annealed titanium/aluminium/titanium/gold n- and nickel/silver/nickel p-contacts.

The MOSFET gate electrode was aluminium rather than the more usual polysilicon. The wafer was passivated with more PECVD SiO_2 in which contact holes are etched out. Aluminium silicide (Al-Si) was sputtered and patterned to give the wire connections between components.

The size of the LED was 30μmx30μm. The n-MOSFET gate was 10μm long and 100μm wide. The researchers give the LED/MOSFET footprint ratio as approximately 0.125.

Characterization of independent n-MOSFETs on the same wafer gave a threshold voltage of about 0.8V at 5V drain bias. The transconductance was 0.62mS/mm. Independent LEDs achieved an external quantum efficiency (EQE) of 6.7% and a turn-on voltage of 3V.

The spectral peak was around 460nm wavelength with 22nm full-width at half-maximum (FWHM). The LED performance was similar to that of devices fabricated on raw GaN LED substrates without silicon layers.

The MOSFET-LED integrated circuit was tested for up to 10MHz pulse modulation with a square signal delivered to the gate of the MOSFET (Figure 2). The response of the circuit showed the effects of parasitic capacitance that will need to be reduced for higher-bandwidth performance.

The researchers point out that the 5μm design rule used in the CMOS fabrication is equivalent to what was used in 1970s ~10MHz microprocessors. The team suggests that scaling down the design rule would increase performance without LED drivability deterioration. ■

http://doi.org/10.7567/APEX.9.104101

Author: Mike Cooke

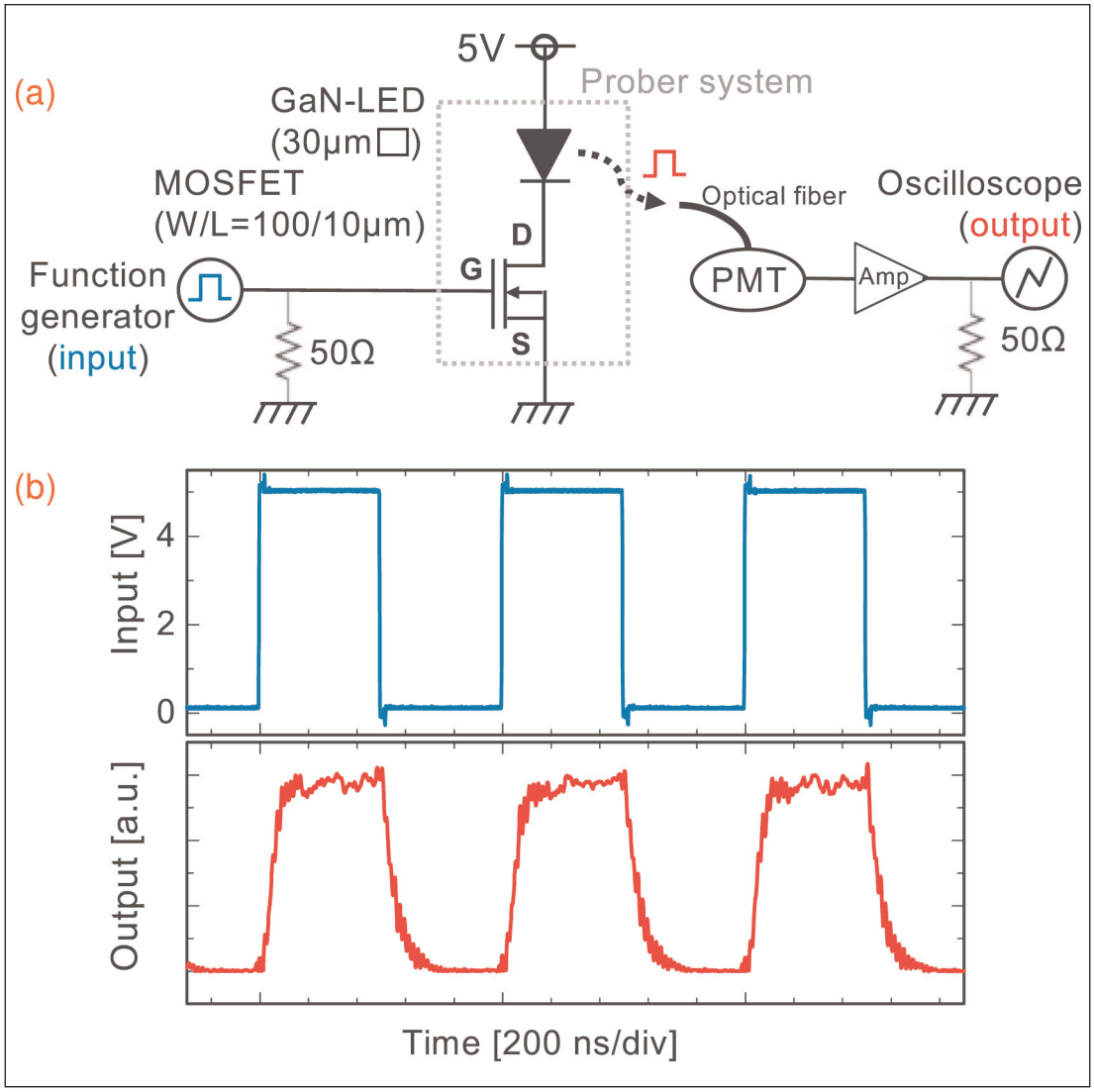


Figure 2. (a) Pulse driving system for evaluating dynamic characteristics of GaN-μLED driver circuit. (b) 1MHz input voltage signal applied to gate of silicon n-MOSFET (blue) and light output response emitted from GaN-μLED (red).

Silicon carbide technology preferred over traditional silicon technology

Improvement in power conversion by using silicon carbide will increase demand for the technology in developing countries, says Allied Market Research.

Silicon carbide (SiC) is used in a wide range of industries such as IT & telecoms, aerospace, defense, energy, power, and automotive applications, and the material's adoption in various industrial sectors has boosted growth in the silicon carbide market worldwide. The market is expected to grow through the period 2014–2022 due to various advantages of using SiC, such as low conductance loss at high temperature and low switching and input losses compared with traditional silicon power semiconductors. A market report published by Allied Market Research offers key insights of the silicon carbide (SiC) market, such as market share, size, and growth. Great demand is developing for advanced ICs operating at high temperature and voltage levels, and the ever growing electronic industry is a major driver of the market.

Silicon carbide used to develop new inverter

In 2010, the US Department of Energy set a target to manufacture efficient electric vehicle inverters. The organization urged manufacturers to produce inverters from 4.1kW/L to 13.4kW/L by 2020. In September 2016, a 12.1kW/L received a green signal from the Department of Energy. The inverter is a stepping stone towards the goal set by the organization and will help other manufacturers to manufacture efficient and reliable electric vehicle inverters. Silicon carbide was used to manufacture the electric inverter which has improved the performance significantly.

Iqbal Hussain, a professor at North Carolina State University (NCSU), throws light on the matter by revealing how wide-bandgap power switches offer higher-temperature, higher-voltage operation capability with minimum losses compared with the silicon-based power switches that are widely used today. In addition to the improved performance exhibited by the new inverter, the packaging of the inverter is simple, as it can be packaged in a smaller and lighter module. As a result, fuel efficiency will also show a significant improvement for a wide range of hybrid electric and all-electric vehicles (HEV/EV). The professor claims that, with more research, the target set by the DoE can be reached through development at the component level.

SiC technology to be adopted in railways

There is great demand for power electronics components in modern trains. The components are required to be light to enhance the system energy efficiency in local transport means such as trams and trains. In long-distance and high-speed transportation, the need for powerful and reliable devices is on the rise as fuel efficiency is an important parameter that needs to be considered to safeguard resources and the environment.

Borderline BC is a new battery that has been developed by ABB by incorporating SiC technology for the first time. With the help of silicon carbide technology, satisfactory levels of power density and performance was achieved that is beyond the scope of regular silicon power semiconductors. SiC technology reduces the size, weight, and cooling requirements. It is also said to have helped to improve the system efficiency and all the crucial parameters considered by rail operators in modern times.

The president of ABB's Discrete Automation and Motion department revealed that the newly developed battery charger leverages the benefits of SiC and soft switching technologies. This opens the door to achieving improved performance levels for power electronics in railway applications. The technology will be implemented in Europe for the first time in high-speed trains operated by the Swiss Federal Railways.

Silicon carbide in solar efficiency

In modern times, the need to develop and manufacture products that are environmentally friendly and comply with environmental norms has been identified. The use of conventional energy resources is discouraged and non-conventional resources are gradually making their way into manufacturing processes and energy production.

In September, GE unveiled its new silicon carbide technology, which will enhance the efficiency of the North America region's solar energy production. The SiC technology introduced by GE can enable the

renewable energy industry to improve efficiency, along with reducing the cost of electricity. The SiC technology is the unique feature of the firm's new LV5+ Series Solar Inverter, which improves power conversion efficiency by up to 99%. By achieving higher power conversion efficiency, greater levels of energy can be produced from the same renewable resources over time.

Silicon carbide technology is gradually being adopted in different industries. Demand for traditional silicon power semiconductors is declining, as SiC technology is cost-effective and complies with environmental norms. The silicon carbide market is thriving in developed regions such as the USA and Europe owing to the advances made in technology as well as research and development activities in the region. However, developing regions such as the Asia–Pacific are making widespread use of silicon carbon technology due to the growth in the electronic industry, power sector, and the automotive industry. The silicon carbide market has a few obstacles that need to be addressed, such as the high initial capital investment required for manufacturing facilities. However, the demand in China, Brazil, and India for photovoltaic cells that use SiC will also offer commendable opportunities for market growth in the aforementioned regions, concludes the report. ■

www.alliedmarketresearch.com/silicon-carbide-market

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www.compoundsemi.co.uk

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

19 Facility equipment

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

20 Facility consumables

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

21 Computer hardware & software

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

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

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

22 Used equipment

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

23 Services

Henry Butcher International
Brownlow House, 50–51
High Holborn, London WC1V 6EG,
UK
Tel: +44 (0)20 7405 8411
Fax: +44 (0)20 7405 9772
www.henrybutcher.com

M+W Zander Holding AG
Lotterbergstrasse 30,
Stuttgart,
Germany
Tel: +49 711 8804 1141
Fax: +49 711 8804 1950
www.mw-zander.com

24 Consulting

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

25 Resources

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

3–5 December 2016
Optics & Photonics Taiwan, the International Conference (OPTIC 2016)
National Taiwan University of Science and Technology (Taiwan Tech), Taipei, Taiwan
E-mail: optic2016tpc@mail.ntust.edu.tw
www.tl.ntu.edu.tw/2016/optic2016

3–7 December 2016
IEDM 2016: 62nd annual IEEE International Electron Devices Meeting
San Francisco Union Square Hilton Hotel, CA, USA
E-mail: info@ieee-iedm.org
www.ieee-iedm.org

7–10 December 2016
47th IEEE Semiconductor Interface Specialists Conference (SISC 2016)
Catamaran Hotel, San Diego, CA, USA
www.ieeesisc.org

13–14 December 2016
International MicroNanoConference 2016
Beurs van Berlage, Amsterdam, The Netherlands
E-mail: info@micronanoconference.org
www.micronanoconference.org

14–16 December 2016
SEMICON Japan 2016
Tokyo International Exhibition Center (Tokyo Big Sight), Japan
E-mail: jcustomer@semi.org
www.semiconjapan.org

27–30 December 2016
3rd International Conference on Emerging Electronics (ICEE 2016)
Indian Institute of Technology Bombay (IIT Bombay)
E-mail: icee@ee.iitb.ac.in
www.iceeconf.org

28 January – 2 February 2017
SPIE Photonics West 2017
Moscone Center, San Francisco, CA, USA
E-mail: customerservice@spie.org
http://spie.org/SPIE-PHOTONICS-WEST-conference

5–9 February 2017
IEEE International Solid-State Circuits Conference (ISSCC 2017)
San Francisco, CA, USA
E-mail: m.figueroa@ieee.org
www.isscc.org

27 February – 1 March 2017
PHOTOPTICS 2017 — 5th International Conference on Photonics, Optics and Laser Technology
Porto, Portugal
E-mail: photoptics.secretariat@insticc.org
www.photoptics.org

28 February – 2 March 2017
IEEE Electron Devices Technology and Manufacturing Conference (EDTM 2017)
Toyama International Conference Center, Japan
E-mail: edtm@jtbcom.co.jp
http://ewh.ieee.org/conf/edtm/2017

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14–16 March 2017
SEMICON China 2017
Shanghai New International Expo Centre, China
E-mail: semichina@semi.org
www.semiconchina.org

19–23 March 2017
Optical Fiber Communication Conference & Exhibition (OFC 2017)
Los Angeles Convention Center, CA, USA
E-mail: OFC@compusystems.com
www.ofcconference.org

3–5 April 2017
19th European Conference on Integrated Optics (ECIO 2017)
Technical University of Eindhoven, The Netherlands
E-mail: info@jakajima.eu
www.ecio-conference.org

3–5 April 2017
2017 Joint International EUROSOI Workshop and International Conference on Ultimate Integration on Silicon (ULIS)
Institute of Nanoscience & Nanotechnology of NCSR 'Demokritos', Athens, Greece
E-mail: a.nasiopoulou@inn.demokritos.gr
www.eurosoi-ulis2017.inn.demokritos.gr

9–13 April 2017
SPIE Defense + Commercial Sensing (DCS 2017)
Anaheim Convention Center, CA, USA
E-mail: customerservice@spie.org
http://spie.org/SPIE-DCS-conference

18–21 April 2017
SNEC's 11th International Photovoltaic Power Generation Conference & Exhibition (SNEC PV Power EXPO 2017)
Shanghai, China
E-mail: info@snec.org.cn
www.snec.org.cn

24–27 April 2017
SPIE Optics + Optoelectronics 2017
Clarion Congress Hotel, Prague, Czech Republic
E-mail: info@spieeurope.org
www.spie.org/SPIE-Optics-Optoelectronics

1–3 May 2017
13th International Conference on Concentrator Photovoltaics (CPV-13)
University of Ottawa, Canada
E-mail: info@cpv-13.org
www.cpv-13.org

14–19 May 2017
Conference on Lasers and Electro-Optics (CLEO 2017)
San Jose Convention Center, CA, USA
E-mail: CLEO@compusystems.com
www.cleoconference.org

22–25 May 2017
2017 CS ManTech (International Conference on Compound Semiconductor Manufacturing Technology)
Hyatt Regency Indian Wells Resort & Spa, Indian Wells, CA, USA
E-mail: lynn_fincher@msn.com
www.csmantech.org

28 May – 1 June 2017
29th International Symposium on Power Semiconductor Devices and ICs (ISPSD 2017)
Sapporo, Japan
E-mail: ispsd2017reg@ech.co.jp
http://eds.ieee.org/eds-meetings-calendars.html

4–6 June 2017
IEEE Radio Frequency Integrated Circuits Symposium (RFIC 2017)
Hawaii Convention Center, Honolulu, HI, USA
http://rfic-ieee.org

25–29 June 2017
Conference on Lasers and Electro-Optics/ Europe & the European Quantum Electronics Conference (CLEO/Europe-EQEC 2017)
Munich, Germany
E-mail: info@cleoconference.org
www.cleoeurope.org

25–30 June 2017
44th IEEE Photovoltaic Specialists Conference (PVSC 2017)
Marriot Wardman Park Hotel, Washington DC, USA
E-mail: info@ieee-pvsc.org
www.ieee-pvsc.org/PVSC44

10–12 July 2017
IEEE Photonics Society's 2017 Summer Topicals Meeting Series
San Juan, Puerto Rico
E-mail: i.donnelly@ieee.org
www.sum-ieee.org

6–10 August 2017
SPIE Optics + Photonics 2017
San Diego Convention Center, CA, USA
E-mail: customerservice@spie.org
http://spie.org/optics-photonics1

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