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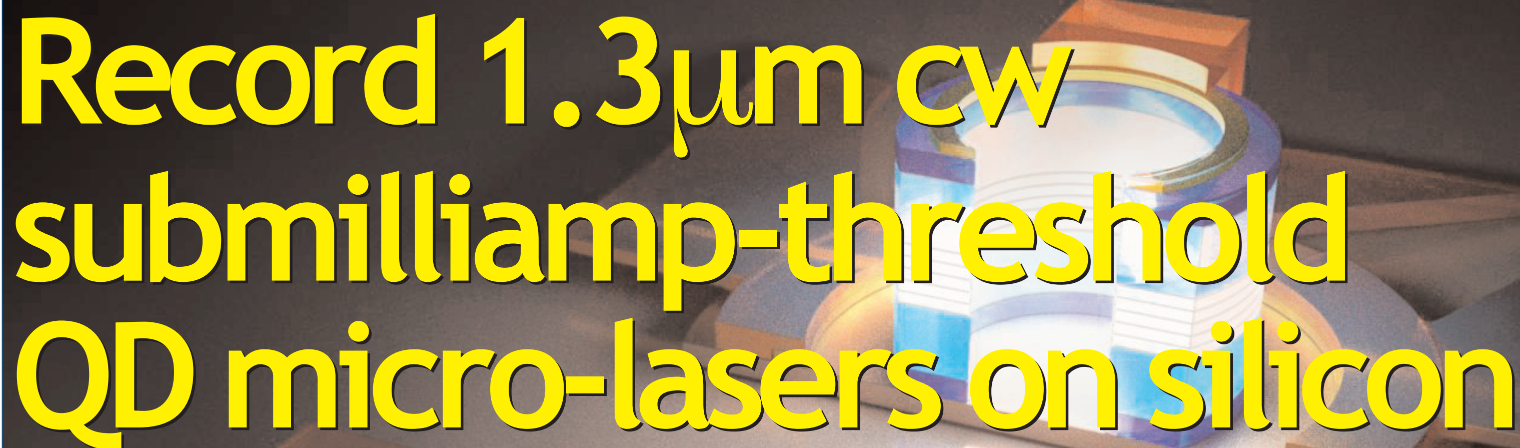

Record 1.3μm cw submilliamp-threshold QD micro-lasers on silicon

Newport Wafer Fab re-emerging after Infineon sells IR plant

ams invests in Singapore VCSEL line • Littelfuse buying IXYS

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

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Veeco's New TurboDisc EPIK700 GaN MOCVD System

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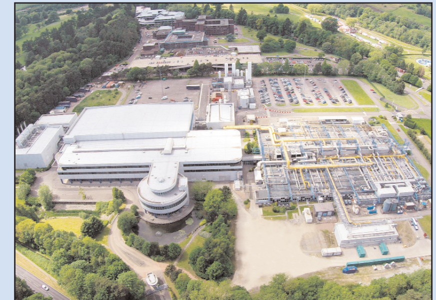
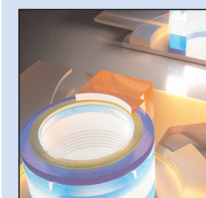


p12 Infineon's IR Newport site is being sold to new firm Neptune 6, reviving the Newport Wafer Fab name.

p16 Jay Baliga, who has developed NCSU's new PRESiCE process for manufacturing SiC power devices.

p28 Cardiff Capital Region, the Welsh & UK Governments and IQE have ratified development of the Compound Semiconductor Foundry, supporting the CS Connected Cluster.



Cover: A team at HKUST/UCSB has demonstrated record 1.3μm CW submilliamp-threshold electrically pumped quantum dot micro-lasers on silicon, following the team's prior development of CW optically pumped micro-lasers. **p45**

editorial

Compound semis powering ahead

The ongoing surge of interest in compound semiconductors — including wide-bandgap gallium nitride (GaN) and silicon carbide (SiC) power semiconductors — continues to gather pace, with more developments in commercial-scale manufacturing as firms gear up to supply the forecasted demand.

Germany's Infineon Technologies has agreed for the newly founded firm Neptune 6 to acquire its subsidiary manufacturing site IR Newport in Wales, UK (see page 12). After its acquisition in early 2015 of California-based International Rectifier (IR) — which made not only silicon-based but also gallium nitride on silicon (GaN-on-Si) power semiconductors — Infineon said the Newport site would be either sold or closed in 2017 as it continued to outsource manufacturing to foundries. It has now found a buyer that can better leverage the fabrication plant.

The fab began operation as INMOS in 1982 then operated as the silicon foundry Newport Wafer Fab before its acquisition in 2002 by IR, becoming captive. Neptune 6 now plans to re-establish the Newport Wafer Fab brand, but instead offering advanced silicon and compound-semiconductor-on-silicon foundry.

One of the three directors of Neptune 6 is Drew Nelson, CEO of epiwafer foundry and substrate maker IQE plc of Cardiff, Wales, UK.

Previously, on 11 September, Cardiff Capital Region City Deal, the Welsh and UK Governments and IQE ratified the development of the Compound Semiconductor Foundry (see page 28), supporting the development of the CS Connected Cluster in South Wales. This followed an agreement in May by the Cardiff Capital Region (CCR) Regional Cabinet to contribute £37.9m from its City Deal's Wider Investment Fund towards establishing a foundry. Ownership is shared by the 10 Councils in the Regional Cabinet via CSC Foundry Ltd, and the space will be leased to IQE.

The increasing focus on compound semiconductors is also indicated by the JEDEC Solid State Technology Association forming a new standards committee on 'Wide Bandgap Power Electronic Conversion Semiconductors', with subcommittees on GaN and SiC (see page 15).

Regarding SiC specifically, commercial developments are indicated by Littelfuse (which since March has owned a majority stake of SiC diode and MOSFET power device start-up Monolith Semiconductor Inc of Round Rock, TX, USA) agreeing to acquire IXYS Corp of Milpitas, CA, USA and Leiden, The Netherlands (which provides mixed-signal ICs and power semiconductors including SiC Schottky diodes and MOSFETs), allowing "heightened engineering expertise and intellectual property around high-voltage and silicon carbide semiconductor technologies" (page 13).

In addition, in Sweden, Ascatron has just launched its first SiC power device products (see page 15), and Norstel exhibited its first 150mm SiC n-type substrates at the International Conference on Silicon Carbide and Related Materials (ICSCRM) in Washington DC, while Japan's SDK is expanding its SiC epi production capacity from 3000 to 5000 wafers per month (page 14).

Such investments are targeting a market for SiC power devices that is already growing at a CAGR of 28% during 2016 to 2020 but — after a tipping point in 2019 — is forecast to accelerate to 40% in 2020–2022, forecasts market research firm Yole Développement (pages 82–84).

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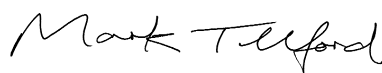

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***Semiconductor Today* covers the R&D and manufacturing of compound semiconductor and advanced silicon materials and devices** (e.g. GaAs, InP and SiGe wafers, chips and modules for microelectronic and optoelectronic devices such as RFICs, lasers 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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LED lamp shipments to reach nearly 2 billion in 2026

With declining prices and increased efficacy of LEDs continuing to drive the adoption, global LED lamp shipments will increase from 961.1 million in 2017 to nearly 2 billion in 2026, according to the report 'Market Data: LED Global Outlook' from Navigant Research. The primary driver for adoption was initially reducing energy costs, but better light quality, longer lifespans and improved controllability have helped to accelerate LED market growth across all segments.

"There are various drivers across the commercial, residential, industrial and outdoor lighting segments, but the declining prices of LEDs and increased energy savings over legacy lighting technologies are spurring adoption," says research analyst Krystal Maxwell. "Beyond those drivers, building codes and regulations and the desire for increased control are helping to further propel the adoption of LEDs."

While all segments of the lighting market have experienced change due to the increased adoption of LEDs, the commercial segment is further along than the residential or industrial segments, notes the report. Not all segments are expected to see the same growth over the next 10 years or experience the same penetration rates. However, due to the slower adoption in the latter two markets, they present increased opportunities for the uptake of LEDs.

www.navigantresearch.com/research/market-data-led-global-outlook

Automotive LIDAR semiconductor revenue growing from $103m in 2016 to $1.8bn in 2026

The automotive LIDAR (light detection and ranging) system market is growing from $230m in 2016 to $2.5bn in 2026, with semiconductor revenue rising from $103m to $1.8bn, according to a report by IHS Markit.

The current generation of automated functions — automatic emergency braking, adaptive cruise control, and lane keep assistance — rely largely on cameras, radars and ultrasonic sensors. Each of these devices is limited to different conditions, e.g. weather, object detection, distance, etc. As the complexity of automated driving functions proliferate through L3 to L5, OEMs need to produce more reliable and fail-operational platforms.

Currently, LIDAR is a primary choice for redundant sensing in supporting cameras and radars with object recognition, distance estimations and dynamic mapping. In addition, it offers 3D map localization and high-resolution cloud-point images serving as a key to the development of automated driving technology.

The technology muddle

With regard to LIDAR, OEMs are currently technology agnostic and aim to roll out automated car platforms around 2020. However, existing commercialized LIDAR technologies do not meet the performance requirements of automated driving, says the IHS Markit report. Range, low-reflectivity targets, high resolution and eye-safety are some of the key requirements. In addition, mechanical scanning LIDARs are vulnerable to shocks, vibration and degradation. Furthermore, its large form factor and high cost restricts its entry into production volumes.

"Better technology is needed," says Akhilesh Kona, senior analyst for automotive electronics and semiconductors. "A battle is now ensuing with solid-state LIDAR technology based on either MEMS or electro-optics or optical phased arrays and high-resolution flash devices, all aiming to address the performance requirements of automated driving. Of the promising technologies under development today, each has its advantages and limitations regarding manufacturing, cost, automotive qualification, and other factors."

So far, most of the emerging LIDAR suppliers differentiate via in-house design capabilities, starting at the semiconductor level, and it is unclear which combination of LIDAR emitter, detector and beam-steering technology will lead 10 years from now. IHS Markit has evaluated the LIDAR market and supply chain by four emitter technologies, five detector types, and up to 10 beam-steering mechanisms.

Supplier landscape

Continental, Valeo and Denso are currently the sole suppliers of flash LIDAR solutions, while Velodyne, Valeo and Ibeo are the major suppliers of mechanical scanning LIDARs. The LIDAR market will become increasingly crowded after 2020, when more than 15 suppliers will enter the fray with different solutions, forecasts IHS Markit.

LIDAR technology is driven mostly by non-automotive optical companies and many start-ups. Business models see partnerships among the traditional tier-1s and LIDAR suppliers starting to coalesce. Examples of this include Magna and Innoviz Technologies and Infineon's acquisition of Innoluce. Strategic investments include Denso with Trilumina, ZF with Ibeo, Delphi with Quanergy, Delphi and Magna with Innoviz Technologies, notes the report.

https://technology.ihs.com/595094/automotive-lidar-technology-market-report-2017

LED market growing at 18% CAGR, boosted by demand for energy-efficient lighting

High luminous efficacy, life span, reduced energy use and falling ASP driving consumers to switch to LEDs

The global light-emitting diode (LED) market is increasing at a compound annual growth rate (CAGR) of more than 18% during 2017–2021, rising from $18.51bn in 2016 to $24.67bn in 2012, forecasts market research firm Technavio.

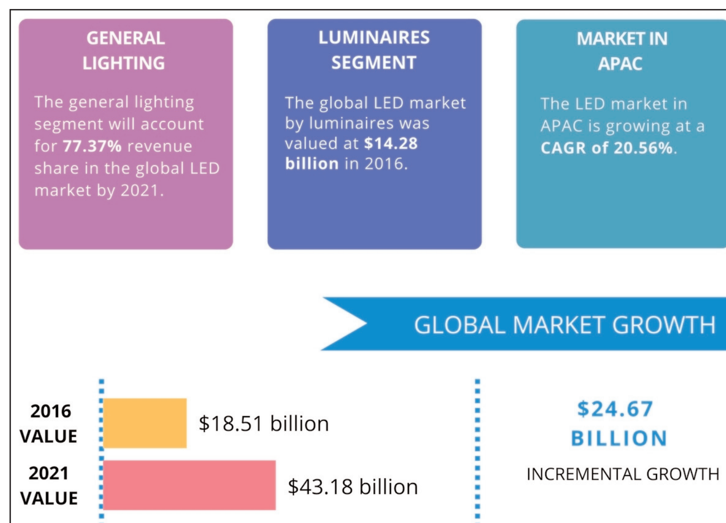
In particular, the luminaires segment comprised $14.28bn in 2016, while the general lighting segment will account for 77.37% market share by 2021. The Asia-Pacific (APAC) region is growing at 20.56% during the forecast period.

Demand for energy-efficient lighting solutions across sectors (such as the retail, hospitality, architecture, commercial and residential) is leading to increased adoption of LED lighting worldwide, notes the report 'Global Light-emitting Diode (LED) Market 2017–2021'. The high luminous efficacy, greater life span, reduced energy use and falling average selling price (ASP) of LED lighting products is compelling consumers to switch to LED technology, it adds.

Four market drivers are contributing to the growth of the global LED market: a favorable policy environment and governmental support; demand for energy-efficient lighting solutions; increasing outreach of energy-efficiency certification programs; and upcoming international events and infrastructure projects.

Favorable policy environment and governmental support

The rapid depletion of natural resources and global warming have generated an indispensable need for energy conservation worldwide. In 2016, lighting applications were estimated to account for more than 20% of global energy consumption. There is an urgent need to reduce this energy consumption, and governments across the globe are focusing on the implementation of favorable policies to promote the use of energy-efficient lighting products.



"Governments of established economies like the US and the UK and emerging economies like China and India are engaging in the promotion of LED lighting products by providing tax incentives and subsidies on these products," says Chetan Mohan, lead analyst for lighting research.

Demand for energy-efficient lighting

Both governments and organizations across the globe are working on reducing the energy consumption and running costs for lighting. Compared with their counterparts such as incandescent lamps, LEDs are technically advanced and efficient in terms of energy consumption, luminous intensity and efficacy.

"In addition to providing energy-efficient lighting, LED bulbs provide larger product life spans compared to incandescent bulbs, by up to thousands of hours," notes Chetan. "As a result, the consumers spend lesser amounts on the replacement of these products, given the high product lifetime."

Increasing outreach of energy-efficiency certification programs

Energy-efficiency programs (such as the ENERGY STAR certification, DLC, and Lighting Design Lab certification) aim to highlight the importance and need for energy efficiency. These programs are actively encouraging and promoting the use of energy-efficient lighting sources that help organizations and households to reduce their carbon footprints.

The ENERGY STAR program was established by the US Environmental Protection Agency (EPA) in 1992 to promote the use of energy-efficient lighting for buildings, homes and industries. The introduction of stringent government regulations on energy efficiency has encouraged the adoption of ENERGY STAR-certified products worldwide.

Upcoming international events and infrastructure projects

The FIFA World Cup 2018 (to be held in Russia) is expected to contribute significantly to the global LED market. The increased construction of sports infrastructure such as stadiums and the athletes' village; public infrastructure like roads; and commercial buildings like hotels, tourist facilities, and shopping complexes will drive demand for LED lighting, especially in the outdoor segment in the country till 2018.

In addition to the events, the governments of various countries such as China and India are making significant investments in the development of infrastructure projects and smart cities to complement the economic growth and to cater to the requirements of the growing urban population. These developments augur well for the growth of the global LED market during the forecast period, concludes Technavio.

www.technavio.com/report/global-led-market

GlobalFoundries 300mm 8SW RF SOI process targets 4G LTE & sub-6GHz 5G applications

GlobalFoundries of Santa Clara, CA, USA has made available what it says is the first RF silicon-on-insulator (SOI) foundry solution on 300mm wafers, delivering performance, integration and area advantages in front-end modules (FEMs) for 4G LTE and sub-6GHz 5G mobile and wireless communication applications.

The new 8SW technology offers a low-cost, low-power, highly flexible solution with superior switching, low-noise amplifiers (LNA) and logic processing capabilities on a 300mm manufacturing line. It features up to 70% power reduction compared with the previous generation, with higher voltage handling, a best-in-class on-resistance (R_{on}) and off-capacitance (C_{off}) for reduced insertion loss with high isolation, and an all-copper interconnect that improves power-handling capacity.

"Skyworks continues to leverage our broad systems expertise to bring highly customized solutions to customers worldwide," comments Joel King, VP & general manager of Advanced Mobile Solutions at Skyworks Solutions. "Our collaboration with GlobalFoundries has provided Skyworks early access to best-in-class switch and LNA technology that will further advance RF front-ends for next-generation mobile devices and evolving IoT [Internet of Things] applications," he adds.

"We now live in a world of connected intelligence where people expect and demand seamless, reliable data connectivity everywhere," says Bami Bastani, senior VP of GlobalFoundries' RF business unit. "But that's only getting more difficult to achieve, as front-ends increasingly must be able to handle many different frequency bands and many different types of RF signals, along with integrated digital processing and control," he adds. "We have developed the new 8SW process specifically to help customers meet their most pressing needs."

GlobalFoundries says that the 300mm RF SOI-based technology gives designers a cost-effective platform with an optimal combination of performance, integration and power efficiency with greater digital integration ability. The 8SW process incorporates a specialized substrate optimization that maximizes the quality factor for passive devices, reduces parasitic capacitances for active circuits and minimizes the disparity in phase and voltage swing for devices operating in the sub-GHz frequency range. The technology showcases an optimized LNA with what is claimed to be leading noise figure and high f_T/f_{max}, supporting diversity receive and main antenna path LNA applications for existing 4G operating frequencies and future sub-6GHz 5G front-end modules.

The 8SW technology is manufactured on GlobalFoundries' 300mm production line at Fab 10 in East Fishkill, NY, providing the industry with capacity to meet the expected market demand at a lower cost. Process design kits are available now.

www.globalfoundries.com

Enhanced RF SOI PDK for use with CWS' SiPEX simulation tool

GlobalFoundries has made available a new set of enhanced RF silicon-on-insulator (RF SOI) process design kits (PDKs) to help designers improve their designs of RF switches and deliver differentiated RF front-end solutions for a range of markets including front-end modules for mobile devices, millimeter-wave (mmWave), 5G and other high-frequency applications.

The 7SW SOI RF technology platform is optimized for multi-band RF switching in next-generation smartphones and poised to drive innovation in Internet of Things (IoT) applications. Designed for use with Coupling Wave Solutions' (CWS) simulation tool SiPEX, its 7SW SOI PDK allows designers to integrate RF switches with other critical RF blocks that are essential to the design of complex electronic systems for future RF communication chips. Specifically, this new capability allows designers to improve RF simulation output by simulating a highly resistive substrate parasitic effect across their entire design.

"CWS' SiPEX tool provides our customers with best-in-class correlation between simulated results and real-world measurements, further optimizing the design layout to achieve efficiency and deliver differentiated RF front-end solutions," says Bami Bastani, senior VP of RF.

"The integration of SiPEX into GlobalFoundries' RF SOI PDKs is a major milestone to achieve first-time correct complex and optimized RF SOI designs for high-performing cellular, IoT, 5G and Wi-Fi communication chips," comments CWS' chairman & CEO Brieuc Turluche.

GlobalFoundries says that its RF SOI technologies offer performance, integration and area advantages in front-end RF solutions for mobile devices and RF chips for high-frequency, high-bandwidth wireless infrastructure applications. CWS' SiPEX accelerates the design of RF SOI switches by improving linearity simulation accuracy. It can also be effective in the design of low-noise amplifiers (LNA) and power amplifiers (PA), enabling designers to reduce their size to lower costs.

SiPEX is available in the current release of the 7SW SOI PDK.

www.cwseda.com

Skyworks' SkyOne Ultra front-end and DRx diversity receive modules powering 4G LTE connectivity in M2M applications

Skyworks Solutions Inc of Woburn, MA, USA (which makes analog and mixed-signal semiconductors) says that its SkyOne Ultra 2.5 and diversity receive (DRx) modules for mobile applications have been adopted by machine-to-machine (M2M) module manufacturers to provide high-speed 4G LTE capability. The fully integrated and tested systems, packaged in extremely small form factors, are enabling M2M suppliers including Fibocom, Sierra Wireless, and Telit to extend plug & play, high-speed cellular connectivity across Internet of Things (IoT) products and applications — in any global region and on any wireless network.

SkyOne Ultra 2.5 covers more than 20 LTE frequency bands in a complete front-end solution; inclusive of power amplification, duplex filtering and antenna switching. DRx improves receiver sensitivity and cell edge performance while addressing all major downlink carrier aggregation combinations. The highly differentiated solution integrates low-noise amplification, receive filtering, and band switching. By supporting global and regionally optimized stock-keeping units (SKUs) in the same PCB footprint, the platforms enable cost-effective, high-performance architectures with flexibility.

"As always-on connectivity proliferates from mobile to the IoT, including M2M applications, there is an increasing demand for fully integrated, turnkey systems that can effectively connect everyone and everything, all the time," says VP of sales & marketing Carlos Bori. "We're excited to leverage our scale and technology leadership in mobile to accelerate the adoption of high-speed cellular functionality in a growing number of new and innovative markets that depend on seamless wireless connectivity."

According to a Cisco VNI report, M2M will be one of the fastest-growing mobile connection vehicles as global IoT applications continue to gain traction in consumer and business environments. Cisco forecasts that, globally, M2M connections will increase at a compounded annual growth rate of 34% from 780 million in 2016 to 3.3 billion by 2021. Further, M2M mobile connections will exceed a quarter of total devices and connections by 2021, as devices evolve from 2G to 3G, 4G and higher technologies.

www.skyworksinc.com/products_IoT_M2M.aspx

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Qty	ID	Diam	Type
1	1394	25.4mm	P
22	2483	25.4mm	Undoped
500	444	50.8mm	P
267	446	50.8mm	N

Anokiwave completes Series C financing round

Funding to speed launch of second-generation ICs, aid development of third generation, and grow teams worldwide

Anokiwave Inc of San Diego, CA, USA — which provides highly integrated silicon core chips and III-V front-end integrated circuits for 5G communications, mobile satellite communications and aerospace & defense markets that require millimeter-wave (mmW) active antenna based solutions — has closed a Series C financing round led by new investor Gefinor Capital in conjunction with US Boston Capital Corp and its affiliate Pear Tree Partners, as well as other previous investors. Gefinor Capital partner Chris Davis will join Anokiwave's board of directors.

Following significant growth since the firm launched its first millimeter-wave active antenna silicon core IC family in 2015, the latest financing round is expected to drive continued growth in the 5G, SatCom and A&D markets. Anokiwave continues to see widespread and growing demand in its key markets from customers looking to industrialize planar active antennas at millimeter wavelengths via its all-silicon core ICs for commercial markets.

"Anokiwave is the only company with a production-ready suite of silicon ICs for the nascent 5G telecom market," notes Davis. "This leading position is directly attributable to great foresight from management, coupled with excellence in engineering and decades of team experience designing advanced communications antenna ICs," he comments.

"As the first 5G network deployments are starting in 2018, the urgency heightens to make millimeter-wave 5G technology commercially ready for consumers," says Bill Umphrey, US Boston managing partner. "Anokiwave is continuing to make 5G a reality by leading the market with industrialized, production-ready products for millimeter-wave active antennas," he adds. "With over 10 years of experience designing core ICs for millimeter waves, they are pushing this technology into prime-time for the 5G, SatCom, and A&D markets."

Anokiwave has developed a family of highly integrated millimeter-wave beam-steering silicon ICs. Silicon offers the ability to integrate RF, digital and analog functions on a single IC, the firm notes. This enables all of the requisite functions for the active antennas to be placed on the IC, which then resides within the radiating element lattice of the antenna, enabling low-profile, low-cost, low-weight planar (flat) solutions.

"This latest funding round allows us to accelerate the introduction of our second generation of ICs, to develop the third generation of ICs, and to grow our teams worldwide," says CEO Robert S. Donahue.

www.anokiwave.com

Peregrine's patent portfolio surpasses 450 issued and pending patents

Peregrine Semiconductor Corp of San Diego, CA, USA — a fabless provider of radio-frequency integrated circuits (RFICs) based on silicon-on-insulator (SOI) — says that its intellectual property (IP) portfolio has now surpassed 450 issued and pending patents.

The IEEE Spectrum published scorecard 'Patent Power 2016' ranks Peregrine's portfolio 6th in the semiconductor-manufacturing sector and 24th overall. This overall ranking combines 17 industry scorecards and places Peregrine's US patent portfolio among organizations such as Google, Apple, Qualcomm, Facebook, Intel, IBM, Microsoft, Samsung and Massachusetts Institute of Technology (MIT).

The 'Patent Power Scorecard' is an annual benchmarking of company patent portfolios by 1790 analytics. Companies are ranked on pipeline power — an overall measure of the strength of the patent portfolio that considers both its size and quality. The 2016 Scorecard is based on an analysis of US Patent and Trademark Office records through the end of 2015.

Since acquisition by Murata in December 2014, Peregrine has more than doubled its patent portfolio, through both company innovation and strategic acquisitions such as the acquisition in March of power management startup Arctic Sand Technologies of Burlington, MA, USA.

The patent portfolio is "a recognition of the innovation of Peregrine's engineers and the pioneering role Peregrine has played in the commercialization of RF SOI technology," says Peregrine's VP of corporate research & IP development Dan Nobbe. "Peregrine's top-25 ranking on the 'Patent Power 2016 Scorecard' signifies our inventiveness and benchmarks the strength of our portfolio against the technology world's most valuable patent portfolios," he adds. "This objective ranking also validates our company-wide focus on invention and proves the value of Murata's continued investment and commitment to our IP portfolio… Peregrine will continue to strengthen and protect its IP."

www.psemi.com
https://spectrum.ieee.org/

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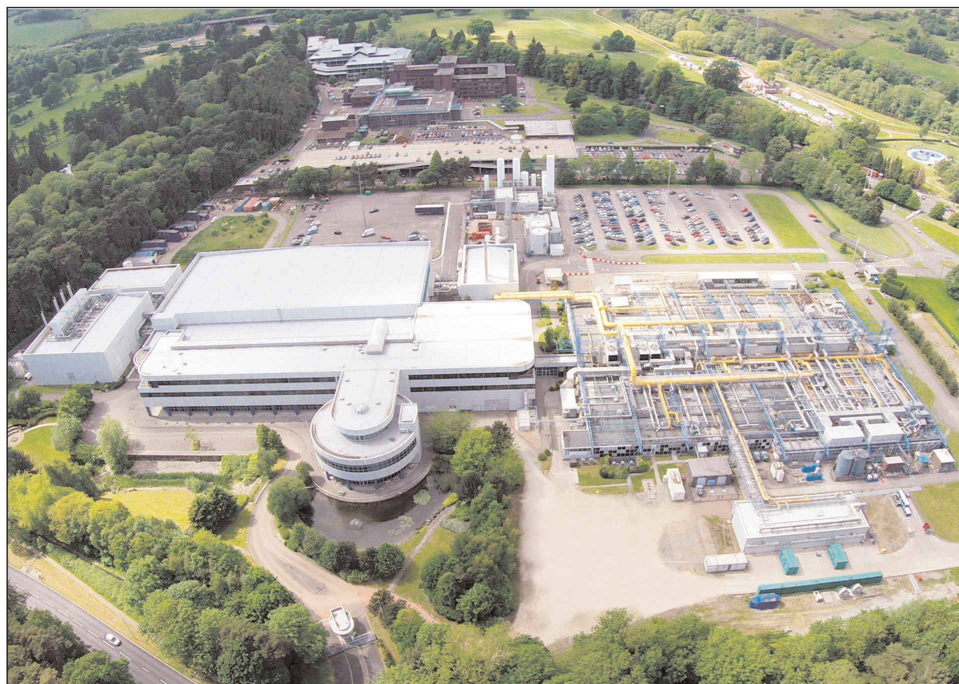
Infineon selling IR Newport manufacturing site to new firm Neptune 6

Newport Wafer Fab to be revived as foundry for advanced silicon and compound semiconductors on silicon

Infineon Technologies AG of Munich, Germany has signed a definitive agreement for the newly founded private company Neptune 6 Ltd to acquire its subsidiary manufacturing site IR Newport Ltd in Newport, Wales, UK. The deal is expected to conclude by the end of September, after which Neptune 6 intends to operate the site under the name Newport Wafer Fab Ltd (NWF Ltd).

Infineon and Neptune 6 have also entered into a two-year supply agreement, aiming for a smooth transition phase.

After acquiring International Rectifier Corp (IR) of El Segundo, CA, USA at the beginning of 2015, Infineon said that the Newport manufacturing site would be either sold or closed in 2017. It now says that it has found a buyer that can better leverage the factory.



The IR Newport manufacturing site.

"With Neptune 6 we have found the right partner who will secure production and jobs in Newport," says Jochen Hanebeck, a member of Infineon's management board operations. "Knowing we would have to part with the Newport site, it was my personal concern to make sure it will be in good hands... the solution we have found now enables us to support our customers even better and more flexibly. The transfer of the fab is a major step in consolidating our front-end manufacturing footprint after the acquisition of International Rectifier," he adds.

The name Newport Wafer Fab is a silicon foundry brand under which the existing Newport site was operated before acquisition by International Rectifier in 2003. Neptune 6 intends to re-establish the brand to offer advanced silicon and compound semiconductor on silicon foundry services.

"The Newport site, which comes with a skilled workforce of highly reliable and very experienced people, is extremely well placed to contribute to the rapidly emerging international Compound Semiconductor Cluster of South Wales," reckons Neptune 6 legal director Steve Berry. "The fab is very well equipped to act as a globally competitive chip foundry, and Newport Wafer Fab Ltd. will be highly complementary to the existing semiconductor expertise in the region." Berry expressed his gratitude to the involved parties, including Infineon, HSBC Bank and the Welsh Government, for facilitating the transaction. "Newport Wafer Fab can provide the employees, the region and the UK with a very bright future in high-volume advanced semiconductor chip manufacturing," he believes.

"The Welsh Government has been able to support a deal to save the Newport site and the jobs of the people employed there," states Welsh Cabinet Secretary for Economy and Infrastructure Ken Skates. "The closure of the site in Newport would have been a major setback for the local and national economy and would greatly detract from the substantial investments made to establish Wales as a global centre for advanced compound semiconductor technologies." The site will form a key part of the Compound Semiconductor Cluster over the coming years, he adds. "The cluster will make a significant contribution to the future of the Welsh economy and support many global companies based here, such as Airbus, GD, Sony and GE," Skates continues. "The synergies this can deliver will contribute to increased skills levels in the region and will attract further technology businesses to Wales. Highly skilled technology roles, such as these retained in Newport, are of significant value to our economy and vital to ensure Wales capitalizes on the growth of the digital economy."

www.infineon.com

Littelfuse to acquire IXYS for $750m

Acquisition expands capabilities across power semiconductor markets, focusing on silicon carbide

Littelfuse Inc of Chicago, IL, USA, which provides circuit protection technologies (including fuses, semiconductors, polymers, ceramics, relays and sensors), has agreed to acquire IXYS Corp of Milpitas, CA, USA and Leiden, The Netherlands (which provides power semiconductors and mixed-signal ICs for power conversion and motor control applications) in a cash and stock transaction with an equity value of about $750m (and enterprise value of $655m), representing the largest acquisition in Littelfuse's 90-year history .

Per share, each IXYS stockholder will be entitled to receive either $23 in cash or 0.1265 of a share of Littelfuse common stock. In total, 50% of IXYS stock will be converted into the cash option and 50% into the stock option.

IXYS focuses on medium- to high-voltage power control semiconductors across the industrial, communications, consumer and medical markets, serving a broad base of more than 3500 customers through its direct salesforce and global distribution partners. In fiscal 2017, revenue was $322m, with an adjusted EBITDA margin of about 13.5%.

The combined company is expected to have annual revenue of about $1.5bn, with the following strategic and financial benefits:

- a broader technology platform and capability to expand growth into industrial and electronics markets;
- increased long-term penetration of power control portfolio in automotive markets (expanding global content per vehicle);
- heightened engineering expertise and intellectual property around high-voltage and silicon carbide semiconductor technologies;
- increased presence in the semiconductor industry, adding to scale and volume; and
- strong relationships and complementary overlap in major global electronics distribution partnerships, enabling cross-selling.

IXYS' extensive power semiconductor portfolio and technology expertise fit squarely within our strategy to accelerate our growth within power control and industrial OEM markets

"IXYS' extensive power semiconductor portfolio and technology expertise fit squarely within our strategy to accelerate our growth within power control and industrial OEM markets," says Littelfuse's president & CEO Dave Heinzmann. "The combination of Littelfuse and IXYS unites complementary capabilities, cultures and relationships," he adds.

IXYS will operate as the cornerstone of the combined companies' power semiconductor business. Combination of IXYS and Littelfuse creates a stronger player in the power semiconductor industry, with the ability to leverage our collective resources and portfolio

"IXYS will operate as the cornerstone of the combined companies' power semiconductor business," says IXYS' chairman & CEO Dr Nathan Zommer. "Both Littelfuse and IXYS have long histories of innovation and customer-focused product development, and together we will embrace the entrepreneurial spirit that has contributed to IXYS' success in the power semiconductor and integrated circuits market," he believes.

"The combination of IXYS and Littelfuse creates a stronger player in the power semiconductor industry, with the ability to leverage our collective resources and portfolio," comments IXYS' president & CEO Uzi Sasson.

The transaction is expected to be immediately accretive to Littelfuse's adjusted earnings per share and free cash flow in the first full year post transaction close (excluding any acquisition- and integration-related costs). Littelfuse expects to achieve more than $30m of annualized cost savings within the first two years after closing the transaction. Longer term, the combination is also expected to create significant revenue synergy opportunities, given the companies' complementary offerings, as well as benefits from future tax rate reduction.

In conjunction with the agreement, Zommer (IXYS' founder and currently its largest stockholder, with about 21% ownership) has entered into a voting and support agreement. Subject to the agreement's terms and conditions, he has agreed to vote his shares in favor of the transaction. After close of the transaction, Zommer is expected to join Littelfuse's board of directors, subject to the board's governance and approval process. His technical skills and extensive experience across the semiconductor industry are expected to benefit the combined company with its integration efforts, innovation roadmap and revenue expansion.

The transaction is expected to close in first-quarter 2018, subject to customary closing conditions (including regulatory approvals and approval by IXYS stockholders). Littelfuse expects to finance the cash portion of the transaction through a combination of existing cash and additional debt.

www.littelfuse.com
www.ixys.com

Norstel completes 150mm SiC n-type wafer development

Customer samples to be available by first-quarter 2018

Norstel AB of Norrköping, Sweden has developed low-defect-density 150mm silicon carbide (SiC) n-type substrates, as exhibited at the International Conference on Silicon Carbide and Related Materials (ICSCRM 2017) in Washington DC, USA (16–22 September).

Norstel manufactures conductive (n-type) and semi-insulating SiC substrates and provides services such as epitaxy deposited by chemical vapor deposition (CVD) as well as wafer characterization and polishing. Applications include diodes and switches for power electronics and GaN/SiC devices for RF components used in power conversion, electric vehicles (EVs), telecom base-stations etc.

"With a micropipe density (MPD) below $0.2cm^{-2}$ and a threading screw dislocation (TSD) density below $500cm^{-2}$, our first 150mm conductive 4H SiC substrates demonstrate our commitment to quality as an enabler for high-yield device processing," says chief technology officer Dr Alexandre Ellison.

The firm states that it has prioritized wafer quality over time to get to the next wafer size. As a result, emphasis was given in R&D to first decreasing the dislocation density in the SiC wafers prior to diameter expansion from 100mm to 150mm. The first 150mm customer samples will be available by first-quarter 2018.

"Our SiC Perfection development program performed in the recent years has enabled us to achieve a leading position in terms of high-quality SiC wafers," claims chief operating officer Ronald Vogel, adding that the firm has now managed to preserve the quality during the expansion to 150mm.

"In light of the growing market demand for SiC-based energy efficient power electronics solutions in applications like PVs, EVs/HEVs, charging infrastructure, trains, energy storage and many more, the SiC device and module industry scales up to meet such demand," continues Vogel. "Larger-diameter and lower-defect SiC wafers will enable them to increase production efficiency, device yields and volume supply capability to meet their customers' expectations."

www.mrs.org/icscrm-2017
www.norstel.com

SDK expanding high-grade SiC epi production capacity from 3000 to 5000 wafers per month

Expanded facilities to begin operation in April 2018

Tokyo-based Showa Denko K.K. (SDK) has decided to expand its facilities for producing high-quality-grade silicon carbide (SiC) epitaxial wafers for power devices — which have already been marketed under the trade name High-Grade Epi (HGE) — from a capacity of 3000 wafers per month to 5000 wafers per month (equivalent, for SiC epiwafers for power devices with a withstand voltage of 1200V). The expanded facilities will begin operation in April 2018.

Compared with mainstream silicon-based semiconductors, SiC-based power devices can operate under high-temperature, high-voltage and high-current conditions while substantially conserving energy, enabling the production of smaller, lighter and more energy-efficient power control modules. SiC power devices are already used in the power sources of servers for data centers, and in distributed power supply systems for renewable energy. Moreover, the application of SiC power devices in inverter modules for railcars and in quick-charging stations for electric vehicles has been making progress in recent years. The market for SiC power devices is hence expected to grow 27% annually until 2020.

In HGE, the density of basal plane dislocations (BPDs) is controlled to be within $0.1/cm^2$

Power modules for high-voltage, high-current applications mainly contain devices with a Schottky barrier diode (SBD) structure and transistors with a MOSFET (metal-oxide-semiconductor field-effect transistor) structure. While manufacturers have entered into the mass production of SiC SBDs, the practical application of SiC MOSFETs has required a further reduction in various types of surface and crystal defects. In HGE (developed by SDK), the density of basal plane dislocations (BPDs), which is a typical crystal defect, is controlled to be within $0.1/cm^2$.

Since its launch in October 2015, HGE has been adopted as a key component of SiC SBDs, claims SDK. In addition, HGE is being adopted increasingly by device makers as a key component of developing SiC MOSFET for practical use, the firm adds. SDK has now decided to expand its HGE production capacity because its existing facilities are operating at full capacity, and it expects that the SiC MOSFET market will begin to take off in 2018.

SDK reckons that the SiC epiwafer market for power devices will reach 20 billion in 2020, as the early use of SiC power devices in vehicles is under consideration. The firm says that it aims to continue to meet market demand for high-quality SiC epiwafers in future.

www.sdk.co.jp

JEDEC WBG power semiconductor committee

JEDEC Solid State Technology Association, which develops standards for the microelectronics industry, has formed a new JEDEC committee: JC-70 Wide Bandgap Power Electronic Conversion Semiconductors.

Led by interim chairs from Infineon, Texas Instruments and Wolfspeed (a Cree Company), the JC-70 committee will initially have two subcommittees, Gallium Nitride (GaN) and Silicon Carbide (SiC), and focus on Reliability and Qualification Procedures; Datasheet Elements and Parameters; and Test and Characterization Methods.

JC-70's first committee meeting will be co-located with the 5th IEEE Workshop on Wide Bandgap Power Devices and Applications (WiPDA 2017) on 30 October in Albuquerque, NM. JEDEC meetings are open to committee members and invited guests only, and interested companies worldwide can join JEDEC to participate in standardization efforts (by e-mailing emilyd@jedec.org).

As the most mature wide-bandgap (WBG) power semiconductor materials, silicon carbide and gallium nitride offer immense potential for enabling higher-performance, more compact and energy-efficient power systems, says JEDEC. "WBG GaN and SiC technologies are poised to benefit from the development of standards focused on quality and reliability, datasheets, and test methods," says Tim McDonald, senior director GaN Applications and Marketing at Infineon Technologies.

During an industry conference in spring 2016, a working group of industry experts was formed. Designated as GaNSPEC DWG, it began laying the necessary groundwork for the development of standards for GaN. JEDEC began providing logistical support to the group shortly thereafter.

"To meet the demand of today's energy and product requirements, this team is helping to create the mature industry infrastructure that customers need to design power supplies," says Dr Stephanie Watts Butler, technology innovation architect at Texas Instruments. "The broad academic and industry participation is indicative of the importance of wide bandgap for complying with these requirements."

GaNSPEC DWG was soon joined by a counterpart: the SiCSPEC working group. The two groups grew to almost 50 device makers, equipment manufacturers, technology creators, academic representatives and government labs from the USA, Europe and Asia. "Our consensus is that JEDEC is the logical home for the continuation of these efforts in a public forum," says Dr Jeff Casady, business development & programs manager at Wolfspeed. "Creating clear, universal standards is a key step in advancing the adoption of wide-bandgap technologies. These new parameters will enable users to design SiC and GaN devices into the systems of tomorrow," he adds.

"The formation of the JC-70 committee is part of an ongoing effort within JEDEC to extend our standards-setting expertise to new technologies to meet market demands," says JEDEC's president John Kelly. "We welcome all interested companies to participate in the development of open industry standards within JEDEC."

www.wipda.org
www.jedec.org

Ascatron launches its first SiC power device products

Ascatron AB of Kista, Stockholm, Sweden (which was spun out of research institute Acreo in 2011) says that it is now providing silicon carbide (SiC) power semiconductor devices using its proprietary 3DSiC technology with what is claimed to be a quality and performance unattainable through existing methods.

With background in producing SiC epitaxial material for global customers, Ascatron has recently transformed from a service provider to a device product company. The first products available for customer testing are diodes rated to 1200V, 1700V and 10kV. MOSFET switches are under development and will be introduced 2018.

"We have developed a unique material technology that makes it possible to fully use the potential of SiC to handle very high power with minimal losses, while maintaining the reliability of silicon," says chief technology officer Adolf Schöner. "We call it 3DSiC and it is based on our expertise in producing advanced SiC epitaxy material. The technology has the potential to lower the losses up to 30% compared to conventional solutions," he reckons.

The 3DSiC technology enables a modular design of the product line. Each device is divided into a high-voltage module (related to the desired voltage class) and a low-voltage part (for each type of component). Combining various modules yields a wide range of products.

"Our business target is to be highly trusted and innovative supplier of SiC semiconductors for power electronics in industry, automotive and energy," states CEO Christian Vieider. "We foresee a period of technology change when shifting from silicon to SiC," adding that the firm aims to take part in such industry consolidation.

The business model is semi-fabless, where Ascatron designs the power device and maintains in-house production of the key epitaxy material, while chip fabrication and packaging are outsourced. In addition, to address the Chinese market a company has been set up in Shenzhen with a local partner.

Ascatron says that it will continue to support customers with small-scale manufacturing of SiC epi material.

www.ascatron.com

NCSU rolls out PRESiCE manufacturing process to open up SiC power device market to more companies

PowerAmerica-supported development qualified at X-Fab foundry

North Carolina State University (NCSU) is rolling out a new manufacturing process and chip design for silicon carbide (SiC) power devices, which can be used to more efficiently regulate power in technologies that use electronics. The PRESiCE process was developed with support from the US Department of Energy (DoE)-funded PowerAmerica institute, which focuses on boosting manufacturing of wide-bandgap semiconductor-based power electronics, in order to make it easier for companies to enter the SiC marketplace and develop new products.

"PRESiCE will allow more companies to get into the SiC market, because they won't have to initially develop their own design and manufacturing process for power devices — an expensive, time-consuming engineering effort," says Jay Baliga, Distinguished University Professor of Electrical and Computer Engineering and lead author of a paper 'PRESiCE: PRocess Engineered for manufacturing SiC Electronic-devices' being presented at the International Conference on Silicon Carbide and Related Materials (ICSCRM 2017) in Washington DC (17-22 September). "The companies can instead use the PRESiCE technology to develop their own products. That's good for the companies, good for consumers, and good for US manufacturing," Baliga adds.

Jay Baliga, who developed the PRESiCE process.

Up to now, companies that have developed manufacturing processes for creating SiC power devices have kept their processes proprietary, making it difficult for other companies to get into the field. This has limited the participation of other companies and kept the cost of SiC devices high. The NC State researchers hence developed PRESiCE to address this bottleneck, with the goal of lowering the barrier of entry to the field for companies and increasing innovation.

The PRESiCE team worked with Texas-based foundry X-Fab to implement the manufacturing process. It has now been qualified it, showing that it has the high yield and tight statistical distribution of electrical properties for SiC power devices necessary to make them attractive to industry.

"If more companies get involved in manufacturing SiC power devices, it will increase the volume of production at the foundry, significantly driving down costs," Baliga says. Presently, SiC devices cost about five times more than silicon power devices. "Our goal is to get it down to 1.5 times the cost of silicon devices," he adds. "Hopefully that will begin the 'virtuous cycle': lower cost will lead to higher use; higher use leads to greater production volume; greater production volume further reduces cost, and so on. And consumers are getting a better, more energy-efficient product." The researchers have already licensed the PRESiCE process and chip design to one company, and are in talks with several others.

"I conceived the development of wide-bandgap semiconductor (SiC) power devices in 1979 and have been promoting the technology for more than three decades," Baliga says. "Now, I feel privileged to have created PRESiCE as the nation's technology for manufacturing SiC power devices to generate high-paying jobs in the USA," he adds. "We're optimistic that our technology can expedite the commercialization of SiC devices and contribute to a competitive manufacturing sector here in the USA."

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University of Arkansas awarded $3.2m by ARPA-E for two projects as part of CIRCUITS program

The US Department of Energy's Advanced Research Projects Agency-Energy (ARPA-E) has awarded Distinguished Professor Alan Mantooth of the University of Arkansas (U of A) in Fayetteville, AR, a total of $3.2m for two projects that aim to accelerate the development and deployment of a new class of efficient, lightweight and reliable power converters.

They are two of the 21 projects that in August were awarded a total of $30m in ARPA-E funding as part of the CIRCUITS program ('Creating Innovative and Reliable Circuits Using Inventive Topologies and Semiconductors').

Power converters and other electronic devices condition, control and convert electrical power to optimize the transmission, distribution and consumption of electricity. The award will fund projects to help reduce the size and complexity of these systems.

As a part of the CIRCUITS program, the ARPA-E supported projects employ power converters based on wide-bandgap semiconductor technology using materials including silicon carbide (SiC) and gallium nitride (GaN) instead of silicon. The Department of Energy (DoE) estimates that 80% of all US electricity will pass through power electronics by 2030.

The award was based on Mantooth's extensive and long-term investigation of wide-bandgap semiconductors.

"We are very fortunate to have built a very strong program with the support of the U of A administration and state of Arkansas," says Mantooth. "These awards reflect the competitiveness of our program, the expertise of our faculty, our excellent students, and the great teams we have been able to assemble and collaborate with."

Mantooth will be lead investigator for 'Reliable, High Power Density Inverters for Heavy Equipment Applications', which receives $2,163,630 of the total funding. This project focuses on developing a 2x 250kW dual-power inverter system for use in the electrification of heavy equipment and other, higher-volume transportation vehicles, such as trucks and buses.

The research team includes Yue Zhao (assistant professor of electrical engineering), David Huitink (assistant professor of mechanical engineering), Jia Di (professor of computer science and computer engineering), and Juan Carlos Balda (professor of electrical engineering).

They will design SiC-based power electronics and integrated circuits with advanced thermal management to achieve high levels of efficiency, while increasing the power density. The goal is to make the power density of the inverter four times greater than existing technology and to reduce converter cost by 50%. Other organizations on this team include Caterpillar, Wolfspeed, and the University of Illinois at Urbana-Champaign (UIUC).

UIUC associate professor Robert Pilawa-Podgurski will lead the second project 'Enabling Ultra-compact, Lightweight, Efficient, and Reliable 6.6kW On-board Bi-directional Electric Vehicle Charging with Advanced Topology and Control', which receives $1,737,545, of which the U of A will receive $461,604. Mantooth will participate as a member of the research team, focusing on integrated circuit design. Other participants include Oak Ridge National Laboratory (ORNL) and Delphi Automotive.

This project will develop an on-board electric vehicle charger, using a high-density conversion technology known as a flying capacitor multi-level converter, which reduces charging time while also servicing the vehicle's auxiliary loads to maximize overall system utilization. The team will exploit recent advances in GaN devices and new control techniques to produce the 6.6kW converter that will have 15-times greater power density than existing converters but will also be lighter and more efficient.

Mantooth holds the Twenty-First Century Research Leadership Chair in electrical engineering. He serves as executive director of the DoE-funded Cybersecurity Center for Secure Evolvable Energy Delivery Systems and the National Science Foundation (NSF)-funded GRid-connected Advanced Power Electronic Systems. He is also deputy director of the Center for Power Optimization in Mobile Electronics. Mantooth has served as executive director of the National Center for Reliable Electric Power Transmission since its inception in 2005 and has overseen its research and building program. He is an IEEE Fellow, has served on the IEEE Power Electronics Society (PELS) Advisory Committee since 2004, and is currently serving as PELS president until 2019.

www.arpa-e.energy.gov/sites/default/files/documents/files/CIRCUITS_Project_Descriptions.pdf

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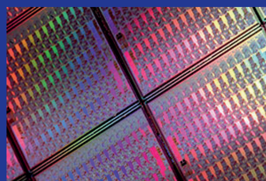

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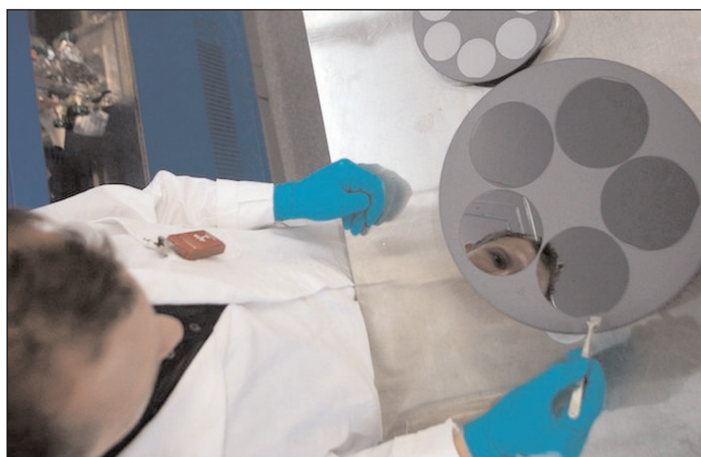
BluGlass, Griffith University and IMCRC to co-develop normally-off GaN HEMTs on SiC-on-Si wafers

Two-year $600,000 project aims to develop Australian wafer supply chain for power electronics industry

In partnership with Griffith University, BluGlass Ltd of Silverwater, Australia is leading a two-year project — involving a $600,000 cash investment, including a $300,000 grant from the not-for-profit, independent Innovative Manufacturing Cooperative Research Centre (IMCRC) — to develop high-performance normally-off gallium nitride (GaN) high-electron-mobility transistors (HEMTs) that promise a positive and stable threshold voltage, low on-resistance, and high breakdown field.



The project aims to combines BluGlass' low-temperature remote-plasma chemical vapor deposition (RPCVD) technology and Griffith University's Queensland Microtechnology Facility (QMF) atomically smooth silicon carbide on large silicon (SiC-on-Si) wafers.

"Electronics manufacturers face high cost barriers for higher-performing materials," says BluGlass' managing director Giles Bourne. "The research project aims to overcome those industry challenges," he adds.

"Silicon is incredibly cheap and traditionally difficult to displace despite the performance advantages of other materials such as GaN… RPCVD operates at temperatures hundreds of degrees cooler than the current industry incumbent technology. This offers electronics manufacturers many advantages, including higher-performance, lower-cost throughputs and the ability to deposit on lower-cost substrate such as silicon." The ability to produce fail-safe, normally-off devices will be critical for widespread adoption of GaN transistors, he states.

"Our unique low-temperature deposition of the p-GaN gate is required to enable high-performance normally-off devices, and this has significant commercial implications, not only for BluGlass but for the Australian power electronics industry," Bourne continues.

The atomically smooth SiC on large Si wafers of the Queensland Microtechnology Facility (QMF) — part of Griffith University's Queensland Micro- and Nanotechnology Centre — provides a chemical barrier and template for the epitaxial growth of nitride layers that helps to address the challenges of defectivity and long-term device reliability. The partnership "highlights the university's commitment to advancing technology through industry collaborations," says professor Ned Pankhurst, Griffith University's senior deputy vice chancellor.

Throughout the project, BluGlass will work closely with Griffith University's QMF and access their process and test equipment, infrastructure, device knowledge and resources to develop and optimize HEMT devices.

The project has the potential to create high-value IP and foundry technologies that could lead to the generation of a local semiconductor wafer economy, reckons IMCRC managing director & CEO David Chuter. "Addressing industry challenges and combining key enabling technologies, we believe this project can boost the commercial value of the sector, and create new opportunities, in Australia and into global value chains," he adds.

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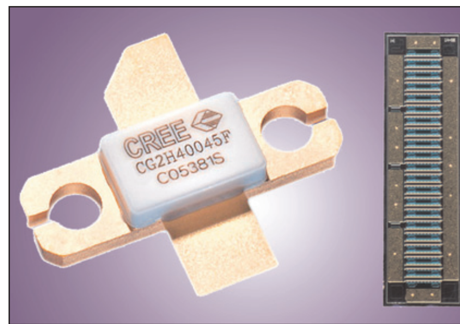
Wolfspeed transitions 28V GaN HEMTs from 0.4µm to 0.25µm, boosting frequency, gain and efficiency

Wolfspeed of Raleigh, NC, USA — a Cree Company that makes silicon carbide (SiC) power products and GaN-on-SiC high-electron-mobility transistors (HEMTs) and monolithic microwave integrated circuits (MMICs) — has launched a series of 28V GaN HEMT RF power devices capable of higher-frequency operation to 8GHz with increased efficiency and higher gain as well as what is claimed to be best-in-class reliability, enabling RF design engineers to build more efficient broadband power amplifiers for commercial and military wireless communications and radar applications.

The new 28V GaN HEMT devices have been developed using Wolfspeed's proven 0.25µm GaN-on-SiC process, and are designed with the same package footprint as the previous generation of 0.4µm devices, making it possible for RF design engineers to use them as drop-in replacements for the earlier devices in existing designs. Available as both packaged devices (CG2H400 Series) and bare die (CG2H800 Series), the new GaN HEMTs deliver 33% higher frequency operation to 8GHz (from 6GHz), an additional 1.5–2.0dB of gain, as well as a 5–10% boost in operating efficiency compared with Wolfspeed's earlier-generation devices.

"By moving to our proven 0.25µm process for these next-generation devices, we are able to deliver significant performance advantages to a wide range of customers while maintaining the superior reliability these types of applications require," says RF and microwave director Jim Milligan. "Offering these new devices in the same packages as our previous generation parts enables RF design engineers to quickly and easily boost the performance of their RF amplifiers."

The higher efficiency (up to 70% at P_{SAT}) and higher bandwidth



A CG2H40045 28V GaN HEMT.

By moving to our proven 0.25µm process for these next-generation devices, we are able to deliver significant performance advantages to a wide range of customers while maintaining the superior reliability these types of applications require. Offering these new devices in the same packages as our previous generation parts enables RF design engineers to quickly and easily boost the performance of their RF amplifiers

capability makes the devices suitable for an extensive range of RF power amplifier applications, including military communications systems, radar equipment (UHF, L-, S-, C-, and X-band), electronic warfare (EW) and electronic countermeasure (ECM) systems as well as commercial RF applications in the industrial, medical & scientific (ISM) band.

The CG2H400 Series include the following packaged 28V unmatched GaN HEMT devices (available in screw-down flanged or solder-down pill packages):

- CG2H40010 — 10W, 8GHz operation with 70% efficiency (at P_{SAT}) and 18dB/16dB small-signal gain (at 2.0GHz and 4.0GHz, respectively);
- CG2H40025 — 25W, 6GHz operation with 65% efficiency (at P_{SAT}) and 17dB/15dB small-signal gain (at 2.0GHz and 4.0GHz, respectively);
- CG2H40045 — 45W, 4GHz operation with 60% efficiency (at P_{SAT}) and 18dB/14dB small-signal gain (at 2.0GHz and 4.0GHz, respectively).

The CG2H800 Series include the following bare die 28V unmatched GaN HEMT devices:

- CG2H80015 — 15W, 8GHz operation with 65% efficiency (at P_{SAT}) and 17dB/12dB small-signal gain (at 4.0GHz and 8.0GHz, respectively);
- CG2H80030 — 30W, 8GHz operation with 65% efficiency (at P_{SAT}) and 17dB/12dB small-signal gain (at 4.0GHz and 8.0GHz, respectively);
- CG2H80060 — 60W, 8GHz operation with 65% efficiency (at P_{SAT}) and 15dB/12dB small-signal gain (at 4.0GHz and 8.0GHz, respectively).

Compared with conventional silicon and gallium arsenide (GaAs) devices, Wolfspeed's GaN-on-SiC RF devices deliver higher breakdown voltage, higher-temperature operation, higher efficiency, higher thermal conductivity, higher power density and wider bandwidths, all of which are critical for achieving smaller, lighter and more efficient microwave and RF products. They enable next-generation broadband, public safety and ISM amplifiers; broadcast, satellite and tactical communications amplifiers; unmanned aerial vehicle (UAV) data links; cellular infrastructure; test instrumentation; and two-way private radios.

www.eumweek.com
www.wolfspeed.com/rf/products/general-purpose-broadband-28-v/table

Transphorm previews GaN 3.3kW bridgeless totem-pole PFC reference design at EPE'17 ECCE Europe

Transphorm Inc of Goleta, near Santa Barbara, CA, USA — which designs and manufactures JEDEC- and AEC-Q101-qualified 650V gallium nitride (GaN) devices for high-voltage power conversion applications, was at the 19th European Conference on Power Electronics and Applications (EPE'17 ECCE Europe) in Warsaw, Poland (11–14 September) as the latest initiative in its mission to educate application design engineers on high-voltage (HV) GaN use as well as to introduce Transphorm's new reference design and latest development tools.

Transphorm's GaN field-effect transistors (FETs) are used in power electronics systems including data center and industrial power supplies, servo motors, photovoltaic inverters and automotive applications, such as on-board chargers.

Preview: 3.3kW bridgeless totem-pole PFC reference design

Transphorm Silicon Valley Center of Excellence's soon-to-be-released totem-pole power factor correction (PFC) reference design is built on the firm's next-generation (Gen-III) 650V 35mΩ GaN FET and is being displayed for the first time. The board leverages digital signal processing (DSP) firmware to deliver a turnkey design solution with no code expertise required. The reference design targets engineers building high-efficiency applications for automotive on-board chargers and industrial power supplies.

Education Session: 'Reliability Testing of High-voltage GaN FETs'

In addition to applying industry-standard qualification tests (i.e. JEDEC and AEC-Q101) to GaN devices, aggressive lifetime testing is required to establish operating life expectancy. Accelerated stress tests, such as high-voltage off-state and high-temperature DC current tests, are used to determine activation energies and acceleration factors that can be used to estimate operating life for any given mission profile. Jim Honea, senior manager of Applications Engineering, p rovided an overview of test results and typical application of them during Transphorm's EPE vendor session.

www.epe2017.com

Transphorm partner Yaskawa's new servo motor first to use GaN

Transphorm says that the Σ-7 F of Japan's Yaskawa Electric Corp is the first servo motor to use high-voltage (HV) GaN.

Transphorm says that its technology enables Yaskawa to deliver better performance in a smaller form factor versus what is possible with incumbent silicon. The co-developed Σ-7 F device integrates the servo amplifier with the servo motor itself. Further, Yaskawa's use of Transphorm's GaN FETs produces an integrated servo motor half the size of a similar design using silicon technology.

The Σ-7 F resulted from a multi-year partnership between Yaskawa and Transphorm. Yaskawa's R&D team as well as its Quality and Production team worked closely with members of Transphorm's GaN Development, Applications, Quality and Manufacturing teams. Additionally, Yaskawa tapped into Transphorm's design resources and tools throughout the development process, which are available to customers through Transphorm's Silicon Valley Center of Excellence.

The Σ-7 F series — AC servo motors in a three-phase bridge configuration — uses Transphorm's HV GaN FETs in a standard three-lead TO-220 package. The topology will be deployed across Yaskawa's full Σ-7 F product line, which currently includes three servo motors ranging from 100W to 400W. The integrated motor allows the industrial manufacturing system to simplify cabling in a daisy-chain configuration. Further, it reduces the system's control panel cabinet size by as much as 30%, given: a reduction in the size of the servo motor itself; elimination of the power supply cable's terminal block due to a reduction in cabling required; and a smaller heat-sink due to lower losses using Transphorm's GaN

Transphorm says that, compared with incumbent technologies, its HV GaN technology inherently delivers better efficiency via lower gate charge, faster switching speeds and smaller reverse recovery charge, while offering high reliability. Applications designed on Transphorm GaN also achieve smaller device size, higher power density and lower overall system costs, it adds.

The Σ-7 F targets industrial multi-axis automation systems commonly used in conveyance equipment as well as food product and packaging manufacturing. Such automation systems must provide high precision, high throughput, repeatability and design flexibility.

"The Σ-7 F servo motor is our second Transphorm GaN product," says Kazuhiro Imanaga, general manager, Servo Drives Technology Department, Motion Control Division, Yaskawa Electric. "When delivered by trusted suppliers, GaN has the potential to radically change what's possible in industrial automation systems," he comments. "Our belief in the Q+R of Transphorm's GaN, along with our positive partnership experience with the company's engineers, enables us to fulfill that vision."

www.yaskawa.co.jp/en

Energous launches GaN-based wireless solution for charging electronic devices with up to 10W

Energous Corp of San Jose, CA, USA (a developer of WattUp wire-free RF charging technology that provides over-the-air power-at-a-distance) has launched a high-power Near Field WattUp charging solution for electronic devices such as smartphones, tablets, smart speakers, game controllers, drones etc.

The new high-power Near Field WattUp charging solution includes: a GaN-based 5–10W RF receiver IC; a GaN-based 10–15W RF power amplifier (PA); allowance for full 2D/planar movement; support for 90° charging angles (sideways charging); a smaller receiver (RX) size, superior accommodation of metal and other foreign objects; and PA integration into the overall system, leading to a lowered bill-of-materials (BOM) cost.

The new transmitter reference design can charge devices with up to 10W of energy, significantly increasing the amount of power delivered to receiving devices and eliminating connectors and charging contacts for a much wider variety of devices.

"We continue to grow our WattUp wire-free charging ecosystem with reference design solutions that will support the technology adoption in an even broader range of customer products," says president & CEO Stephen Rizzone. "Extending the high-power capabilities of Near Field WattUp charging enables many different types of devices to be charged from multiple transmitter options. By continuing to expand the portfolio of reference designs available to customers, we are able to support increasing requests from our various partners for additional options and power levels," he adds.

These first GaN-based solutions for our WattUp wire-free charging technology support higher power and improved charging flexibility, says founder & chief technology officer Michael Leabman

"With a catalog of reference designs ranging from high-power, quick-charging, low-power, small-form-factor, Mid Field and Far Field power-at-a-distance, customers now have the ability to meet virtually all of their wireless charging requirements from a single source," comments Mark Tyndall, senior VP of corporate development & strategy at Dialog.

"These first GaN-based solutions for our WattUp wire-free charging technology support higher power and improved charging flexibility," says founder & chief technology officer Michael Leabman. "Our ability to develop multiple components within the WattUp ecosystem allows us to innovate based on our customer needs," he adds.

www.Energous.com

EPC presents GaN-based large-surface-area wireless power solution at Wireless Power Summit

At the Wireless Power Summit 2017 in Denver, CO (5–6 October), 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 — is exhibiting a wireless power tabletop highlighting the capability of GaN-based magnetic resonance technology to provide wireless power over a large surface area to many receiving devices (such as cell phones, laptop computers, and table lamps) simultaneously.

The future of wireless power and its eventual ubiquitous adoption is dependent on the ability of end users to place any electrical item on a surface and have it powered without having to 'plug in', says EPC. The fundamental technology to achieve this 'drop-and-go' power is defined by the AirFuel Alliance standard.

eGaN FETs and ICs, operating at 6.78MHz, are featured in the amplifiers that power the transmit coils of the wireless power surface and in the receive circuits used in the devices placed on the surface. eGaN technology is suitable for wireless power applications due to its ability to operate at high frequency, high voltage, and high power, says EPC. The wireless power table being demonstrated at the Summit is capable of delivering a total of 165W of power, enabling simultaneous powering of multiple devices.

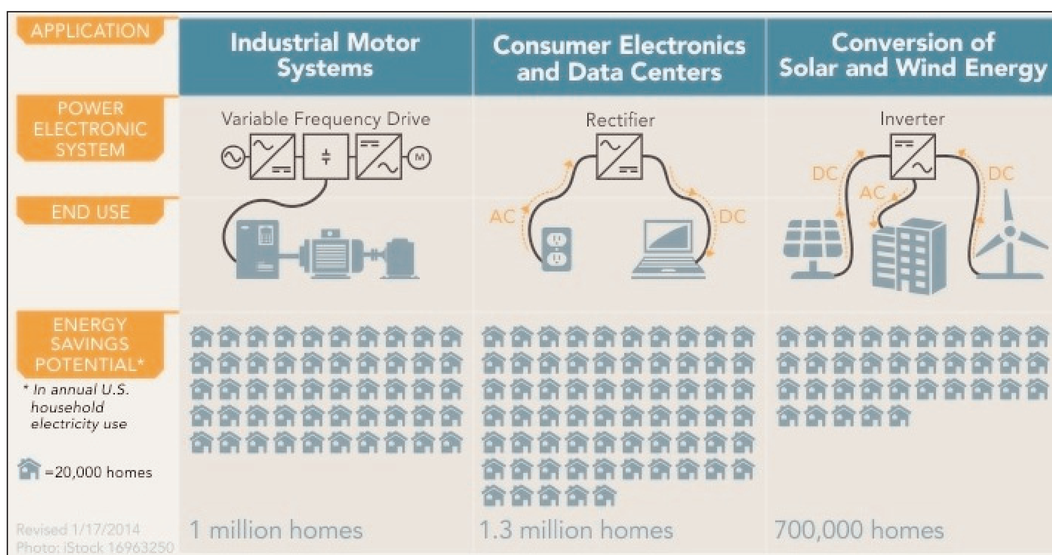
Several eGaN products are critical to the wireless power table design. Specifically, the amplifier on the transmit side of the table uses the EPC9512 power amplifier. The amplifier takes advantage of the performance of the EPC8010 as the main power stage FET, the EPC2038 as the synchronous bootstrap FET and the EPC2019 is critical in the SEPIC pre-regulator. On the receive side, the EPC2019 is also used as a boost FET to accommodate the multiple power levels of the receive devices to be placed on the tabletop, which range from 5W for cell-phone charging to 25W to power the laptop.

The Wireless Power Summit will also provide wireless power industry forecasts, showcase the latest technologies, and give current insights into the wireless power market.

www.wirelesspowersummit.com
www.epc-co.com

Navitas chosen by PowerAmerica to enable high-efficiency, high-density mobile fast chargers

PowerAmerica — a manufacturing institute consisting of public and private partners from the semiconductor industry, the US Department of Energy (DoE), national laboratories and academia — has selected Navitas Semiconductor Inc of El Segundo, CA, USA to enable a new class of high-efficiency, high-density mobile fast chargers.



Using its proprietary 'AllGaN' technology, Navitas' gallium nitride (GaN) power ICs integrate high-voltage GaN field-effect transistors (FETs) with logic, drive and protection circuits to allow power systems to operate at frequencies above 1MHz. This high-speed operation, with simultaneous improvement in efficiency, yields dramatically reduced system size, weight and cost — and 3x faster charging for the consumer, it is reckoned. "Our GaN power ICs, with their unprecedented level of integration, speed and efficiency, are uniquely qualified to deliver on this market-driven challenge," reckons CEO Gene Sheridan.

"Navitas and PowerAmerica share a common vision for increasing technical capabilities and creating manufacturing jobs in wide-bandgap technology," comments PowerAmerica's chief technology officer Victor Veliadis. "We are confident this cooperation will yield remarkable results, including a world-class mobile fast charger."

www.poweramericainstitute.org
www.navitassemi.com

Navitas showcasing new GaN power IC technology at China's Power 2017 conference

At China's annual multi-city Power 2017 conference (at Shenzhen's Venetian Hotel, Shanghai's Zhongyou Sunshine Hotel, and Beijing's Guobin Hotel on 2, 7 and 15 September, respectively), Navitas Semiconductor Inc of El Segundo, CA, USA showcased new gallium nitride (GaN) power IC applications for advanced mobile, industrial and consumer markets.

Founded in 2013, Navitas introduced what it claimed to be the first commercial GaN power ICs. The firm says that its proprietary 'AllGaN' 650V platform monolithically integrates GaN power field-effect transistors (FETs) with logic and analog circuits, enabling smaller, higher-energy-efficiency and lower-cost power for mobile, consumer, enterprise and new energy markets.

Navitas says that, at Power 2017, its executives will also meet with key customers to enable first-to-market, AC–DC applications from 20W to 500W using the firm's high-speed AllGaN technology.

"Power 2017 is a great opportunity for us to demonstrate the benefits of Navitas GaN technology and enable our Chinese customers to achieve market-leading converter performance," says VP of sales & marketing Stephen Oliver. "Our high-performance, easy-to-use GaN Power ICs help Chinese designers to deliver next-generation power solutions on schedule and at the right price."

In February, Navitas launched what it claimed was the first integrated half-bridge GaN power IC, enabling up to a 100x increase in switching speeds while increasing energy savings by 40% or more. In June, the firm announced its 150W AC–DC demonstration board, which has a power density of more than 21W/in^3 and efficiency of over 95%, making it half the size of typical commercial designs, it is reckoned.

"Chinese designers are hungry for new, proven solutions that can be used for best-in-class power converters for smartphone, laptop and TV/monitor applications," comments Daphne Liu, general manager of 21IC China Electronics Network, a strategic partnership between Aichi Nova (Beijing) Information Technology Co Ltd and Arrow Electronics that organizes Power 2017.

www.poweric-china.com
www.navitassemi.com

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EpiGaN gains FPIM as fifth investor

New capital for product portfolio expansion & global strategy execution

nv of Hasselt, near Antwerp, Belgium, which supplies gallium nitride on silicon (GaN-on-Si) and gallium nitride on silicon carbide (GaN-on-SiC) epitaxial wafers for power switching and RF devices as well as sensors, says that the Belgium Federal Holding and Investment Company (FPIM/SFPI) has joined its group of investors to fund its product portfolio expansion and global strategy execution. Joining the capital increase, existing investors LRM and Capricorn Cleantech Fund have re-confirmed their support for EpiGaN's market and technology strategies.

EpiGaN notes that gallium nitride has started to revolutionize key market segments such as the energy sector, where it enables smaller, lighter and more energy-efficient power conversion systems, such as consumer power supplies, and data servers. GaN is also the key technology enabler for wireless communication, offering the capability for a larger data exchange capacity, low latency, and enhanced mobile broadband communication, as required for transitioning from LTE/4G to 5G, as well as autonomous driving and the Internet of Things (IoT).

EpiGaN was founded in 2010 as a spin-off from Belgian micro- and nano-electronics research center imec. Over the past few years it has released product solutions for epitaxial GaN layer structures deposited on 150mm and 200mm silicon substrates, in particular with its in-situ silicon nitride (SiN) passivation, which is said to enable more robust high-performance devices. The firm's product portfolio spans solutions for low-loss power switching, next-generation 5G radio-frequency/mobile communication and sensor applications.

"This investment will support our efforts to execute our strategy towards offering turn-key solutions and services to our global customer base," says co-founder & CEO Dr Marianne Germain. "FPIM and our initial investors share our views about the vast opportunities ahead for EpiGaN," she adds.

"We are very pleased to support a Belgian high-tech company like EpiGaN during their global expansion and strategy execution phase," comments FPIM's CEO Koen Van Loo. "EpiGaN has developed a unique expertise and differentiating technology, and we expect the company to capture a significant share of these high-growth markets."

www.epigan.com
www.lrm.be

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❍ We buy used wafer and sell recycled wafer

AXT completes purchase of new manufacturing facility in Dingxing, China

Staged relocation of GaAs manufacturing from Beijing begins

AXT Inc of Fremont, CA, USA — which makes gallium arsenide (GaAs), indium phosphide (InP) and germanium (Ge) substrates and raw materials — has completed the purchase of its new manufacturing facility in the city of Dingxing, China. Located in the province of Hebei and under the jurisdiction of the prefecture-level city of Baoding, Dingxing is approximately a 90-minute drive south of the firm's existing Beijing location.

Featuring ample space for expansion, the new site currently has three existing buildings, comprising about 140,000ft^2 of manufacturing space, and 50,000ft^2 designated for offices and dormitories. The existing structures will enable the company to move more quickly to production, it is expected.

AXT has already begun to prepare the site for GaAs substrate manufacturing, and is planning a staged relocation of its GaAs equipment and personnel throughout 2017 and 2018, pursuant to its relocation plan. Initial qualification substrates are expected to be available in fourth-quarter 2017. The firm expects to have production-level quantities from both its current site in Beijing and the new Dingxing site for a period of time, and then gradually increase production volume at the new site.

AXT has acquired a total of about 18.8 acres and expects to increase manufacturing capacity at the new location as needed to meet customer requirements. In addition, it will continue to evaluate the potential timing of relocation of its indium phosphide and germanium substrate manufacturing, which is expected to remain at the Beijing facility while the relocation of its GaAs business is completed.

"We have worked closely and collaboratively with both local and central government authorities in China to fulfill the government's request for the relocation of our gallium arsenide production, while ensuring that we can continue to serve the needs of our customers and support the growth of our business," says CEO Morris Young. "This step underscores the desire of all parties involved to make our relocation a success. I want to thank the city officials of Dingxing and Baoding for welcoming AXT to this site," he adds.

"With its relative close proximity to our current facility, its existing manufacturing space, and its room for expansion, we believe our new location positions us for both a successful and efficient relocation of our gallium arsenide business, as well as the expansion of our capacity as current and emerging applications for our technology increase customer demand," Young continues. "Our goal is to make our new location a world-class manufacturing facility and a showcase of our capabilities for customers and investors," he adds.

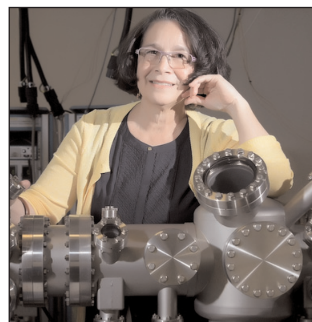
"Our dedicated manufacturing and operations teams have been working diligently over the past year to prepare for a smooth and efficient transition for our customers," notes chief operating officer Wilson Lin. "We are committed to supporting their requirements from our current location, while providing an efficient qualification process and transition plan for the new facility."

www.axt.com

City College of New York professor Maria Tamargo receives 2017 MBE Innovator Award

Chemistry professor Maria Tamargo of The City College of New York (CCNY) has been chosen by the North American Molecular Beam Epitaxy (MBE) Advisory Board to receive its 2017 MBE Innovator Award for "advancing the growth of wide-bandgap II-VI semiconductors by molecular beam epitaxy and demonstrating their unique physical properties and potential novel device applications".

Tamargo will receive a $3000 prize, a plaque and the opportunity to give an invited talk at the 33rd North American Conference on Molecular Beam Epitaxy (NAMBE 2017) in Galveston, TX, USA (15–18 October), where she will receive the honor.



CCNY chemistry professor Maria Tamargo.

Established in 2004, the international award recognizes individuals whose innovative work has significantly advanced the field of MBE. Recipients are highly distinguished scientists whose inventive work must have had/or continue to have a significant impact on the advancement of MBE technology.

In addition to her faculty position in City College's Division of Science, Tamargo is director of the US National Science Foundation's CREST Center for Interface Design and Engineered Assembly of Low-dimensional Systems (IDEALS).

www.nambe2017.org
www.ccny.cuny.edu/science
www.idealscrest.org

Cardiff Capital Region, Welsh & UK Governments and IQE ratify development of Compound Semiconductor Foundry

Foundry to support CS Connected Cluster in South-East Wales

Epiwafer foundry & substrate maker IQE plc of Cardiff, Wales, UK has hosted a signing ceremony between Cardiff Capital Region City Deal, the Welsh and UK Governments and IQE to ratify the development of the Compound Semiconductor Foundry, which will support the development of the CS Connected Cluster (which unites international businesses, policymakers and academics working on next-generation technology).

The project was formally confirmed in a signing ceremony at IQE's headquarters in Cardiff by Secretary of State for Wales the Right Hon. Alun Cairns MP, Welsh Economy and Infrastructure Secretary Ken Skates, CSC Foundry directors Councillors Bob Greenland (Monmouthshire) and Andrew Barry (Merthyr), and IQE chief executive Dr Drew Nelson.

The signing followed an agreement in May by the Cardiff Capital Region (CCR) Regional Cabinet to contribute £37.9m from the CCR City Deal's Wider Investment Fund towards establishing a foundry, as an anchor in the region for high-end production of compound semiconductors.

The aim is to support the development of a compound semiconductor industrial cluster in the region, with the potential to:

- leverage £375m of private sector investment;
- create up to 2000 high skilled jobs;
- return the investment for use on other regional schemes; and
- create hundreds of further jobs in the wider supply chain cluster.

This is the first such investment since the £1.2bn CCR City Deal program was formally signed by the leaders of the ten local authorities in the region on 1 March.

The facility at Newport will be owned by the 10 Councils in the Regional Cabinet under the special-purpose vehicle CSC Foundry Ltd/ LDC Ffowndri. The space will be leased to IQE for compound semiconductor manufacturing and applications development, helping the establishment of CS Connected (the world's first compound semiconductor cluster) in the region.

The project is not a grant or a loan — it is a commercial investment, with ownership of the foundry shared between the 10 Councils. The proposal seeks to return the original investment plus interest over the life of the project.

The CCR City Deal seeks to position the region as the global leader in compound semiconductor-enabled applications, which was initiated by a £12m investment from the Welsh Government.

In 2016, the UK Government's innovation agency Innovate UK announced a £50m investment to establish a new Compound Semiconductor Applications Catapult in South-East Wales (dedicated to developing compound semiconductor applications), build on existing investment by Cardiff University, IQE, and Welsh Government.

"The objective of this commitment is to create a complete compound semiconductor eco-system in South Wales to take advantage of the growing prominence of compound semiconductor technologies," said Councillor Peter Fox, Leader of Monmouthshire County Council and Deputy Chair of the CCR City Deal Regional Cabinet. The establishment of the world's first compound semiconductor cluster in South East Wales "has the potential to place our region at the heart of this cutting edge sector and will require the development and integration of a compound semiconductor supply chain in South Wales," he added.

"Compound semiconductors are at the heart of many devices we use today, from smart phones to tablets and satellite communication systems. It is an area of UK strength and today's confirmation of the development of a cluster of excellence in Wales reinforces our own strong position in the growth of this important and growing technology," commented Secretary of State for Wales Alun Cairns. "Government does not create innovation, but it can be a catalyst to getting the scientists and engineers, the designers and the entrepreneurs together to make it happen. This collaboration is important because innovation is a shared endeavour," he added.

"It is hugely encouraging that Welsh Government's initial £12m investment in developing the cluster back in 2015 has been the catalyst for today's announcement that IQE plans to expand into the City Deal's new facilities," said Economy Secretary Ken Skates.

"This dedicated compound semiconductor facility between Cardiff and Newport will act as a key component of the burgeoning cluster that is already cementing Wales' reputation for technology leadership," believes IQE's chief executive Dr Drew Nelson. "The Welsh and UK governments, along with the 10 councils that form the Cardiff Capital Region, have worked closely with academic institutes and industry to build an innovation infrastructure that will support and nurture the region as a true global player in new and emerging technologies," he adds. "The facility will become the base for a number of compound semiconductor related activities, including IQE, where we expect to rapidly expand our production capacity to meet increasing demand for our technology."

www.csconnected.com

Compound Semiconductor Applications Catapult appoints chief executive officer

Doran brings over 25 years of experience from Raytheon UK, Wolfson and Motorola

The South Wales-based Compound Semiconductor Applications Catapult has announced the appointment of Stephen Doran as CEO.

Serving as director of operations & transformation at global defence technology firm Raytheon UK, Doran brings over 25 years of experience in the global electronics market, developing and delivering leading-edge products for the commercial and defence sectors.

Prior to Raytheon UK, Doran was chief operating officer at Wolfson Microelectronics, a multi-national company specializing in signal processing and mixed-signal audio semiconductors. His time with consumer electronics firm Motorola saw him spearhead new product development and commercial strategy for the USA, European and Asian markets.

As CEO, Doran will lead the strategic direction of the Compound Semiconductor Applications (CSA) Catapult, to drive its approach to accelerate the UK industry's access and ability to exploit advances in compound semiconductor technologies.

"The Catapult offers the UK its best opportunity to establish itself as the global leader in compound semiconductors (CS)," says Doran. "Ensuring this becomes a reality is a goal I share with my new team and board," he adds. "Having worked in semiconductor design and bringing new systems to market, this position provides the chance to blend these insights, working with industry partners to ensure the application of pioneering UK CS technology."

Stephen Doran.

The Catapult is part of nationwide network of technology innovation centers designed and created by UK Government agency Innovate UK to drive economic growth. "His experience, expertise and energy will help ensure that the Compound Semiconductor Applications Catapult accelerates business growth in this important and growing technology area," comments Paul Mason, Innovate UK's director of emerging and enabling technologies, about Doran.

"The new Compound Semiconductors Applications Catapult recognises Wales' reputation as a leader in advanced electronics, science and innovation," says Alun Cairns, Secretary of State for Wales. "The UK Government's investment in this expert hub and in this technology is helping UK companies exploit what is a very lucrative global market, and create and support jobs right across Wales."

Forming a pillar of the CS Connected cluster in South Wales, the UK-focused CSA Catapult will bring together independent scientists, engineers and industry experts at what is aimed to be an industry-leading research facility, in order to explore novel applications of UK-designed compound semiconductor technology to programs relating to power electronics, photonics, RF and microwave applications. Its 'post-foundry' focus aims to make the most of opportunities for innovation and new product development to bridge the gap between companies developing novel semiconductor materials and those developing leading-edge systems for end-user applications.

"The facilities and expertise the Catapult is creating will accelerate the introduction of UK-developed semiconductor technology into new advanced systems, to solidify the UK's position at the core of international supply chains spanning multiple markets across the globe," reckons Doran.

"He brings a wealth of experience to our team, especially in bringing new technologies to market," comments Kevin Crofton, chairman of the CSA Catapult. "This experience will help the Catapult to identify and develop a range of services designed to help SMEs and larger industry players bring new compound semiconductor based products to commercial reality."

www.catapult.org.uk/catapult-centres

CORIAL opens Asia sales & support office

Plasma etch and deposition equipment maker CORIAL of Bernin, France, a provider of plasma etching and deposition equipment, has opened a customer support office in Taipei City, Taiwan to support customers across Asia.

CORIAL says that it already has a strong installed base across Asia, and that the opening is a direct consequence of its commitment to customer service. "Over 65% of our revenues are generated in the Asia-Pacific zone," notes CEO André LECHAT. "For the next three years, we are even targeting an increase of customer activity and business for CORIAL, across the entire region," he adds.

The Taipei office will also provide field service support and business advice to distributors in China, Singapore, and Korea.

www.corial.com

IQE's first-half wafer revenue up 17% year-on-year, driven by Photonics growth of 48%

Strong ramp in VCSEL wafer sales marks start of new wave of growth with pipeline of new mass-market technologies

For first-half 2017, epiwafer foundry and substrate maker IQE plc of Cardiff, Wales, UK has reported revenue of £70.4m, up 12% on £63m for first-half 2016.

Licensing income from joint ventures was £0.95m, down 71% on £3.5m in first-half 2016 since that included significant upfront license fees (compared with none in first-half 2017).

Wafer revenue rose by 17% from £59.5m to £69.4m, reflecting increased sales in all three primary markets.

Wireless sales rose by 9% from £43.2m to £47.3m (68% of wafer sales, though falling from 73% in first-half 2016).

Comprising IQE's fastest-growing segment (following several years of strong double-digit growth), Photonics sales rose by 48% from £10.7m to £15.9m (23% of wafer sales, rising from 18% in first-half 2016). Continued strong growth in Photonics includes the early phase of a significant ramp in vertical-cavity surface-emitting laser (VCSEL) wafers for a mass-market consumer application, contributing to record monthly Photonics sales in June.

Infrared sales rose by 19% from £4.7m to £5.6m (remaining 8% of wafer sales).

In contrast, CMOS^{++} revenue fell from $0.87m to £0.7m.

Gross margin on wafer sales rose from 24% to 25%, while margin on license income remained at 100%. However, overall margin fell from 28% to 26%, reflecting the mix effect of lower license income in 2017.

Selling, general & administration expenses (SG&A) rose from £7.3m to £7.5m.

Despite the increase in sales, operating profit of £10.6m was lower than first-half 2016's £10.8m (which benefitted from the one-off upfront license income).

Adjusted profit after tax fell by £0.4m from £10.2m to £9.8m which, combined with an increase in the fully diluted share count (due to the increase in share price), resulted in an drop in adjusted fully diluted earnings per share (EPS) from 1.46p to 1.35p. After exceptional charges of £2.5m (up from £1.7m in first-half 2016), the reported profit after tax fell from £9.8m to £7.3m.

Due to the drop in profitability, net cash generated from operations fell from £11m to $9.2m.

To support further growth (including the expected mass-market adoption of VCSELs), investment in capital expenditure (CapEx) and product development has more than doubled from £7.6m in first-half 2016 to £15.4m, funded primarily through organic cash generation and supplemented by debt funding. During first-half 2017, net debt rose by £2.4m, from £39.5m to £41.9m.

A further capacity expansion plan has been initiated to meet the higher levels of demand that are expected in second-half 2018. Five new tools are on order, and a lease has been signed on new premises in South Wales to provide a flexible and cost-effective route to add up to 100 new tools (doubling IQE's existing tool count).

A capacity expansion plan has been initiated to meet the higher levels of demand that are expected in H2/2018. A lease has been signed on new premises in South Wales to provide a flexible and cost-effective route to add up to 100 new tools

IQE reckons that the breadth and depth of its customer engagement across a range of technologies and applications sets the scene for increasing revenue diversity and growth through 2018 and beyond.

The firm says that direct engagement with OEMs has expanded to multiple programs across a range of materials technologies (central to several next-generation mass-market applications), validating the strength of its IP portfolio as a key differentiator.

"The compound semiconductor industry is moving through an inflection point," notes chief executive officer Dr Drew Nelson. "Many of the key innovations that are taking place in the technology world would not be possible without the advanced properties of compound semiconductor materials. Indeed, compound semiconductors are the fundamental enabler of innovations such as 3D sensing, biometric sensors, electric and autonomous vehicles, high-speed wireless and optical communications, and advanced manufacturing. IQE has developed an unparalleled breath of materials IP, which position it to prosper from the inflection that is taking place," he adds.

"The broad range of customer engagements across multiple technologies and multiple end markets provide a clear path to increase revenue diversity and accelerate growth over the coming months and years ahead," continues Nelson. "The breadth and depth of customer engagement underpins the board's confidence in approving the capacity expansion plan, which provides a flexible and cost-effective route to significantly scaling up in our business over the next few years."

www.iqep.com

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Picosun reports repeat sales of P-300BV vacuum batch production tools for 200mm applications

Atomic layer deposition (ALD) thin-film technology firm Picosun Oy of Espoo, Finland has reported repeat sales of automated P-300BV vacuum batch production systems to major Asian discrete device manufacturers.

Even if the 300mm wafer size is the existing state-of-the-art in many key semiconductor applications, and efforts have been made to increase this size to 450mm, the 200mm market shows no signs of tailing off, says Picosun. A major factor supporting this steadfast longevity is the increasing usage of substrate materials such as gallium nitride (GaN), silicon carbide (SiC) and sapphire, where the wafer size is limited to 200mm or smaller, for applications including LED lighting, car and transport automation, power conversion, wireless communication and remote sensing. A prime example of the last two is the rapidly spreading Internet of Things (IoT), with billions of sensors forming its core. All of these applications ensure that the demand for 200mm semiconductor production equipment remains consistently high and is even increasing.

"As so many central semiconductor applications and emerging technologies of today utilize 200mm substrates, there has been even a shortage of suitable manufacturing equipment," notes managing director Juhana Kostamo.

Picosun's P-300BV ALD system is designed for fast batch processing of wafers up to 200mm size. Suitable for applications including micro-electro-mechanical system (MEMS) and compound semiconductor production, it is equipped with a single or dual vacuum load-lock system for semi-automatic loading and unloading of substrates under constant vacuum, enabling deposition of nitrides and other sensitive materials.

Wafer carriers of metal and quartz are available, depending on the application.

Full integration to factory automation is possible via the SECS/GEM protocol.

www.picosun.com

Fully automatic SEMI-GAS Centurion Mini Source System launched for low-volume gas applications

Applied Energy Systems (AES) of Malvern, PA, USA — which provides high- and ultra-high-purity gas delivery systems, services and solutions (including design, manufacturing, testing, installation, and field service) — has launched its Centurion Fully Automatic Mini Source System to support low-volume gas applications. The SEMI S2-compliant system combines SEMI-GAS' ultra-high-purity standard Centurion gas source manifold and GigaGuard CDM400 controller to safely and precisely deliver gases from small, lecture bottle sized cylinders.

Key design features of the system include:

- A compact, wall-mounted design that mimics the performance and precision of a full-sized Centurion Source System.
- A GigaGuard CDM400 Controller with a 4.3" color touchscreen, powered by a Siemens S7-1200 Series CPU to enable automatic purging sequences and ensure the system's safe and intuitive operation. The CDM400 is configurable for either four or eight analog inputs and can control up to 12 solenoid valves.
- Red, yellow and green front-mounted LED lights and a high-performance audible alarm to indicate system status, as well as a front-mounted pneumatic Emergency Off (EMO) button.
- Transducer-based pressure monitoring and an Excess Flow Switch with user-specified set-points to trigger an automatic system shutdown during undesirable system conditions.
- A Magnahelic and Switch Exhaust Monitor to indicate air and exhaust pressure differentials.
- Z-Purge optional upgrade for Class I Division II compliance.

While the system can be tailored for array of gases and UHP application requirements, AES initially developed the 1-Cylinder Mini Source System to support a customer's mixed-signal, connectivity and embedded systems R&D. The complete turnkey solution for ammonia included AES' Applied Services equipment installation; confirmation of system conditions, facility connections, component and EMO function; set up of automated purge routines; validation documentation; and operator training by AES field service experts.

"We strive to be a value-add partner for our customers, from system design to system installation, and the Centurion Mini Source System is another example of how our expertise can be leveraged from end to end," says AES' general manager Jim Murphy. "Not only did we help our semiconductor customer solve a specific delivery challenge — built upon our proven, premier SEMI-GAS products — but our Applied Services team also helped them get their system up and running quickly, minimizing their process downtime and avoiding costly delays."

www.appliedenergysystems.com/semi-gas/centurion-gas-cabinets

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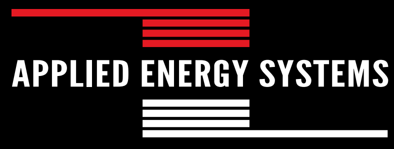

IQE extends production of VCSEL epiwafers with Aixtron AIX 2800G4-TM MOCVD systems

8x6" reactors to be installed in newly leased South Wales plant

Aixtron SE of Herzogenrath, near Aachen, Germany has received an order for multiple metal-organic chemical vapor deposition (MOCVD) systems from epiwafer foundry and substrate maker IQE plc of Cardiff, Wales, UK. The AIX 2800G4-TM automated Planetary reactors are expected to be deployed for the growth of gallium arsenide (GaAs)-based epitaxial wafers on 6" substrates for the production of vertical-cavity surface-emitting lasers (VCSELs) for a range of photonic applications.

All systems are equipped in 8x6" configuration and will complement the existing AIX 2800G4-TM tools already in production at IQE to meet the rapidly growing market demand for VCSEL devices. Aixtron's local support team will commission the new reactors until first-quarter 2018 in a new production facility recently leased as part of the Cardiff Capital Region (CCR) programs, which have a goal of supporting the development of the CS Connected compound semiconductor cluster in South Wales.

"We chose the AIX 2800G4-TM for our capacity expansion due to the excellent results we have already achieved with this platform in the past," comments IQE's chief operating officer Dr Howard Williams. "As a proven tool for high-volume production in the area of photonic applications it enables excellent epitaxial quality and yield on 6-inch wafers whilst also providing the flexibility we require as an epi foundry to serve our customers. Further, the AIX 2800G4-TM platform offers outstanding uniformity and reproducibility. In addition, the backing of the Aixtron local support team will help us to quickly ramp up the systems and serve our customers timely in the current dynamic m arket situation," he adds.

"We have been collaborating with IQE for more than 20 years and we are looking forward to contribute to their business success by supporting the planned production ramp-up in the best way possible," says Aixtron's VP Europe Dr Frank Schulte. "The AIX 2800G4-TM reactor, which can even accommodate 5x8" wafers, has already built itself a strong reputation within the industry, mainly thanks to its unique material performance without compromising on the economies of scale of the Aixtron Planetary batch concept," he concludes.

www.csconnected.com

www.iqep.com

glo orders Aixtron G5+ system for micro-LED production

Aixtron has received an order for an AIX G5+ MOCVD platform from glo-USA Inc in Sunnyvale, CA, USA.

Started at Lund University's Nanometer Structure Consortium by professor Lars Samuelson, Sweden-based glo AB established an R&D and product development pilot line in Sunnyvale in 2010. The firm now focuses on commercializing micro-LED (mLED) products based on its proprietary defect-free gallium nitride (GaN) nanowire technology. Such 3D structures enable the growth of mLEDs while maintaining the reliability of an inorganic material system. Aixtron's AIX G5+ Planetary Reactor system was selected in the scope of glo's strategic expansion and will be delivered in an 8x150mm configuration during fourth-quarter 2017, as glo aims to deliver micro-LED products in 2018.

According to glo, micro-LED technology is on the roadmap of all tier-one display makers as a challenger to the existing display technology for next-generation consumer products. Micro-LED displays consist of micron-sized LED arrays forming individual sub-pixel elements. Compared with existing LCD and OLED technologies, mLED displays offer low power consumption while exhibiting what is reckoned to be superior pixel density, contrast ratio and brightness, hence opening new horizons for consumer mobile products as well as premium TV displays.

"Based on more than 10 years of experience and know-how in the area of nanotechnology, we have developed a game-changing three-color micro-LED display technology," claims glo's CEO Fariba Danesh. "Our three-color pixels are made solely with GaN semiconductor material. We are now focused on taking this exciting technology to a volume production stage. Beyond the epitaxial structure, the manufacturing of mLEDs require scalable processes, very tight uniformity and particle control of the epitaxial wafers to enable the highest yield and therewith cost-efficient transfer to our mLED partners. Aixtron's AIX G5+ MOCVD system provides all these requirements while maintaining low fab economics due to a batch reactor configuration," she adds.

"Our AIX G5+ is being recognized as the tool of record for mLED-related applications as it is the sole technology on the market providing on-wafer uniformity control, low particle levels, and unique advanced features such as wafer-level temperature control with Auto-Feed Forward (AFF) and therefore supporting the demanding micro LED requirements," claims Aixtron's president Dr Bernd Schulte.

www.glo.se

Aixtron's AIX 2800G4-TM Planetary MOCVD technology supporting Osram Opto's production ramp for 150mm IR high-power lasers and LEDs

Aixtron SE of Herzogenrath, near Aachen, Germany says that Osram Opto Semiconductors GmbH of Regensburg, Germany has purchased its AIX 2800G4-TM Planetary metal-organic chemical vapor deposition (MOCVD) system for the manufacturing of mainly infrared-based high-power lasers and LEDs based on gallium arsenide (GaAs).

Aixtron is hence now supporting the capacity expansion at one of the leading suppliers of high-quality optoelectronic semiconductors to be used in an increasing number of applications, especially in the automotive and communication sector. The tool is in 8x6" configuration and was commissioned in Q2/2017.

"Their trust in our AIX 2800G4-TM system confirms our strategy to focus on solutions for the most demanding applications, where superior process performance is mandatory to meet our customer's requirements," says Dr Frank Schulte, vice president Aixtron Europe. "Following the recent qualification of our AIX G5 C platform and achieving this key milestone also with the AIX 2800G4-TM, we are looking forward to further deepen our partnership with one of the most innovative semiconductor manufacturers worldwide," he adds.

www.aixtron.com

SPTS wins fifth consecutive RoSPA Gold Award

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 won a Gold Award in the Royal Society of Prevention of Accidents (RoSPA) Occupational Health and Safety Awards for the fifth consecutive year (presented at a ceremony in Birmingham on 13 July).

Winning a RoSPA award "demonstrates an organization's commitment to maintaining an excellent health and safety record," says Julia Small, RoSPA's head of awards and events.

"We pride ourselves on the level of continuous improvement throughout our organization and being able to provide a safe and stimulating work environment for our employees," says Kevin Crofton, corporate VP at Orbotech and president of SPTS Technologies. "It takes commitment and support of all the staff to maintain this high standard of health and safety practices in the work place."

RoSPA is a safety charity that recognizes companies that have demonstrated a commitment to occupational safety and health for their employees. It is open to businesses and organizations of all types and sizes from across the UK and overseas. A majority of the awards are non-competitive and mark achievement at merit, bronze, silver and gold levels. The RoSPA Awards scheme is the largest and longest-running program of its kind in the UK, now in its 61st year. Competitive awards go to the best entries in 24 industry sectors including construction, healthcare, transport and logistics, engineering, manufacturing and education. There are specialist awards for occupational health, environmental management and fleet safety.

www.rospa.com/awards
www.spts.com

Integra acquires die prep, assembly & test firm CORWIL

Independent integrated circuit test and services firm Integra Technologies LLC of WICHITA, KS, USA has acquired CORWIL Technology Corp of Milpitas, CA, USA, which provides die prep, assembly and test services focusing on high-reliability (hi-rel), fast-turn and wafer processing markets. Founded in 1990, CORWIL provides full back-end assembly services to medical, military/aerospace e and commercial semiconductor companies.

Combination of the two firms will provide a single point of contact for a broad array of semiconductor die prep, assembly, test and evaluation services supporting the military, avionics, space, medical, automotive and fabless semiconductor markets.

"The combination provides our mutual customers with one of the largest US-based semiconductor die prep, assembly and test offerings in the industry," claims Integra's president & CEO Brett Robinson. "Integra has been an employee-owned company since 2008 and we are pleased to welcome our new employee owners from CORWIL," he adds.

Acquisition by Integra provides "great assurance to our customers (especially those in the hi-rel market), employees and suppliers," comments CORWIL's president Matt Bergeron. CORWIL will continue operations in Milpitas with existing employees, management team and product/service offerings.

www.integra-tech.com
www.corwil.com

Evatec expanding Greater China operations to support rapid business growth

Thin-film equipment firm setting up own independent sales & service organizations in both Taiwan and China

Evatec Ltd of Trübbach, Switzerland (which makes thin-film deposition and etch processing equipment for advanced packaging, power device, MEMS, optoelectronics, wireless communication and photonics applications) is setting up its own independent sales and service organizations in both Taiwan and China to support the growth of its business in Greater China. The new offices will be operational from 1 January 2018.

Greater China activities will be led by Kevin Chen (who joined the firm in August 2016 as managing director of Evatec South East Asia), leading the team in sales & marketing, field and application engineers and back-office support functions across the whole region.

Kevin Chen.

Chen has more than 15 years experience holding senior management positions in the capital equipment & materials industry. He managed the sales & service organization of Oerlikon Semiconductor Frontend Division in Taiwan and China starting in 1999, took the general manager position of Oerlikon Semiconductor Backend Division (ESEC) in 2004, and then responsibility as head of sales in China for Oerlikon Solar Division in 2010. The Oerlikon Semiconductor Frontend Divisions was acquired by Evatec in 2015, in the same year that Evatec also took over the know-how and after-sales business of the former Oerlikon Solar Division.

"The creation of our own local organizations in Greater China is the logical next step in the development of our global sales and service network," says CEO Andreas Waelti. "Kevin and his team will be able to leverage the capabilities and experience of our whole team across South East Asia and Greater China for the benefit of our customers in the region," he adds. "We would like to take the opportunity to thank our partner DKSH for the support they gave over the last years and look forward to working closely with them for a successful handover of operations over the coming months."

www.evatecnet.com

Taiwan's STC becomes distribution partner for AP&S' single-wafer and wet bench products

AP&S International GmbH of Donaueschingen, Germany (which designs and produces batch- and single-wafer wet process equipment for surface treatment of substrates under cleanroom/sterile conditions) has entered into a collaboration with new distribution partner STC Standard Technology Corp of Taiwan, beginning with a shared booth at the SEMICON Taiwan 2017 exhibition in Taipei (13–15 September).

"Taiwan, as one of the world's major producers of electronic products, belongs to the most important regions for the semiconductor industry globally," says Oliver Pohl, responsible for the international distributor network at AP&S. "Correspondingly high is the interest for advanced wet process solutions in this market. The goal of our new partnership with this local player is to cover this demand efficiently," he adds.

"Since 2016 we have already successfully cooperated with the company CLC Tech, which was and will remain the exclusive Taiwanese distributor for our cassette, box and FOUP cleaner CB II and CB III," Pohl continues. "With STC as a new distributor for our single-wafer and wet bench product portfolio, our Taiwanese customers and prospective business partners have a reliable contact person right at their front door," he adds. "STC is well established in the market since 1988, is an expert in his field, and is familiar with the specific needs of the local market. Together we offer convenient access to required information for interested parties and achieve short distances between the customer and equipment provider, who can be quickly on-site on request."

At SEMICON Taiwan, AP&S and STC are presenting the full range of AP&S wet process solutions. Highlights of the single-wafer area will be the unique AP&S SpinLift-off tool, which processes with DMSO (an EH&S non-critical substance) and the SpinMask tool (for mask cleaning).

Within the wet bench portfolio the partners are emphasizing the A-Series wet process tool (which is available with a 100 wafer half-space feature for high-volume production) and the AP&S Vulcanio bench (a fully automated e-less plating tool). Both wet benches are capable of handling up to 300mm wafers.

www.ap-s.de

BluGlass' upgraded BLG-300 chamber demonstrates targeted thickness uniformity for LED wafers up to 6"

LED efficiency demonstrated on par with prior RPCVD results, with significantly improved performance uniformity

BluGlass Ltd of Silverwater, Australia says its upgraded BLG-300 chamber has demonstrated RPCVD deposition uniformity within its targets for LED wafers, up to 6" in size.

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

The upgraded BLG-300 (the firm's larger RPCVD platform) is now producing thickness uniformity of <3% variance over 2" and 4" wafers and <3.5% variance over a single 6" wafer, meeting BluGlass' targets to progress on the commercialization projects. The upgraded chamber (a scaled-up version of the BLG-180 design) has also produced LED efficiency on par with the firm's previous best results as BluGlass works to deliver industry acceptance of RPCVD technology.

The improved BLG-300 has also delivered LED performance uniformity (critical benchmarks for demonstrating the commercial application of the firm's unique low-temperature technology, BluGlass reckons).

"The new chamber design has been highly successful in a number of key areas for BluGlass," comments managing director Giles Bourne. "The thickness and performance uniformity have now been demonstrated, and by applying the identical design from the BLG-180 to the larger BLG-300, we have also shown that RPCVD can be scaled in size and for the deposition of larger wafers," he adds. "All of this is substantial progress for the RPCVD technology and our commercialization efforts."

The BLG-300 has now been re-deployed on the development of the firm's industry evaluations with Lumileds, IQE and others, all of which are expected to benefit from the improved uniformity and larger-wafer deposition capability.

www.bluglass.com.au

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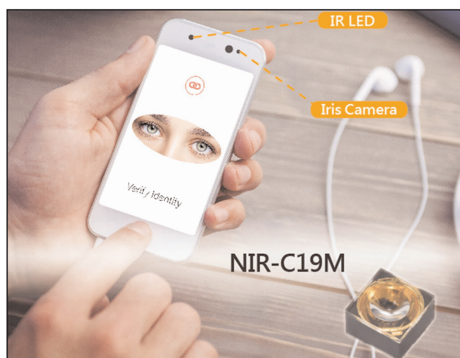
Everlight introduces 810nm IR LED for iris recognition

Taiwan-based Everlight Electronics Co Ltd has launched the NIR-C19M series, which has an emission wavelength of 810nm (since this yields the clearest contrast for reading the pattern of the iris). The recognition process is said to be precise and quick and features excellent heat dissipation, making it suitable for iris recognition applications in security surveillance systems (access control) and portable handsets.

In response to market demand and the resulting development of appropriate technology, the concept of 'body is access code' has been integrated into many systems and devices. Smart biometric identification allows rapid and easy measurement of the users' unique patterns in the fingerprint, voice, iris and face in order to avoid the problem of recalling traditional long passwords. Infrared LEDs for non-contact optical identification have the advantages of compact size, strong security and quick recognition speed, making them increasingly sought-after.



Everlight's NIR-C19M series for non-contact optical iris recognition adopts a molding manufacturing process. Compared with the traditional glue dispense manufacturing process, molding results in a smoother surface that not only enhances the look but also increases reliability. The NIR-C19M series works with a wavelength of 810nm and uses advanced image signal processor (ISP) together with a CMOS sensor to receive the infrared reflection from the human eye in order to authenticate iris identification. The firm says that its unique optical design achieves a clear high reflection rate, a small angle (FOV=25) and a radiant intensity of up to 2700mW/Sr below 1000mA.

With a thermal resistance of 4.38ºC/W, heat dissipation is superior to any other competing product on the market, it is claimed. The device has also passed IEC62471 (a safety regulation proving that no harm arises to human eyes and skin).

As well as these optical features, the dimensions of NIR-C19M series are just 3.5mm x 3.5mm x 2.3mm, which is particularly desirable for space-constrained portable devices.

www.everlight.com

Samsung launches fillet-enhanced chip-scale LED packages for spotlights and high-bay applications

Samsung Electronics Co Ltd of Seoul, South Korea has launched two new additions to its chip-scale package (CSP) line-up: the LM101B 1W-class mid-power LED and the LH231B 5W-class high-power LED. Built with enhanced CSP technology, the new LED packages deliver what is claimed to be industry-leading efficacy and reliability for spotlights and high-bay lighting applications.

The LM101B and LH231B packages are based on Samsung's fillet-enhanced CSP (FEC) technology, which forms TiO_2 walls around the chip surface to reflect its light output toward the top, acting as a plastic mold in conventional EMC-based LEDs.

With their FEC design, the packages provide greater luminous efficacy than Samsung's previous generation of CSP LEDs. The more focused beam also helps to eliminate cross-talk between neighboring packages and enables the new packages to be placed in close proximity to each other, offering greater flexibility to luminaire designers.

The LM101B is claimed to have the highest efficacy among currently available mid-power CSP LEDs with 200lm/W (Ra80 5000K, 65mA, 25ºC). Furthermore, with low thermal resistance (2K/W) and high reliability (0.5W, 105ºC, L90>50,000 hours), it has been optimized for spotlights and high-bay applications, where high efficacy and long lifespan are required.

With an operating current of 2A (maximum 6W), the LH231B has an efficacy of 170lm/W (Ra70 5000K, 700mA, 85ºC), the same as that offered by ceramic-based high-power LEDs, yielding great cost-effectiveness when applied to high-bay applications that require an output of 5000–10,000lm. Due to Samsung's FEC structure, the 120º beam angle allows simple optic designs, making it also suitable for outdoor applications such as street and parking lot lighting.

"Our FEC line-up represents an outstanding set of highly advanced LED component solutions that accommodates a variety of luminaire designs from below 1000lm to well over 10,000lm," says Jacob Tarn, executive VP of the LED business team. "Samsung will continue to pave the way for widespread adoption of CSP technology in the mainstream lighting market, bringing greater performance and cost benefits to a growing number of lighting manufacturers," he adds.

The LM101B and LH231B complement Samsung's currently available 3W-class high-power LH181B CSP LED, and the entire FEC lineup is now in mass production.

www.samsung.com

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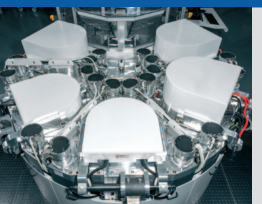
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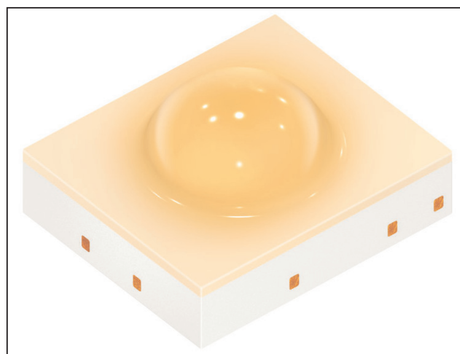
Osram launches Osconiq LED product family for professional applications

Osram Opto Semiconductors GmbH of Regensburg, Germany says that its new Osconiq LED product line will cover professional applications including linear and area lighting, high- and low-bay lighting and street lighting. The familiar Duris P products, which are currently being used for these applications, will be transferred to the new Osconiq line.

The first member of the new family is the Osconiq P 2226 which, due to its robustness, color portfolio and scalable current, offers great versatility.

With their high-quality epoxy package, surface-emitting chip and robust silicone, the various versions of the Osconiq P 2226 are durable and resistant to corrosion. They have the same footprints as the previous Duris P 5 series, namely 2.2mm x 2.6mm x 1.25mm, which means they are interchangeable and can be integrated in existing systems. The small dimensions of the Osconiq P 2226 enable more LEDs with the same or with different colors to be integrated in customer applications to achieve optimum homogeneous color mixing results. These features make the LEDs suitable for outdoor applications such as horticultural and architectural lighting and also for indoor lighting systems such as those installed in restaurants and hotels.



Osram Opto's Osconiq P 2226 LED.

The Osconiq P 2226 is available in the following color versions: deep blue (450nm), blue (465nm), true green (525nm), yellow (595nm) red (623nm), far-red (730nm), and ultra white with a color rendering index of at least 60. The mid-power LED offers luminous efficacy of 100lm/W for the red version, 27lm/W for blue and 92lm/W for true green. The LEDs are designed to be used in professional indoor and outdoor applications where monochromatic colors are required. The LED also offers a large bandwidth of operating points. If required, it can be operated with a flexible range of currents. While the binning current of 100mA provides a competitive luminous flux at what is claimed to be outstanding efficacy, the Osconiq P 2226 can be driven up to 250mA when clients need especially strong light.

"We have been able to develop an extremely robust and efficient initial product with the Osconiq P 2226," says Daniel Doxsee, head of global marketing General Lighting at Osram Opto. "We will continue to expand the Osconiq family to cover industrial applications such as high bay but also outdoor applications such as street, tunnel or area lighting."

www.osram.com

Osram launches compact CSP-based Ceramos C for mobile devices

Osram Opto Semiconductors GmbH of Regensburg, Germany is expanding its existing portfolio for flash applications with a product featuring a specially developed chip-scale package (CSP). With Ceramos C, Osram is following the trend for miniaturization, as the new LED is the smallest yet in its product family, suitable for flash applications on smartphones etc.

The new Ceramos generation no longer has the conventional ceramic package and bond wiring of its predecessors. Instead it uses a CSP platform specially developed by Osram Opto, ensuring that the entire chip surface is uniformly illuminated and that there is virtually no loss of light.

Also, Ceramos C has a smaller footprint (just 1.4mm x 1.4mm x 0.21mm, three times shallower than its predecessor) but produces the same brightness despite its smaller package size, giving designers greater freedom. Ceramos C is suitable for use in smartphones or tablets that need a compact LED particularly for the front camera, but also for the main flash and for the flashlight function. With a typical color rendering index (CRI) of greater than 80, the LED offers natural colors no matter where it is used, claims the firm. Luminous flux is 260lm and the color temperature is 4500K.

"Despite its small size, Ceramos C is extremely powerful and a real bonus for end customers," says marketing manager Fiona Mak. "Our Ceramos C fits perfectly with the trend for miniaturization because it's small enough to be easily installed in even the thinnest smartphones and tablets."

www.osram.com

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ams expands Singapore manufacturing capacity

$200m investment includes VCSEL R&D and manufacturing line

ams of Premstaetten, Austria, which designs and makes high-performance sensor and analog solutions, is expanding its manufacturing operations in Singapore at JTC nanoSpace @ Tampines. The firm will operate a fully automated cleanroom with filter deposition technology for manufacturing high-precision micro-optic sensors. Alongside this, it will also invest in a new vertical-cavity surface-emitting laser (VCSEL) R&D and manufacturing line.

Altogether, ams expects to invest about $200m over the next three years in manufacturing in Tampines. This follows the firm's expansion earlier this year in Ang Mo Kio.

ams says that its continued expansion in Singapore is the result of customer volume requirements for its sensors and high-end optical packaging. At JTC nanoSpace @ Tampines, ams will manufacture micro-optic sensors for mobile applications. The new facility complements the capacity at Ang Mo Kio and the manufacturing operations in Austria, as well as partnerships with major contract manufacturers around the world.

At an official opening ceremony, members of ams' management board hosted Minister for Trade and Industry (Industry) S. Iswaran for a tour of the firm's new JTC nanoSpace @ Tampines operations.

"Singapore is a vital part of ams' R&D and manufacturing strategy," says CEO Alexander Everke. "We are investing in differentiating technologies, advanced equipment and employees in the region, and we are committed to long-term operations in Singapore for our cutting-edge design and process technology. We are grateful for the continued support of the Singapore government, the Economic Development Board (EDB), and JTC as we collaborate to make Singapore a global center for advanced semiconductor design and manufacturing," he adds.

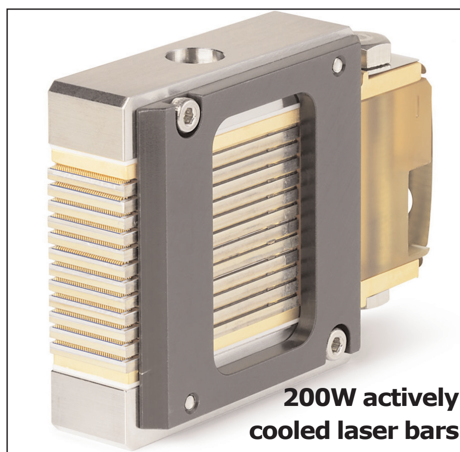
"ams' new activities are in line with Singapore's push to capture new growth opportunities in areas such as sensors in IoT applications," comments Lim Kok Kiang, assistant managing director of the Singapore Economic Development Board.

www.ams.com

II-VI Inc launches 200W actively cooled laser bars and multi-kilowatt stacks for new directed-energy weapons

Engineered materials and optoelectronic component maker II-VI Inc of Saxonburg, PA, USA (which makes high-power semiconductor laser components) has announced the commercial availability of its actively cooled laser bars, emitting 200W of continuous wave (cw) power with greater than 60% efficiency. The laser bars enable multi-kilowatt vertical stacks to optically pump neodymium-doped solid-state lasers, including in below-freezing environments.

Next-generation directed-energy weapon systems require increased mobility and operation at extreme ambient temperatures. Offering a combination of power, efficiency and polarization purity, II-VI's new laser bars enable diode-pumped solid-state laser designs employed in new directed-energy weapon systems to achieve optimum size, weight and energy efficiency. The firm says that use of an ethylene-glycol coolant makes the II-VI laser bars commercially unique in their ability to operate in extremely low-temperature conditions such as in airborne vehicles and to withstand storage temperatures as low as −40°C.


200W actively cooled laser bars

"With these bars we are capable of building stacks with more than 7kW of output power," says Karlheinz Gulden, general manager, II-VI Laser Enterprise. "It's a significant achievement that adds to our 20-year legacy of gallium arsenide laser technology platform development."

With demonstrated cw output of up to 275W, II-VI's new laser diode bars are rated for cw output of 200W in operation. They can be stacked to optically pump multi-kilowatt solid-state lasers. They also feature a proprietary hard solder technology designed to withstand high-power pulsed operation with what is claimed to be excellent reliability.

With short operating wavelengths in the 8xx nm regime, the laser bar stacks are also effective in direct-diode laser systems for processing metals such as copper, bronze, brass, stainless steel and aluminium, which are otherwise highly reflective to the longer wavelengths of typical industrial lasers.

II-VI showcased its optical systems capabilities at the 2017 Directed Energy Systems Symposium in Monterey, CA, USA (25–29 September).

www.ii-vi-photonics.com

AIM Photonics selects University of Arizona for high-impact industrial demo of integrated photonic cryogenic datalink for focal plane arrays

Consortium includes Sandia, Raytheon and aerospace firms

The Rochester, NY-based consortium AIM Photonics (American Institute for Manufacturing Photonics) — an industry-driven public–private partnership advancing the USA's photonics manufacturing capabilities — has announced the winner of a proposal call for a new Defense Department Government Directed Project for photonic integrated circuit (PIC) data links for cryogenic focal plane arrays (FPAs).

The $1,200,000 US Department of Defense (DoD) project, along with an additional $400,000 in matching funds from a team led by the University of Arizona (UA), will support a consortium that includes Sandia National Labs, Raytheon (RTN) and other aerospace firms engaged in FPA technology.

The project will encompass the design, fabrication and test of cryogenic PIC-based datalinks for FPA readout and has the potential to strongly advance imaging capabilities for national defense applications. Capitalizing on the national reach and capabilities of this consortium, the PICs will be manufactured in the AIM Photonics silicon photonics fabrication facility at SUNY Polytechnic Institute in Albany, NY, and could also lead to fabrication opportunities at AIM Photonics' Test, Assembly, and Packaging (TAP) facility, which is being built in in Rochester, NY.

"When you consider the rapid pace of growth in both the FPA size and the required data rates, conventional electronic readouts become limited because they are both a heat source and a communication bottleneck," says Dr Robert Norwood, a professor of Optical Sciences at the University of Arizona, and principal investigator for the program.

The University of Arizona's extensive experience in cryogenic FPAs and integrated photonics, working in concert with major contractors of the defense industrial base, will target a design and development methodology that provides a common PIC datalink solution across multiple system needs and environments.

"The design and development infrastructure we have developed is state-of-the-art, and a key benefit for the team as they create this next integrated photonics technology," says AIM Photonics' CEO Michael Liehr Ph.D.

"Raytheon regards the integration of photonic integrated circuits with focal plane arrays as a critical path for the development of future DoD imaging systems vital to the nation's security," comments Dr Frank Jaworski, program manager, Emerging Technology, at Raytheon Vision Systems.

"This program is a great opportunity for the Department of Defense to leverage advances in integrated photonics manufacturing being realized by the Manufacturing USA program together with its state, industrial, and academic partners," notes Neil Supola, chief of the Infrared Focal Plane Array Branch at the Army's Night Vision and Electronic Sensors Directorate, and government program manager for AIM Photonics. "The scope of industrial participation on this project highlights the relevance photonic integration has within the DoD community, and this project's inherent potential to make a large impact."

www.aimphotonics.com

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POET's DenseLight subsidiary launches high-power 1310nm DFB lasers for 100G silicon photonics

POET Technologies Inc of San Jose, CA, USA —a designer and maker of optoelectronic devices, including light sources, passive wave guides and photonic integrated circuits (PIC) — says its subsidiary DenseLight Semiconductors (which produces lasers for optical sensing) will start sampling high-power, continuous-wave 1310nm distributed feedback (DFB) lasers for 100G silicon photonics applications early in Q4/2017.

DenseLight will also sample long-wavelength 1650nm DFB lasers for test & measurement, optical time domain reflectometry (OTDR) and photonics/biomedical sensing.

This series of DFB lasers is based on DenseLight's proprietary indium phosphide (InP) multiple quantum well (MQW) technology, manufactured in Singapore.

These DFB lasers are the latest addition to POET's product portfolio, which consists of superluminescent LEDs (SLEDs), gain chips, narrow-linewidth fiber Bragg grating (FBG) lasers, and integrated light modules.

With the ever-growing demand for more bandwidth, data-center operators are actively deploying low-cost, scalable, single-mode optics-based 100G transceiver solutions. Further, the growing demand for bandwidth is driving the need for companies to deploy test & measurement systems that monitor the quality of networks.

In response to increasing customer requests, DenseLight has added a range of uncooled DFB lasers to its product portfolio, starting with high-power 1310nm lasers for silicon photonics applications and 1650nm lasers for test & measurement applications. DenseLight will introduce these lasers in either chip form or in multiple packaged configurations, offering optimum performance in a range of demanding applications, including datacoms, OTDR, distributed acoustic sensing (DAS) and spectroscopy (chemical and gas) detection.

The initial samples are expected to be at 1310nm and 1650nm, followed by 1625nm. Other standard wavelength ranges between 1270nm and 1670nm are expected to be available soon.

The high-power continuous-wave 1310nm DFBs are expected to generate peak power levels of 60mW across temperature, which is required for today's 100G silicon photonics applications.

DenseLight exhibited its suite of standard components for datacoms and sensing applications, as well as its 100G-compatible CWDM and LAN WDM multiplexing solutions, at the China International Optoelectronic Optoelectronics Exposition (CIOE) in Shenzhen (6–9 September).

www.cioe.cn/en
www.denselight.com

POET appoints Jean-Louis Malinge to board

POET has appointed Jean-Louis Malinge to its board of directors.

Concurrently, Ajit Manocha, who served on the board since July 2014, has resigned from the board to devote his time to his new role as president & CEO of SEMI (industry association Semiconductor Equipment and Materials International), while remaining engaged with POET as a strategic advisor. Given Manocha's new role, POET will leverage SEMI's outreach in the electronics industry, which also includes photonics.

Malinge is currently a partner with ARCH Venture Partners, an early-stage venture capital firm with nearly $2bn under management. He also serves as a managing director for YADAIS, a consulting firm in the photonics and telecoms industries, and is a board member of EGIDE SA, which designs and manufactures hermetic packages for the protection and interconnection of several types of electronic and photonic chips.

Previously, Malinge was CEO of silicon photonics firm Kotura (which designed and made CMOS optical components) until he sold the firm in 2013 for $82m to Mellanox. Prior to Kotura, he worked for more than 15 years at Corning Inc, where he held various executive positions including VP of optical networking components.

Malinge has a Masters Degree in Physics from Institut National des Sciences Appliquées in Rennes, France, along with an Executive MBA from the MIT Sloan School in Boston.

"Jean-Louis has extensive executive, technical and operational experience across the photonics and optical industry, with specific experience in transitioning companies from the R&D stage to successful commercial businesses by formulating key strategies and infusing organizations with customer-centric processes," says executive chairman, David Lazovsky. "He will add significant value to the board's oversight and operational capabilities with his breadth of experience in the photonics industry.

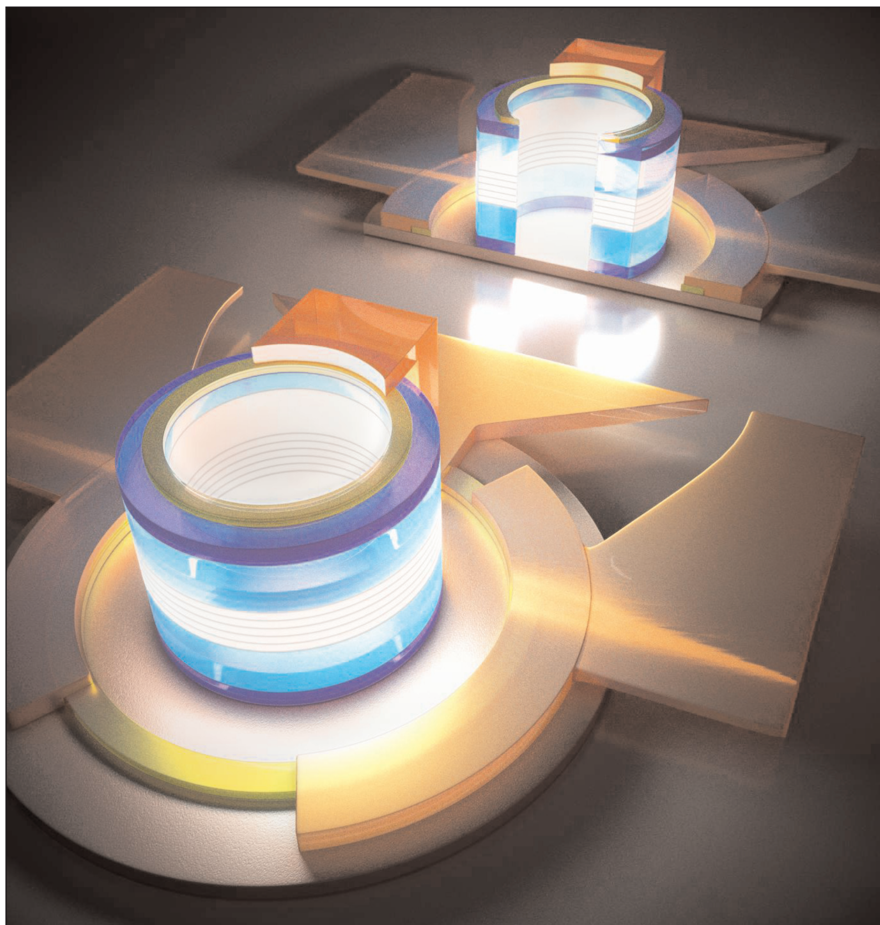
"Ajit has been a valuable contributor to our company, and we are very pleased with his recent success as president & CEO of SEMI. We look forward to continuing to work with him as an advisor," Lazovsky says. "We are enthusiastic to simultaneously add Jean-Louis to the board who brings exceptional and relevant experience that directly complements POET's strategic direction. We look forward to his input and contributions as we aggressively pursue the development and commercialization of our integrated photonics platform."

www.poet-technologies.com

HKUST/UCSB team demonstrates record 1.3μm CW submilliamp-threshold quantum dot micro-lasers on silicon

Electrically pumped QD lasers follow team's prior development of CW optically pumped micro-lasers

With the increasing need for miniaturization and large-scale integration of photonic components on a silicon platform for datacoms and emerging applications in mind, a team of researchers at the Hong Kong University of Science and Technology (HKUST) and the USA's University of California, Santa Barbara (UCSB) have demonstrated record-small electrically pumped micro-lasers epitaxially grown on industry standard (001) silicon substrates (Yating Wan et al, '1.3μm submilliamp threshold quantum dot micro-lasers on Si', Optica vol4, issue 8, p940 (2017)). A submilliamp threshold of 0.6mA, emitting continuous-wave (CW) at the near-infrared telecommunications wavelength of 1.3μm up to 100°C, was achieved for a micro-laser with a radius of 5μm. The thresholds and footprints are orders of magnitude smaller than those previously reported lasers epitaxially grown on silicon.



Schematic of electrically pumped quantum dot micro-ring laser. (Credit: Department of Electronic and Computer Engineering, HKUST.)

"We demonstrated the smallest-current-injection QD lasers directly grown on industry-standard (001) silicon with low power consumption and high temperature stability," says Kei May Lau, Fang Professor of Engineering and Chair Professor in HKUST's Department of Electronic & Computer Engineering. "The realization of high-performance micron-sized lasers directly grown on silicon represents a major step toward utilization of direct III-V/Si epitaxy as an alternate option to wafer-bonding techniques as on-chip silicon light sources with dense integration and low power consumption," he adds.

The two groups have been collaborating and have previously developed CW optically pumped micro-lasers operating at room temperature that were epitaxially grown on silicon with no germanium buffer layer or substrate miscut. This time, they demonstrated record-small electrically pumped QD lasers epitaxially grown on silicon. "Electrical injection of micro-lasers is a much more challenging and daunting task: first, electrode metallization is limited by the micro-size cavity, which may increase the device resistance and thermal impedance; second, the whispering gallery mode (WGM) is sensitive to any process imperfection, which may increase the optical loss," notes Yating Wan, a HKUST PhD graduate and now postdoctoral fellow in UCSB's the Optoelectronics Research Group.

"As a promising integration platform, silicon photonics need on-chip laser sources that dramatically improve capability, while trimming size and power dissipation in a cost-effective way for volume manufacturability," comments John Bowers, deputy CEO of AIM Photonics. "The realization of high-performance micron-sized lasers directly grown on silicon represents a major step toward utilization of direct III-V/Si epitaxy as an alternate option to wafer-bonding techniques."

https://doi.org/10.1364/OPTICA.4.000940
www.ust.hk
http://optoelectronics.ece.ucsb.edu/profile/john-bowers

InnovateUK awards £1.1m to SUPER8 project to develop 200G 8-channel CWDM transceiver for hyper-scale cloud data-centers

CSC, Kaiam and CST to deliver commercial-grade solution for high-volume manufacturing within 30 months

The Compound Semiconductor Centre (CSC) — a joint venture between Cardiff University and epiwafer foundry and substrate maker IQE plc of Cardiff, Wales, UK — has announced the award of a £1.1m collaborative R&D project under the recent InnovateUK Emerging and Enabling Technologies Call.

Project SUPER8 (A scalable 200Gb/s Super-thermal, 8-channel CWDM architecture) will focus on the development of new ultra-high-speed transceiver platform to service the growth market in optical datacoms in hyper-scale cloud data centers.

The project consortium comprises Cardiff-based CSC (founded in 2015 with the mission of accelerating commercialization of compound semiconductor materials and device research), transceiver manufacturer Kaiam of Newark, CA, UA (which has a primary manufacturing plant in Livingston, Scotland, UK) and III-V optoelectronic foundry Compound Semiconductor Technologies Global Ltd (CST Global) of Hamilton (near Glasgow), Scotland (a subsidiary of Sweden-based Sivers IMA Holdings AB). The consortium partners will collaborate to deliver a commercial-grade solution with the target of transfer to high-volume manufacturing in a timescale of 30 months.

This project will deliver an 'all UK'-developed and -manufactured solution which leverages world-class compound semiconductor materials and device expertise at CSC and CST with Kaiam's highly innovative photonic integrated circuit technology

"The adoption of cloud services, video-on-demand and emerging IoT [Internet of Things] services are driving a massively expanding global data bandwidth demand," says CSC project lead Dr Wyn Meredith. "The UK is already a major player in the supply of high-performance compound semiconductor materials and components that underpin the global communications network. However, next-generation high-capacity networks will require higher-transmission-rate, lower-cost transceiver solutions," he adds. "This project will deliver an 'all UK'-developed and -manufactured solution which leverages world-class compound semiconductor materials and device expertise at CSC and CST with Kaiam's highly innovative photonic integrated circuit technology."

www.csc.wales
www.CSTGlobal.uk

CST Global receives £202k grant for MacV CPT-based miniature quantum atomic clock research project

III-V optoelectronic foundry Compound Semiconductor Technologies Global Ltd (CST Global) of Hamilton International Technology Park, Blantyre, near Glasgow, Scotland, UK (a subsidiary of Sweden's Sivers IMA Holdings AB) is receiving a grant of £202,056 as one of three participant members — along with Cardiff University and the National Physical Laboratory Management Ltd in Teddington, UK — in the research project MacV ('VCSELs for miniature atomic clocks'). The government-funded project has a funded value of £705,287, with Compound Semiconductor Centre (CSC) Ltd — a joint venture between Cardiff University and epiwafer foundry and substrate maker IQE plc of Cardiff, Wales, UK — appointed as lead participant.

"The project is endeavouring to develop a commercially viable, mass-produced, coherent population trapping (CPT)-based, miniature quantum atomic clock," says CST Global project engineer Iain Eddie. "Atomic clocks track time by measuring the vibration of an atom, hence the accuracy. The MacV quantum atomic clock will use a caesium ion, which vibrates at a very stable frequency when excited by light of the correct wavelength," he adds.

CST Global's involvement is in the development of a commercially viable, single-mode vertical-cavity surface-emitting laser (VCSEL) producing light at a wavelength of 894nm, which matches the resonance of the caesium ion.

"The MacV project is initially aimed at magnetic sensing applications and communications where the GPS timing signal is not available, such as military and underwater applications," notes Eddie. "However, we foresee its use in other data transmission applications, as knowing when data is transmitted, to atomic clock accuracy, makes subsequent decryption more efficient and secure."

www.compoundsemiconductorcentre.com

CST Global appoints China country manager to grow OEM, distribution and contract manufacturing sales

III-V optoelectronic foundry Compound Semiconductor Technologies Global Ltd (CST Global) of Hamilton International Technology Park, Blantyre, near Glasgow, Scotland, UK (a subsidiary of Sweden-based Sivers IMA Holding AB) has appointed Alex Wen as China country manager.

Wen will act as the firm's exclusive Chinese agent, with responsibility for growing OEM, distribution and contract manufacturing sales in the rapidly developing territory.

Alex Wen.

Wen graduated from Beijing Institute of Technology in 1996 with a Major in Telecommunication Engineering.

"Alex is a well-respected figure in the Chinese photonics market, with over 15 years optoelectronics experience," comments Euan Livingston, VP sales & marketing. "Prior to his appointment by CST Global, he has held senior sales management roles at major international companies, including CyOptics Inc (now part of Avago), Avnet Inc and Com-Star Communication Inc," he adds. "His appointment is essential to supporting our continuing rapid expansion in this region, supporting record sales of lasers into PON and GPON markets and massive growth in silicon photonic devices."

CST Global signs master purchase agreement with large North American network system supplier

CST Global has signed a master purchase agreement (MPA) with a large North American-based global provider of network systems. CST Global is to supply optoelectronic devices, essential for the deployment of next-generation cloud, data-center and hyperscale data-center applications. According to Cisco Global Cloud Index, the number of hyperscale data centers will grow from 259 at the end of 2015 to 485 by 2020.

The order value, over a two-year period, is expected to be worth $10m. The contract "confirms that we offer the right optoelectronic solutions, at the right time, to the rapidly growing, cloud, data-center market," says Sivers IMA's CEO Anders Storm.

Anders Storm.

"It is one of several major growth markets that we have identified, driven by the communication and sensor society," he adds. "This growth will be further supported by billions of connected items, due to the Internet of Things (IoT), as well as future 5G networks."

Hyperscale data centers contain at least 5000 servers each. Data centers of all sizes have massive amounts of fiber connections requiring the optoelectronic devices that CST Global supplies.

"This MPA is the first we have in place with a large North American network systems provider of such global reach and scale," says Storm. "CST Global is amongst a select group of companies in the world capable of providing the optoelectronic devices required, in the necessary quantities," he claims.

www.CSTGlobal.uk

CST and University of Glasgow MOCVD system to be commissioned in time for 2017/2018 academic year

CST Global says that commissioning of its new metal-organic chemical vapor deposition (MOCVD) machine will be completed in time for the 2017/2018 academic year.

"The MOCVD machine project is a unique academic and commercial collaboration between the University of Glasgow and CST Global," says CEO Neil Martin. "Richard Hogg, professor of photonics at the university, is leading the project to commission and operate the new machine. He is sharing his time between the university, the owner of the machine, and CST Global's foundry facility at Blantyre, Glasgow, where it will operate," he adds. "Operational costs are shared, with the machine supporting a range of research programs, jointly managed within our ISO 9001:2015, quality environment."

Commissioning is timed for the 2017/2018 academic year. "The collaboration enables PhD students to undertake research projects in advanced semiconductor materials and devices, in both electronics and photonics," notes Martin. "CST Global will use spare machine capacity to provide epitaxial 'overgrowth' services to customers. It brings this process under our control, reduces costs and improves delivery times. I expect this MOCVD collaboration to pave the way for many similar academic commercial partnerships… We look forward to seeing many talented and motivated post-graduates on site this year, including some potential new recruits."

LiGenTec and VLC Photonics offer silicon nitride photonic integration circuit foundry

Low-loss waveguides, plus low bending loss of thick-film nitride, enables low-cost integrated applications

LiGenTec SA of Lausanne, Switzerland (which provides manufacturing foundry services in silicon nitride) and fabless design house VLC Photonics of Valencia, Spain — which provides optical integration solutions and services including photonic integrated circuit (PIC) design or in-house chip characterization and test, together with fabless manufacturing and packaging services — have collaborated to offer a generic platform for the prototyping and production of photonic integrated circuits.

LiGenTec has matured a proprietary silicon nitride process that is able to achieve ultra-low propagation losses, with several record devices reported in the last few years. "Our process is able to deposit thick-film silicon nitride, from 100nm to 2500nm, overcoming the challenge of crack formation due to stress in the material," says CEO Michael Zervas. The process can also scale up to production volumes using 8" wafers and stepper lithography.

The propriatory low-loss waveguide technology, together with the low bending losses that thick-film nitride enables, paves the way to new integrated applications, says LiGenTec. Thick silicon nitride chips can thus scale down four-fold in cost compared to thin-film silicon nitride, it is said.

The open-access platform provides a generic fabrication process for designing and manufacturing photonic integrated circuits for many different applications. Targeting mainly the most common communications wavelengths, the platform is also customizable for lower visible wavelengths, suitable for biophotonic and sensing applications. The main markets addressed are optical telecom and datacom, supercontinuum generation, microwave photonics and quantum optics.

Fabrication is organized through dedicated full-wafer runs or shared multi-project wafer (MPW) runs, periodically three times a year. Users can subscribe to these runs and prepare their designs using the standardized rules and functional building blocks provided by the foundry and the design house, which have also been implemented under a process design kit (PDK) for two different design software tools: OptoDesigner by PhoeniX Software and IPKISS by Luceda Photonics.

VLC Photonics will also be offering full design or design support for inexperienced users, and also chip characterization and test services once fabrication has been performed. "We have realized that most of the times, end users also require some level of design or test assistance, to speed their developments and reduce the risk when targeting complex projects," notes VLC Photonics' CEO Iñigo Artundo.

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

Firecomms partners with distributor TECNOMIC to expand India and South East Asia sales

Firecomms Ltd of Cork, Ireland and Tongxiang, China (which makes fiber-optic solutions and optical transceivers for communications networks) has partnered with Singapore-based Tecnomic Components, a regional distributor in South East Asia and India for the electronic component industry. Backed by a team of field application engineers, Tecnomic supports customers through all stages of product realization from initial design to volume manufacture.

Multiple market segments in India and South East Asia can now access Firecomms' RedLink transmitter and receivers for plastic optic fiber (POF) and connectorless Optolock transceivers through Tecnomic.

Firecomms combines compound and silicon semiconductor technologies with small-scale integration for rugged communications on short links and across high-voltage isolation barriers. The firm's robust transceivers and receivers feature its POF technology, making them suited to industrial, harsh and noisy environments and applications.

With low power consumption, Firecomms' products offer reduced maintenance cycle times and what is claimed to be best-in-class lifecycle on transceivers and cables.

Firecomms' technology is used in power and energy, industrial, transportation, automotive, medical, gaming, military, aeronautical and consumer markets.

"Tecnomic offers a second-to-none level of technical support for customers, so by leveraging on their expertise I am confident more customers in new geographies will be able to access and utilize Firecomms' leading edge technology," comments Firecomms' European managing director & chief technical officer Dr John Lambkin.

"With our focus on demand creation and customer support, we are confident of taking Firecomms' exciting range of products to key customers in South East Asia and India," adds Tecnomic director Gary Tan.

www.firecomms.com

4WDM MSA for 100G optical networks extended from 10km with specs for 20km and 40km reach

Market for 20 & 40km reach to rise to $300m by 2020, as 10km surpasses $1bn in 2017

The 4WDM MSA (4-wavelength Wavelength Division Multiplexing Multi-Source Agreement) Group has released the first specifications for 100G optical networks with 20km and 40km reaches using forward error correction (FEC). The specs are said to be critical for enabling cost-effective and low-power 100G networking in data-center interconnects, mobile backhaul and other switch, router and transport client-side interfaces in core/metro/access networks where reach longer than 10km is required.

"Sales of 100GbE 10km-reach transceivers are likely to exceed $1bn in 2017 and demand for longer-reach 100GbE optics is picking up," comments Dr Vladimir Kozlov, founder & principal analyst at LightCounting Market Research. "The new 20 and 40km specifications are an important milestone to enable this market, which we expect to reach $300m by 2020," he adds.

"The 4WDM-20 specification, which is an extension of the 100G-4WDM-10 10km specification, enables customers to increase their reach using the same kind of optical components as 100GBASE-LR4 products," says the MSA's chair Jeffery Maki of Juniper Networks. "Similarly, the 100G-4WDM-40 enables 40km reach with lower power consumption and in a smaller form factor than existing 100GBASE-ER4-compliant products that utilize a power-hungry SOA (semiconductor optical amplifier)."

The wavelengths used in the new 20 and 40km specifications are based on the LAN-WDM grid, which is the same as used by the existing 100GBASE-LR4 and 100GBASE-ER4 standards. To enable low cost, the new specifications use IEEE Std. 802.3 'KR4' RS FEC on the host port.

4WDM-40 enables 40km reach with lower power consumption and in a smaller form factor

The 4WDM MSA Group is an industry consortium dedicated to defining optical specifications and promoting adoption of interoperable 100G (4x25G) optical transceivers for 10km based on the CWDM4 wavelength grid, and for 20km and 40km based on the LAN-WDM wavelength grid, over duplex single-mode fiber (SMF). These extended reaches are important for modern data-center interconnects and mobile backhaul applications. The 4WDM MSA Group says that it is responding to previously unmet industry needs for longer reaches, lower costs and lower power consumption compared with previously available standards such that they are implementable in small form factors.

Members of the 4WDM MSA include Applied Optoelectronics Inc, Broadcom Ltd, Brocade, Ciena, ColorChip, Dell Inc, Finisar Corp, Foxconn Interconnect Technology Ltd, Huawei Technology Co Ltd, Inphi Corp, Intel Corp, Juniper Networks, Kaiam Corp, Lumentum, MACOM Technology, NeoPhotonics Corp, Oclaro Inc, Skorpios Technologies Inc, Source Photonics, and Sumitomo Electric Industries Ltd.

www.4wdm-msa.org

NeoPhotonics agrees new five-year $50m credit facility

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 in telecom and data-center applications) has entered into a new five-year $50m revolving credit facility with Wells Fargo Bank, National Association (effective 8 September).

Upon closing, the firm drew $30m under the new facility and will use the proceeds of the credit facility to pay off its existing facility with Comerica Bank and for working capital needs and general corporate purposes.

NeoPhotonics' existing $30m credit facility with Comerica Bank (under which it borrowed $20m) expired on 31 August and a $39.2m credit line with China's CITIC Bank (under which it borrowed $17m) expires on 30 September. NeoPhotonics also has additional capacity of about $17.7m from Shanghai Pudong in China (available until early Q1/2018). "Without any recovery in China, there would be doubt that our existing cash [$79m in cash, cash equivalents, short-term investments and restricted cash, down from $91.5m at the end of Q1] would be adequate for the next full year if we did not extend at least one of these credit lines or secure equivalent financing," said interim chief financial officer Sandra Waechter when reporting NeoPhotonics' second-quarter 2017 financial results in mid-August.

"This new credit facility provides NeoPhotonics with lower capital costs, an extended maturity and increased borrowing capacity for continued execution against our strategic priorities globally," comments president & CEO Tim Jenks.

www.neophotonics.com

100G Lambda MSA to define specification for next-generation optical links

22 founding members collaborate to accelerate specification of 100Gbps per wavelength optical interfaces

The 100G Lambda Multi-Source Agreement (MSA) Group has announced their intent to develop specifications based on 100Gbps per wavelength optical technology.

Under the MSA, 22 participating companies are addressing the technical challenges of achieving optical interfaces utilizing 100Gbps per wavelength technology ensuring optical interoperability for transceivers and interfaces produced by different manufacturers and in various form factors. The new optical specifications target the next generation of networking equipment that is required to address the ever-growing need for bandwidth.

The 100G Lambda MSA Group founding members include: Alibaba, Arista Networks, Broadcom, Ciena, Cisco, Finisar, Foxconn Interconnect Technology, Inphi, Intel, Juniper Networks, Lumentum, Luxtera, MACOM, MaxLinear, Microsoft, Molex, NeoPhotonics, Nokia, Oclaro, Semtech, Source Photonics, and Sumitomo Electric.

The new interfaces defined by the 100G Lambda MSA double the speed per wavelength for 100Gbps and 400Gbps applications. To complement the 100Gbps (100GBASE-DR) and 400Gbps (400GBASE-DR4) 500m-reach interfaces currently being defined by IEEE P802.3, the 100G Lambda MSA is focused on reaches of 2km and 10km over duplex single-mode fiber. By focusing on 100Gbps per wavelength, the 100G Lambda MSA is providing a technology platform required for next-generation networking equipment.

www.100GLambda.com

Mellanox and Accelink partner to provide 100Gb/s PSM4 Ethernet transceivers

Accelink adopts Mellanox's low-power silicon photonics optical engine to meet growing demand for hyperscale Web 2.0 and cloud optical interconnects

End-to-end optoelectronics component maker Accelink Technologies Co Ltd of Wuhan, China has introduced a 1550nm 100Gb/s PSM4 transceiver based on the silicon photonics optical engine of Mellanox Technologies Ltd of Sunnyvale, CA, USA and Yokneam, Israel (a supplier of end-to-end InfiniBand and Ethernet interconnect solutions and services for data-center servers and storage systems). Serving the growing demand of hyperscale Web 2.0 and cloud interconnects, the new Accelink transceiver provides an additional source and full interoperability with PSM4 transceivers from Mellanox.

"PSM4 represents the highest-volume, most cost-effective and flexible 100Gb/s transceiver for single-mode fiber in data-center applications," says Amir Prescher, senior VP of business development & general manager of the interconnect business at Mellanox. "Customers benefit by having more supplier options; Mellanox and Accelink both benefit by expanding the market for 100Gb/s products," he adds.

"Chinese Web 2.0 and datacenters are transitioning to 100Gb/s networks, so the timing is perfect for us," says Accelink's general manager Zhang Jun. "The fully qualified Mellanox optical engine significantly reduced our time to market," he adds. "With no lenses, isolators or hermetic packages, the Mellanox solution is easier to assemble and lower cost than competitor solutions."

The Mellanox optical engine was announced in March at the Optical Fiber Communication Conference (OFC 2017) in Los Angeles. The components are fully qualified for use in low-cost, electronics-style packaging, ensuring a low-risk and quick time to market, says Mellanox. Because the silicon photonics platform eliminates the need for complex optical alignment of lenses, isolators and laser sub-assemblies, users can scale to high-volume manufacturing more easily and more quickly than using traditional technologies.

The new Accelink transceivers were showcased in Mellanox's booth at the China International Optoelectronics Exhibition (CIOE 2017) in Shenzhen, China (6–9 September). The booth featured: Accelink and Mellanox 100Gb/s PSM4 transceivers; 100Gb/s SR4 transceivers for Gen 5 Wireless applications; LinkX 25G/50G/100Gb/s direct attach copper (DAC) cable & active optical cables (AOC) and 100G SR4 & PSM4 transceivers; and silicon photonics optical engines and components.

www.cioe.cn/en
www.accelink.com

O-Net launches 980nm uncooled pump laser in small-form-factor TO-can package

O-Net Technologies (Group) Ltd of Shenzhen, China (which provides optical networking products for both telecommunications and data communications applications) has launched a 980nm uncooled pump laser in small-form-factor TO-Can package, a high-power laser for optical amplification applications for coherent transmission modules and compact optical fiber amplifier applications.

The product is expected to aid the transition to the next generation of small-form-factor compact erbium-doped fiber amplifier (EDFA), which can be incorporated inside CFP2 ACO/DCO modules. With the launch of the new product, O-Net Technologies will begin the qualification process with various major customers, and mass production of the TO pump is expected to start in first-quarter 2018.

As it continues to expand from its origin as a supplier of optical networking products, O-Net says that, in view of the strong demand for coherent transmission products to support rising bandwidth demand for data-center interconnect and metro networks, it is leveraging its TO-Can packaging technology together with the design and manufacturing capability of France-based 3SP Technologies (formerly 3S Photonics, before it was acquired in 2014 by Advance Photonics Investments Ltd and O-Net Communications (Group) Ltd) in order to develop pump laser technology.

The new TO pump is derived from a 980nm uncooled pump laser platform for optical amplification that is claimed to significantly reduce product size and enable operation in confined physical environments.

"The launch of the TO pump is a testament to our ability to develop the next generation of optical networking products for the data-center interconnect market," says chairman & CEO Austin Na. "We expect both passive and active optical networking products will continue to present numerous opportunities," he adds.

"With a strong global R&D and manufacturing presence, we will continue to expand our portfolio of high-growth new products in a bid to enlarge the group's market share and create synergies for our businesses," Na concludes.

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QSFP-DD MSA Group releases 3.0 Hardware spec

The Quad Small Form Factor Pluggable Double Density (QSFP-DD) Multi Source Agreement (MSA) group has released an updated 3.0 Hardware specification for the new QSFP-DD form factor. In total, 62 companies have come together in support of the QSFP-DD MSA to address the industry need for a high-density, high-speed networking solution.

Established in March 2016, the QSFP-DD MSA group accepted the challenge to meet the market demand for a next-generation high-density, high-speed pluggable backwards-compatible module form factor. The MSA group has now released a 3.0 Hardware specification with broad market support that is said to overcome the technical challenges of specifying a QSFP28-compatible double-density interface. The QSFP-DD specification defines mechanical, electrical, and thermal management requirements to enable multi-vendor interoperability.

QSFP-DD pluggable modules can support quadruple the bandwidth of conventional QSFP modules, allowing networking equipment to keep pace with advances in application-specific integrated circuit (ASIC) technology. Systems designed for QSFP-DD modules will be backwards compatible with existing QSFP form factors and provide increased flexibility for end users, network platform designers and integrators.

The QSFP-DD 3.0 Hardware specification defines a module and both a stacked-height integrated cage/connector system and a single-height cage/connector system. The MSA has redefined the scope on the QSFP form factor, the industry's leading multi-lane pluggable form factor used across Ethernet, Fibre Channel and InfiniBand. QSFP was initially launched at 40 and 100Gbps network applications and now QSFP-DD supports up to 400Gbps in aggregate over an 8 x 50Gbps electrical interface.

QSFP-DD MSA founder-promoters include Broadcom, Brocade, Cisco, Corning, Finisar, Foxconn Interconnect Technology, Huawei, Intel, Juniper Networks, Lumentum, Luxtera, Mellanox Technologies, Molex, Oclaro, and TE Connectivity.

Contributors to the QSFP-DD MSA include Acacia, ACON, Alibaba, Amphenol, Applied Optoelectronics, APRESIA Systems, Cavium, Celestica, Ciena, ColorChip, Dell EMC, Delta Products, Fujitsu Optical Components, Genesis, H3C, Hisense Broadband, Hitachi Metals, Hewlett Packard Enterprise, Innovium, Inphi, Ixia, JPC, Kaiam, LEONI, Lorom, Luxshare-ICT, MACOM Technology Solutions, MaxLinear, MultiLane, NeoPhotonics, Nokia, Panduit, PHY-SI, Ranovus, Samtec, SENKO, Semtech, Sicoya, Siemon, Skorpios Technologies, Source Photonics, Spectra7 Microsystems, Spirent, Sumitomo Electric, US Conec, Xilinx, and Yamaichi Electronics.

www.qsfp-dd.com

SFP-DD MSA releases spec for high-speed, high-density interface

The Small Form Factor Pluggable Double Density (SFP-DD) Multi Source Agreement (MSA) Group has completed the initial hardware specification and drawings for the SFP-DD pluggable interface designed to enable high-speed, high-density networking equipment.

Targeting support up to 3.5W optical modules in an enterprise environment, the SFP-DD form factor addresses the technical challenges of achieving a double-density interface and ensuring mechanical interoperability for module components produced by different manufacturers.

SFP-DD MSA founding members include Alibaba, Broadcom, Brocade, Cisco, Dell EMC, Finisar, Hewlett Packard Enterprise, Huawei, Intel, Juniper Networks, Lumentum, Mellanox Technologies, Molex, and TE Connectivity.

The SFP-DD electrical interface expands on the existing SFP pluggable form factor, a widely adopted interface used in data centers and other networking platforms. The SFP single-lane interface operates up to 28Gbps NRZ (non-return-to-zero) or 56Gbps PAM-4 (4-level pulse amplitude modulation). The new SFP-DD electrical interface is designed to support two lanes that operate up to 28Gbps NRZ or 56Gbps PAM-4 per lane, providing aggregate bandwidth of 56Gbps or 112Gbps.

By doubling the lane density and data speed, the SFP-DD interface will help to address demand for greater port density and scalability in next-generation applications, with a primary focus on the server-side interconnect. An SFP-DD server port along with QSFP-DD switch ports provides an overall doubling of the port density in network applications.

The SFP-DD hardware specification and drawings define key module, plug and cage characteristics. SFP-DD modules and direct-attach cable (DAC) plugs use a common mechanical outline. Modules and plugs provide a means to self-lock with the cage upon insertion. Network equipment based on the SFP-DD will support legacy SFP modules and cables, and new double-density products, for optimal design flexibility.

Key SFP-DD features are listed as: a single-port SMT connector and cage; heat-sink options for thermal management flexibility; module mechanical definition; and support for optical and copper interfaces, with physical layer specifications to be determined outside the scope of the SFP-DD MSA.

www.sfp-dd.com

CWDM8 MSA Group formed to support deployment of 400G 2km and 10km optical links in data centers

The CWDM8 MSA (8-wavelength Coarse Wavelength Division Multiplexing Multi-Source Agreement) Group has announced its formation as an industry consortium dedicated to defining optical specifications and promoting adoption of interoperable 2km and 10km 400Gb/s interfaces over duplex single-mode fiber (SMF).

CWDM8 MSA founding members include Accton, Barefoot Networks, Credo Semiconductor, Hisense, Innovium, Intel, MACOM, Mellanox, Neophotonics and Rockley Photonics.

"There is currently no adequate solution in the market to meet our needs for cost-effective and uncooled 400G optical interfaces for 2km and 10km reaches," notes Yu Li, VP of data-center switching at Huawei.

To meet the bandwidth and expansion needs of modern data centers and to support the deployment of 12.8T Ethernet switches and other advanced networking equipment with 50G SerDes, the CWDM8 MSA participants are developing optical link specs that will enable cost-effective, low-power-consumption 400G duplex single-mode optics using 50G-per-wavelength optical NRZ (non-return-to-zero) modulation, all while maintaining full compatibility with standard 50G PAM4 (4-level pulse amplitude modulation) electrical interfaces.

The CWDM8 MSA offers "proven 50G NRZ technology to enable compact and low-power-dissipation form factors for 400G," says Yu Li.

These optical interfaces can be implemented in next-generation module form factors such as QSFP-DD, OSFP and COBO, and are believed to have significant time to market and performance advantages compared with other approaches. MSA participants expect to address industry needs by advancing unique technologies to create a diverse and competitive supply chain, while providing products that are optically compatible and interoperable.

"400G QSFP-DD optics are a key component of Nokia's FP4 routing platforms," notes Nokia's director of product line management Samuel Liu. "The CWDM8 MSA has formed to support our customers' needs for low-powered, high-density 400G in both 2km and 10km applications… We look forward to working with the CWDM8 member companies enabling the migration to high-density 400G."

"Our next-generation Ethernet switches are designed for 50G electrical interfaces, driving the need for 400G pluggable optics that is reliable and has low power dissipation," says Mike Yang, president of Quanta Cloud Technology (QCT). "The CWDM8 ecosystem is developing solutions that will accelerate adoption of duplex fiber interfaces for our applications," he adds.

"The CWDM8 MSA enables 400G optical interfaces with significantly improved link budgets over other solutions and we look forward to working with the CWDM8 member companies to validate their products in our router and switch systems and drive a fast time to market for these next-generation interfaces for 2km and 10km reaches," says Zhang Yun, director of optical network, ZTE.

www.cwdm8-msa.org

Kaiam shipping LightScale2 platform in volume for 100G CWDM4 transceivers

Kaiam Corp of Newark, CA, UA (which makes optical transceivers for hyperscale data centers) has announced general availability of the XQX5000-series of QSFP28 100G-CWDM4 transceivers based on its LightScale2 platform. The product is qualified at multiple premier customers and volume production out of Kaiam's large-scale manufacturing plant in Livingston, Scotland, UK is meeting high demand.

The LightScale2 architecture is said to reduce the cost of parts and manufacturing while improving electrical and thermal performance by eliminating hermetic 'gold boxes' and flex circuits. "The LightScale2 production ramp has gone very smoothly," says Russell Childs, general manager of Kaiam Europe Ltd. Kaiam's UK factory has manufactured traditional hermetic TOSAs (transmitter optical sub-assemblies) and ROSAs (receiver optical sub-assemblies) in high volumes for years. "The LightScale2 platform is far simpler to manufacture in terms of assembly steps, capital equipment, and labor. This has allowed us to ramp to high volumes with high yields much more quickly than was possible with more complex legacy products," he adds.

"Our micromechanical alignment technology allows multi-mode packaging techniques to be used in a single-mode application," says Kaiam's CEO Bardia Pezeshki. "The Lightscale2 platform is optimized to deliver maximum value and performance in the data-center environment at dramatically lower costs than traditionally aligned hybrid approaches."

Kaiam raised substantial expansion capital to support the build-out of LightScale2 manufacturing capacity by selling its fabrication plant in Newton Aycliffe, UK to II-VI Inc. Kaiam aims to continue the development of indium phosphide (InP) photonic integrated circuits (PICs) for future transceiver products via foundry services and partnerships.

www.kaiam.com

Finisar's quarterly revenue falls 4.4%, as lower 10G transceiver demand offsets growth in 100G QSFP28 transceivers

High-power VCSEL array production ramp delayed a quarter by change in manufacturing process

For fiscal first-quarter 2018 (ended 30 July 2017), fiber-optic communications component and subsystem maker Finisar Corp of Sunnyvale, CA, USA has reported revenue of $341.8m, roughly level with $341.3m a year ago but down 4.4% on $357.5m last quarter, due mainly to a decline in telecom revenue as well as a drop in 10G-and-below datacom transceivers.

Datacom product sales were $258.3m, up 5.8% on $243.4m a year ago but down 3.1% on $266.7m last quarter, due to lower demand for datacom products, primarily 10G-and-below transceivers, partially offset by a rise in sales of 100G QSFP28 transceivers.

Telecom product sales were $83.5m, down 8.1% on $90.9m last quarter and 14.7% on $97.9m a year ago.

Finisar had two 10%-or-greater customers. The top 10 customers comprised 62.5% of revenue, compared with 58.9% last quarter.

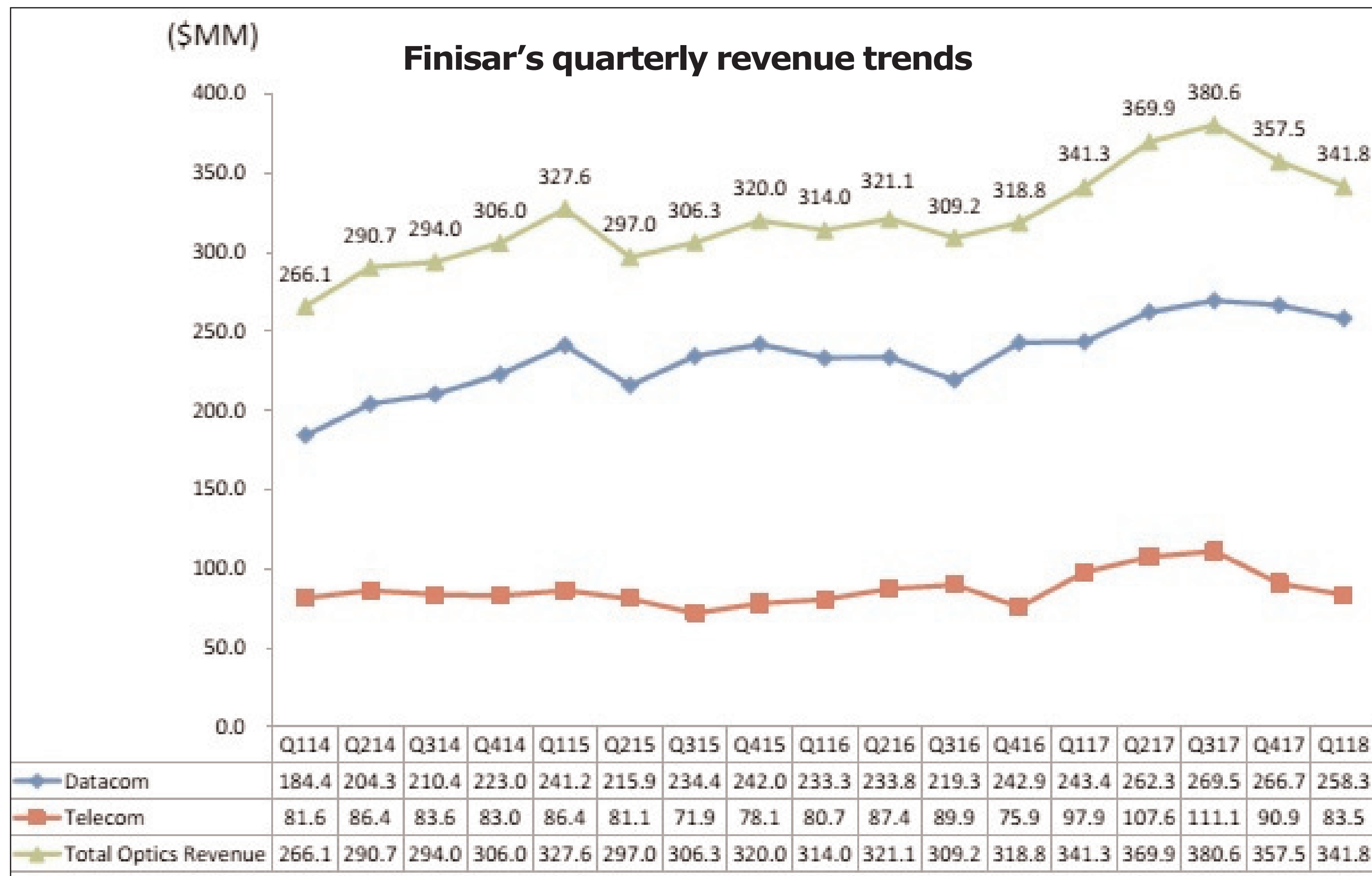
On a non-GAAP basis, gross margin was 34.9%, up on 33.1% a year ago but down from 36.2% last quarter. Operating expenses have risen further, from $69.3m a year ago and $71m last quarter to $73.2m.

Operating margin was 13.5% of revenue, down from 16.3% margin last quarter. Net income was $45.8m ($0.40 per diluted share), up from $41.8m ($0.38 a year ago) but down from $57.5m ($0.50 per diluted share) last quarter, primarily due to the lower revenue.

Capital expenditure (CapEx) has risen from $47.8m last quarter to $51.9m, as construction continues on the third building of Finisar's manufacturing site in Wuxi, China (to be completed in calendar second-half 2018).

During the quarter, cash, cash equivalents and short-term investments hence fell by about $4m, from $1.237bn to $1.233bn.

For fiscal second-quarter 2018, revenue should be $322–342m. Datacom product revenue will be relatively flat, with growth for 100G QSFP28 transceivers as well as initial sales of high-power vertical-cavity surface-emitting laser (VCSEL) arrays for 3D sensing being offset by declines in both 100G CFP and



	Q114	Q214	Q314	Q414	Q115	Q215	Q315	Q415	Q116	Q216	Q316	Q416	Q117	Q217	Q317	Q417	Q118
Datacom	184.4	204.3	210.4	223.0	241.2	215.9	234.4	242.0	233.3	233.8	219.3	242.9	243.4	262.3	269.5	266.7	258.3
Telecom	81.6	86.4	83.6	83.0	86.4	81.1	71.9	78.1	80.7	87.4	89.9	75.9	97.9	107.6	111.1	90.9	83.5
Total Optics Revenue	266.1	290.7	294.0	306.0	327.6	297.0	306.3	320.0	314.0	321.1	309.2	318.8	341.3	369.9	380.6	357.5	341.8

CFP2 Ethernet transceivers as well as 10G-and-below transceivers. Telecom product revenue is expected to fall, due mainly to lower demand from Chinese OEM customers.

Gross margin will fall to 33–34%, due to lower revenue, higher depreciation and the impact of the annual employee merit increases that took effect on 1 August. Operating expenses are targeted to rise further to $75–76m, driven mainly by the impact of the annual merit increases. Operating margin should fall to 10–11% and earnings per fully diluted share to $0.27–0.33. Targeted CapEx is $50–55m.

"We remain very optimistic about our long-term growth prospects and we expect to increase our revenues in the second half of the fiscal year," says chairman & CEO Jerry Rawls. "This growth will be driven primarily by sales of a 100G QSFP28 transceivers for hyper-scale data centers and high-power VCSEL arrays for 3D sensing," he adds. "While we continue to make progress with our high-power VCSEL array program, the timing of our production ramp has been delayed due to a change we needed to make in our manufacturing process. Therefore, while we do expect to receive customer approval to ship production units in the second quarter, we only expect to achieve a relatively low level of revenue in the quarter," he adds. "We expect to start shipping much larger quantities in the fiscal third quarter."

"In addition, by the end of the second quarter we expect our 100G & 200G coherent CFP2 ACO transceiver to be fully qualified by a key OEM customer that supplies into the Verizon Metro network. And in the third quarter we also expect our ROADM line-card to be qualified at the same customer," Rawls concludes.

www.finisar.com

Finisar co-founder & CEO Jerry Rawls to retire

Finisar's chairman & CEO Jerry Rawls has informed its board of directors that he intends to retire as CEO by the end of 2018. The board will conduct a search to identify a successor and will consider internal and external candidates.

"Jerry's decision to retire as CEO of Finisar caps a remarkable business career and chapter in the company's history," comments lead director Robert Stephens. "We are deeply grateful to Jerry for his innumerable contributions to Finisar's growth and success. Jerry co-founded the company nearly 30 years ago in a Quonset hut in Menlo Park, California. Under Jerry's leadership, Finisar went public in 1999 and has grown to be one of the world's top optics companies, with industry-leading revenues of more than $1.4bn during its most recent fiscal year. While his leadership will be missed, Jerry has placed Finisar on solid ground to continue to build on its success and market-leading position," he adds.

"Finisar is a strong company with fantastic employees dedicated to serving our customers' needs and developing world-leading, cutting-edge technology products," comments Rawls. "I am confident that Finisar will continue on its successful path."

Oclaro enters volume production of 100G ER4-Lite QSFP28 transceivers supporting up to 40km reach

Oclaro Inc of San Jose, CA, USA (which provides components, modules and subsystems for optical communications) has begun volume production of 100G 40km pluggable solutions in compact QSFP28 transceivers that support the new ER4-Lite specification. With their ability to reach 40km while maintaining low power and high faceplate density, the new ER4-Lite QSFP28 transceivers enable customers in the metro edge and access networks to deploy high-speed 100G networks without the use of optical amplifiers, according to the firm.

"Achieving volume production of these critical 100G transceivers is an important milestone for our layer 2 switch, core router and optical transport system equipment manufacturers transitioning from 10G to 100G solutions," says Yves LeMaitre, president of Oclaro's Optical Connectivity business. "With the addition of an ER4-Lite solution to our growing 100G portfolio, Oclaro now has product offerings ranging from 2km and 10km up to 40km. This allows tremendous flexibility for distributed data centers and metro optical network installations," he adds.

The QSFP28 ER4-Lite complements Oclaro's ER4-Lite CFP2 transceiver module, which has been shipping in volume since 2015. To develop this transceiver, the firm leveraged its 28G electro-absorption modulated laser (EML) that is proven in its CFPx and QSFP28 LR4 product families. The ER4-Lite QSFP28 supports both 100GbE and OTU4 applications and supports up to 40km with forward error correction (FEC), up to 25km without FEC, and will interoperate with existing ER4 solutions in the field up to 25km.

The new ER4-Lite QSFP28 is compliant to the newly introduced ITU-T standard G.959.1 4L1-9D1F and the new 4WDM-40 specification released in July by the 4WDM MSA Group for 100GbE applications.

www.oclaro.com
www.4wdm-msa.org

Wafer-bonded GaInP/GaAs/Si triple-junction solar cell by NREL/ISFH achieves 35.4% efficiency

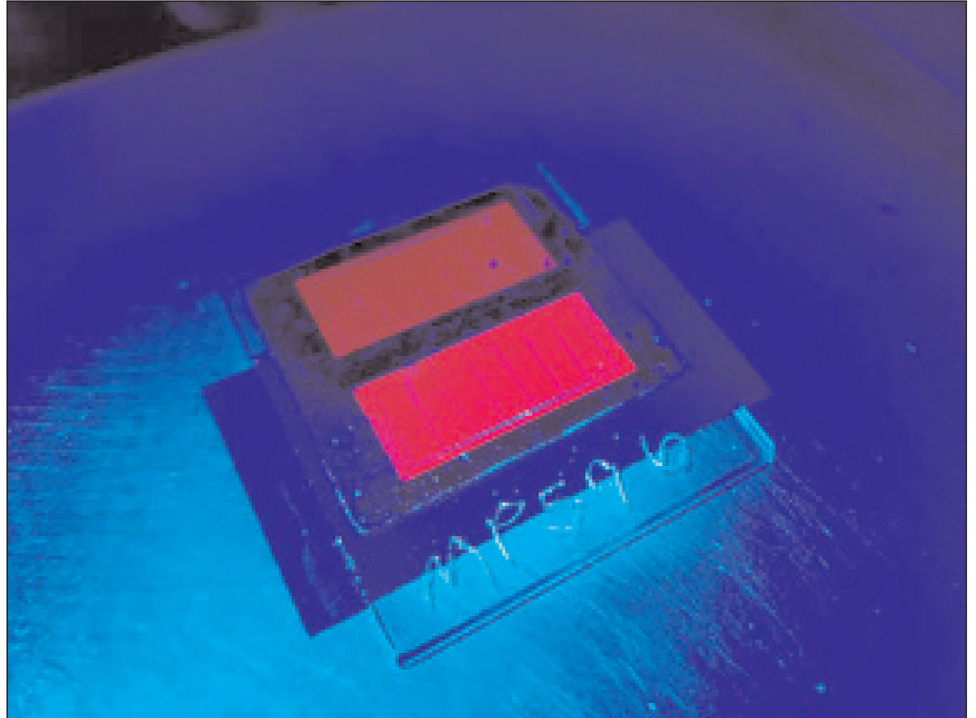
Efficiency close to new III–V/Si tandem cell record of 35.9% by NREL/CSEM/EPFL, and not far off 37.9% for III–V triple-junction solar cells

Germany's Institute for Solar Energy Research Hamelin (Institut für Solarenergieforschung Hameln, ISFH) and the US National Renewable Energy Laboratory (NREL) have jointly achieved a confirmed one-sun solar energy conversion efficiency of 35.4% with a mechanically stacked GaInP/GaAs/Si triple-junction solar cell. The bottom cell with POLO (poly-silicon on oxide) passivating contacts was fabricated by ISFH, while the monolithic GaInP/GaAs (gallium indium phosphide/gallium arsenide) top cell was fabricated at NREL.

The efficiency is a close second to the record of 35.9% for III–V/Si tandem cells, reported in late August by NREL in collaboration with the Swiss Center for Electronics and Microtechnology CSEM (Centre Suisse d'Electronique et de Microtechnique) and EPFL (École Polytechnique Fédérale de Lausanne) in Switzerland for a triple-junction GaInP/GaAs/Si solar cell.

Notably, ISFH's silicon bottom cell is optimized for converting the full one-sun solar spectrum. On its own the efficiency of this type of silicon solar cell with POLO junctions reaches 25%. Combination with the NREL GaInP/GaAs top cell therefore raises the efficiency by about a further 10%.

The efficiency of the mechanically stacked GaInP/GaAs//Si solar cell is even close to the record of 37.9% for a pure III–V triple-junction solar cell. This comparison shows the suitability of silicon wafer-based solar cells (which provide a mature and inexpensive basis for over 90% of today's photovoltaic devices) for tandem applications. To keep cell interconnection within the module format, a monolithic tandem device is desirable. Mimicking this with two-terminal (2T) interconnection, the efficiency of the serial-connected GaInP/GaAs//Si cell triple-junction solar cell is 31.1%.



Mechanically stacked GaInP/GaAs/Si triple-junction solar cell with 35.4% conversion efficiency. Photo: M. Schnabel, NREL.

Although this is already excellent, there is a deficit of 4.3% in efficiency compared with the measurement without serial connection. The difference is due to the current mismatch between sub-cells, such that in serial-connected stacked solar cells every sub-cell must carry the same current, and hence the sub-cell with the smallest current limits the current of the cell stack.

On its own the efficiency of this type of silicon solar cell with POLO junctions reaches 25%. Combination with the NREL GaInP/GaAs top cell therefore raises the efficiency by about a further 10%

This is a basic challenge for all serial-connected stacked solar cells, regardless of the top-cell absorber material (perovskites, III–Vs,…) with only two contacts (2T).

A promising approach to bypass this constraint even for monolithic stacked solar cells is to use an interdigitated back-contact (IBC) POLO cell with an additional front contact as the bottom cell. The rear base contact serves as a third terminal for the collection of excess charge carriers or the injection of missing charge carriers.

Further insights into this concept were presented at the 33rd European Photovoltaic Solar Energy Conference and Exhibition (EU PVSEC 2017) in Amsterdam, The Netherlands (25–29 September) in a plenary talk about the collaborative work by ISFH and NREL.

www.nrel.gov
www.isfh.de/en

DOE achieves SunShot's 2020 utility-scale solar cost target of $0.06/kWh

$82m early-stage funding announced for CSP and power electronics as part of new 2030 focus on reliability, resilience and storage

In conjunction with the annual Solar Power International conference, the US Department of Energy (DOE) has released new research showing that the solar industry has achieved the 2020 utility-scale solar cost target set by the SunShot Initiative. Largely due to rapid cost reductions in solar photovoltaic (PV) hardware, the average price of utility-scale solar is now 6 cents per kilowatt-hour (kWh).

Given this success, DOE is looking beyond SunShot's 2020 goals with an expanded 2030 vision for the Solar Energy Technologies Office. Specifically, while DOE will continue research to drive down costs, new funding programs will focus on a broader scope of Administration priorities, which includes early-stage research to address solar energy's critical challenges of grid reliability, resilience and storage.

"With the impressive decline in solar prices, it is time to address additional emerging challenges," says Daniel Simmons, acting assistant secretary for Energy Efficiency and Renewable Energy. "As we look to the future, DOE will focus new solar R&D on the Secretary's priorities, which include strengthening the reliability and resilience of the electric grid while integrating solar energy."

To further the new priorities for DOE's Solar Energy Technologies Office, Simmons has announced up to $82m in early-stage research in two areas:

- Concentrating solar power (CSP): Up to $62m will support advances in CSP technologies to enable on-demand solar energy. CSP technologies use mirrors to reflect and concentrate sunlight onto a focused point where it is collected and converted into heat. This thermal energy can be stored and used to produce electricity when the sun is not shining or integrated into other applications, such as producing fresh water or supplying process heat.
- Power electronics: Up to $20m is dedicated to early-stage projects to advance power electronics technologies. Such innovations are fundamental to solar PV as the critical link between PV arrays and the electric grid. Advances in power electronics will help grid operators to rapidly detect problems and respond, protect against physical and cyber vulnerabilities, and enable consumers to manage electricity use.

Awardees will be required to contribute 20% of the funds to their overall project budget (yielding total public and private spending of nearly $100m). The funds provided are not grants, but cooperative agreements, which involve substantial federal oversight and consist of go/no-go technical milestones that ensure attentive stewardship of projects, says the DOE.

Solar energy currently supplies about 1.5% of US electricity. With the DOE's help, the solar industry has drastically cut costs to enable technological innovation and market growth. In the last 10 years, the amount of solar power installed in the USA has increased from 1.1GW in 2007 to an estimated 47.1GW in 2017 (enough to power the equivalent of 9.1 million average American homes).

According to a new report from the US National Renewable Energy Laboratory (NREL), low module prices have been the primary driver of cost reductions for solar energy. The more stubborn 'soft' costs like labor, permitting, interconnection, customer acquisition, financing, and grid integration, remain challenges, it concludes.

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Solar Frontier Americas sells 28MW of solar project sites to Capital Dynamics

San Jose-based Solar Frontier Americas, the US subsidiary of Tokyo-based Solar Frontier — the largest manufacturer of CIS (copper indium selenium) thin-film photovoltaic (PV) solar modules — has sold two fully developed solar project sites to Capital Dynamics, a Swiss-based asset management company investing in private equity and clean energy infrastructure. "Our team has successfully acquired 14 solar portfolios to date," notes John Breckenridge, head of Capital Dynamics' Clean Energy Infrastructure (CEI).

Located in Fresno County, just south of San Joaquin, California, the two sites combined have a planned capacity of $28MW_{DC}$. Capital Dynamics plans to execute construction on the projects, which are packaged with permits and power purchase agreements (PPA) with Pacific Gas & Electric.

"Solar Frontier continues to grow its development organization and deliver world-class, utility-scale solar projects," says Charles Pimentel, CEO of Solar Frontier Americas Development. "We are pleased to close the sale of these California projects and expand our relationship with one of the leading clean energy infrastructure firms, Capital Dynamics," he adds.

"Solar Frontier Americas Development has delivered well-executed solar sites that we plan to progress into construction in the next quarter," says Breckenridge, adding that the projects will "contribute to helping the national solar leader, the state of California, move closer to its impressive renewable energy goal of 50% by 2030."

www.solar-frontier.com

Flisom launches lightweight flexible CIGS solar panels

At a roll-out event for customers and partners in Zurich, Flisom AG of Niederhasli, Switzerland — which has the Swiss Federal Laboratories for Materials Science and Technology (Empa) as a technology partner — showcased its flexible copper indium gallium selenide (CIGS) solar panels with a range of applications including buildings-integrated photovoltaic (PV) modules for lightweight roofs and facades, and a stratospheric weather balloon covered with ultra-lightweight solar film, powering electronic equipment.

Flisom's solar modules are light (down to $200g/m^2$), highly efficient (up to 50x power-to-weight ratio compared with silicon solar panels) and ultra-thin (under 2mm).

Flisom was founded in 2005 as a spin-off of the Solid State Physics of the Swiss Federal Institute of Technology Zurich (ETH Zurich). Since 2013, it has invested in developing proprietary manufacturing equipment and components, creating a unique 'roll to roll' manufacturing process that can replicate the laboratory success of CIGS solar technology on an industrial scale. It is already scaling up production in Switzerland to fulfil incoming orders and scouting for locations globally for further scale up.

The firm says that it is already working with leading global automotive aerospace, and transportation companies to create custom solar-integrated solutions, for cars, unmanned aerial vehicles (UAVs) and public transportation carriages.

Over the past few years, Flisom has received significant investment from Tata Industries (part of the $100bn Tata group) and a group of Swiss investors. Over the next year, Flisom will be targeting opportunities in the UK, continental Europe and the USA.

"Our support has enabled Flisom to create the best and most efficient flexible solar panels available," says Tata Industries' executive director K.R.S. Jamwal. "It will enable solar to be used in ways and in places never possible before, such as in transportation and aerospace, and much more effectively on all roofs," he adds.

"We can scale up industrial production in a way that hasn't been possible before for flexible CIGS solar technology," claims Flisom's CEO Rahul Budhwar.

"Empa researchers hold the world record for energy conversion efficiency in a CIGS solar cell — and our technology, in turn, forms the core of Flisom's transformative solar modules," notes Empa's CEO professor Gian-Luca Bona. "We are delighted to host the first full-scale Flisom pilot installation on our campus, where it will supply sustainable energy for 'move', our demonstration platform for future mobility."

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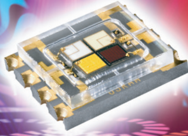
Efficiency droop in nitride & phosphide LEDs
First single-crystal gallium oxide FET



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Silicon implantation for gallium nitride LEDs

Devices give single spectral peak of blue ~450nm wavelength without yellow or near-ultraviolet luminescence from defects and other sources.

Southern Taiwan University of Science and Technology and Taiwan's National Cheng Kung University have used silicon (Si) implantation to create n-type regions on top of indium gallium nitride (InGaN) multiple quantum wells (MQW), allowing a new blue light-emitting diode (LED) structure to be fabricated [Ming-Lun Lee et al, IEEE Transactions on Electron Devices, published online 18 August 2017].

The epitaxial material was grown by vertical metal-organic vapor phase epitaxy on sapphire: 30nm of a GaN 530°C nucleation layer, a 3μm GaN buffer, 2μm of 1000°C n-GaN, 10 well/barrier pairs of 3nm/12nm 750°C In0.2Ga0.8N/GaN, a 100nm 950°C p-GaN cap, and a 2nm n^+-GaN tunnel-junction layer.

The silicon ion implant was carried out through a silicon dioxide layer and patterning was supplied by 6μm photoresist (Figure 1). The silicon dioxide scattered the ions to reduce channeling effects where ions penetrate further through the lattice in some directions. After implant, the silicon dioxide and resist were removed using chemical etching.

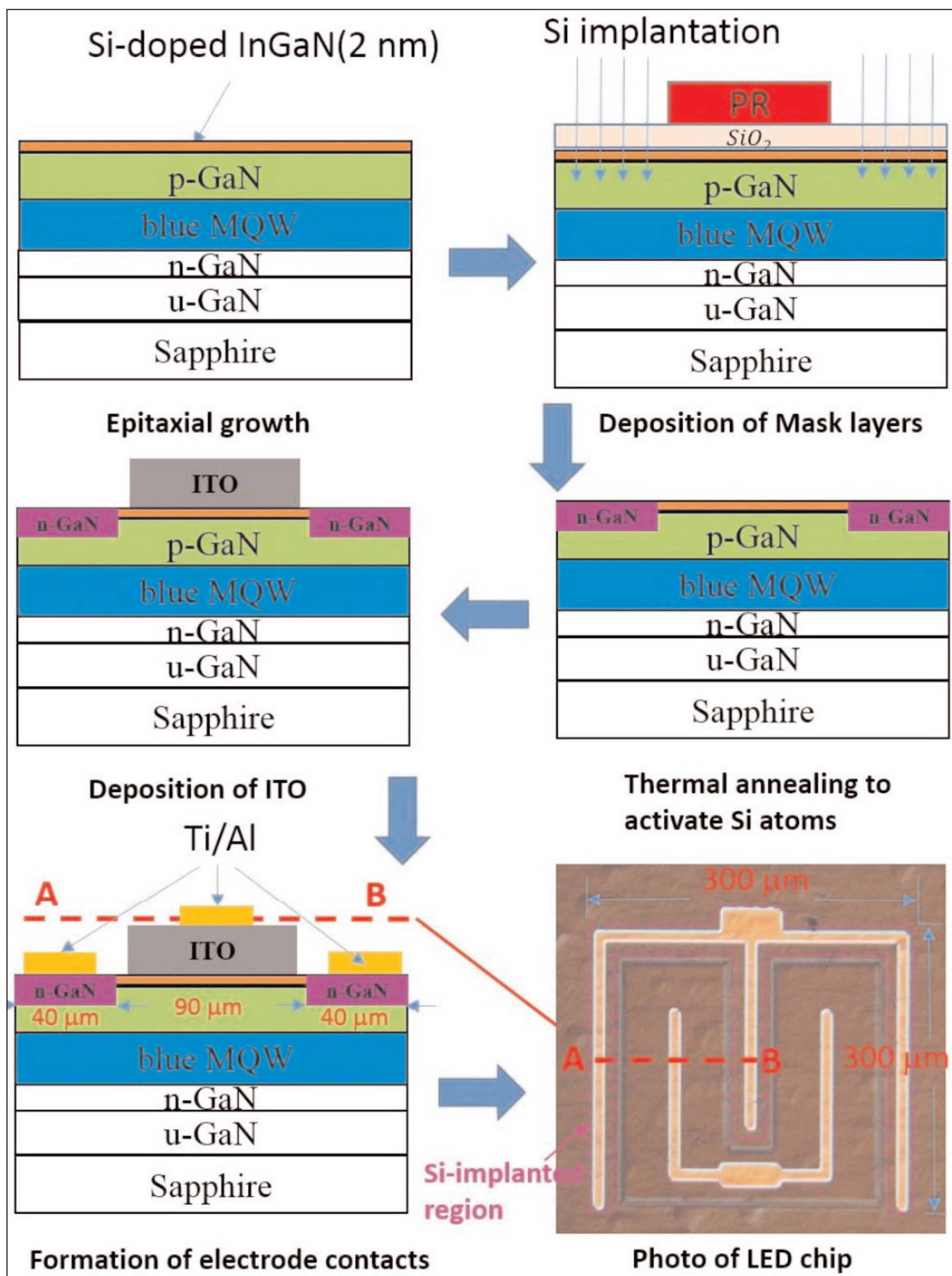

Figure 1. Schematic steps for fabrication of GaN-based MQW LEDs with surface p–n-junction structure formed by selective-area Si implantation into p-GaN top layer.

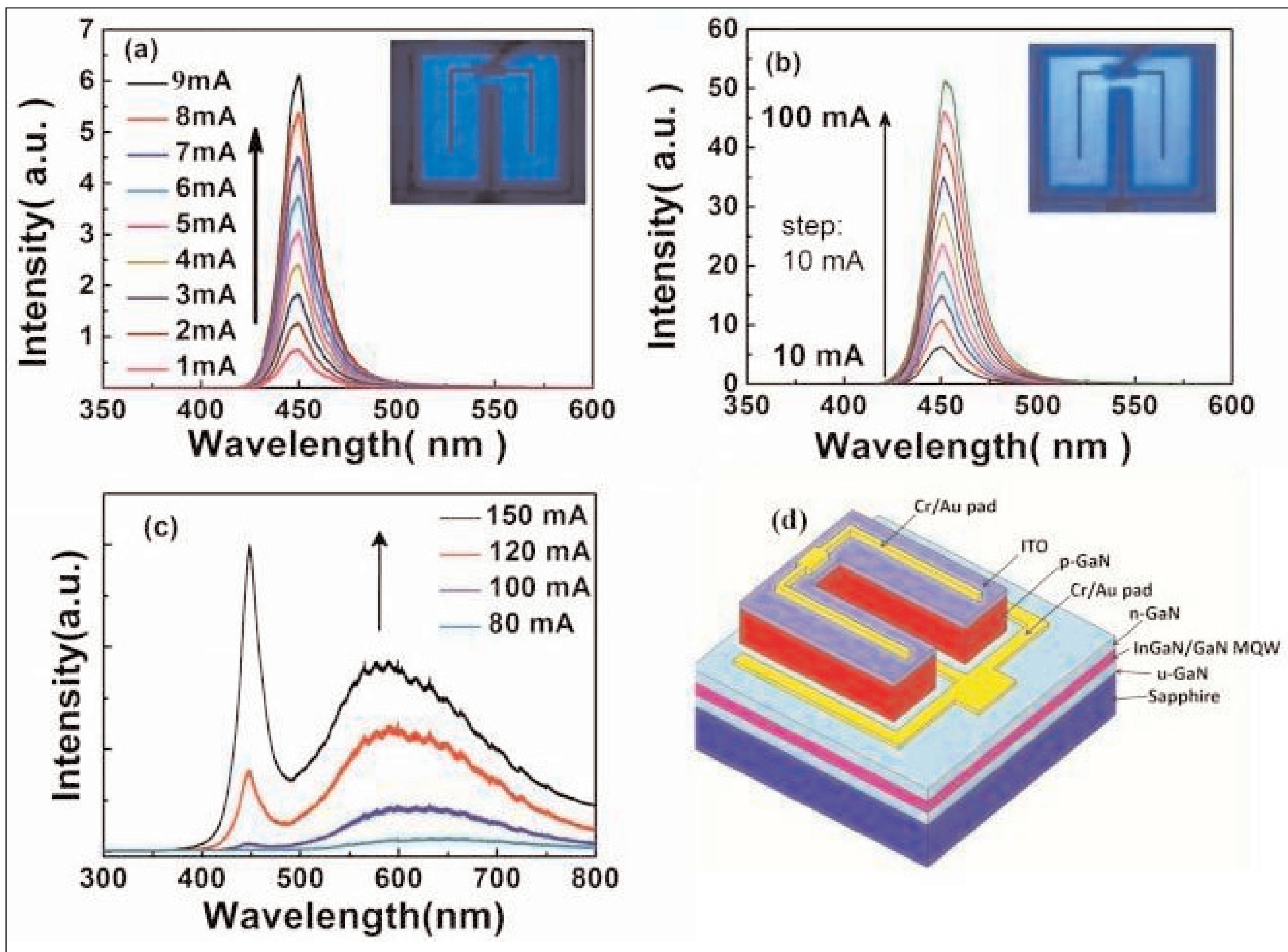

Figure 2. Typical current-dependent electro-luminescence spectra taken from Si-implanted LEDs driven at (a) currents lower than 10mA, (b) currents of 10–100mA, and (c) typical current-dependent spectra taken from conventional LEDs with non-planar p–n homojunction formed by epitaxial growth and subsequent dry etching process, (d) schematic structure of LEDs with nonplanar surface p–n homojunction.

The researchers estimate that the silicon ions penetrated 60nm into the top layer, on average.

The n-type doping of the silicon ions was activated with a 90-second rapid thermal anneal at 1000°C in nitrogen. The researchers believe that the n-type doping achieved $3x10^{14}/cm^2$ sheet concentration with $21cm^2/V$-s mobility. The researchers came to these conclusions on the basis of Hall-effect measurements on test wafers without patterning.

The implantation forms a p-n junction above the MQW structure, unlike the usual GaN LED structure where the n-contact is made by etching and making an ohmic contact with the underlying n-GaN layer. The p-contact consisted of a 200nm transparent indium tin oxide (ITO) layer from radio frequency sputtering. The n-contact was electron-beam evaporated titanium/aluminium.

The fabricated LEDs were 300μmx300μm. The electro-luminescence had a single peak at ~450nm (Figure 2). This is unlike the spectrum from conventional GaN LEDs that usually exhibit 'yellow luminescence' from defect-related transitions. One might also expect ~365nm near-ultraviolet emission from the p–n junction in the overlying GaN, but this was not seen either. The p–n junction device experienced efficiency droop similar to that seen in conventional mesa LEDs, although beyond $20mA/cm^2$ there is a slight recovery of EQE.

The researchers think that this may be due to improved carrier diffusion to the MQW at high current. The dynamic resistance is high (greater than 400Ω) but decreases with forward voltage. The rate of descent becomes less steep above 5V (~300Ω), but becomes steeper again above 15V (~150Ω). The 15V mark corresponds to $\sim 20mA/cm^2$ current. The researchers suggest that the faster decrease in resistance is related to a second current path opening up through the MQW structure. Before 15V the near-surface path dominates, it is suggested. ■

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Author: Mike Cooke

Monolithic red-green-blue InGaN pixels from strain engineered nanopillars

University of Michigan reports on a potential path towards future LED-based microdisplay technology and augmented reality applications.

University of Michigan in the USA has used local strain engineering of nanopillars to produce light-emitting diode (LED) red-green-blue (RGB) subpixel arrays based on indium gallium nitride (InGaN) multiple quantum wells (MQWs) [Kunook Chung et al, Appl. Phys. Lett., vol111, p041101, 2017].

The researchers comment: "The proposed nanopillar LED devices can potentially provide a practical path for the future LED based microdisplay technology, especially aimed for augmented reality applications."

Such displays need high brightness, contrast, resolution, power efficiency, and device lifetime. These requirements can't be met by present-day liquid crystal or organic LED display technologies.

Also key for microdisplays is color mixing capability. The researchers note that despite there being a range of monolithic RGB LED technologies, usually based on InGaN, color mixing has not yet been demonstrated.

The team explains: "Color mixing is one of the key elements for any display technology. It requires independent and linear control of the intensity from each color channel. At the same time, the color coordinates of these color channels must remain stable."

Metal-organic chemical vapor deposition (MOCVD) on 2-inch c-plane sapphire substrate produced a five-period multiple quantum well InGaN/GaN structure. The indium composition and well thickness were designed to produce red photolumi-

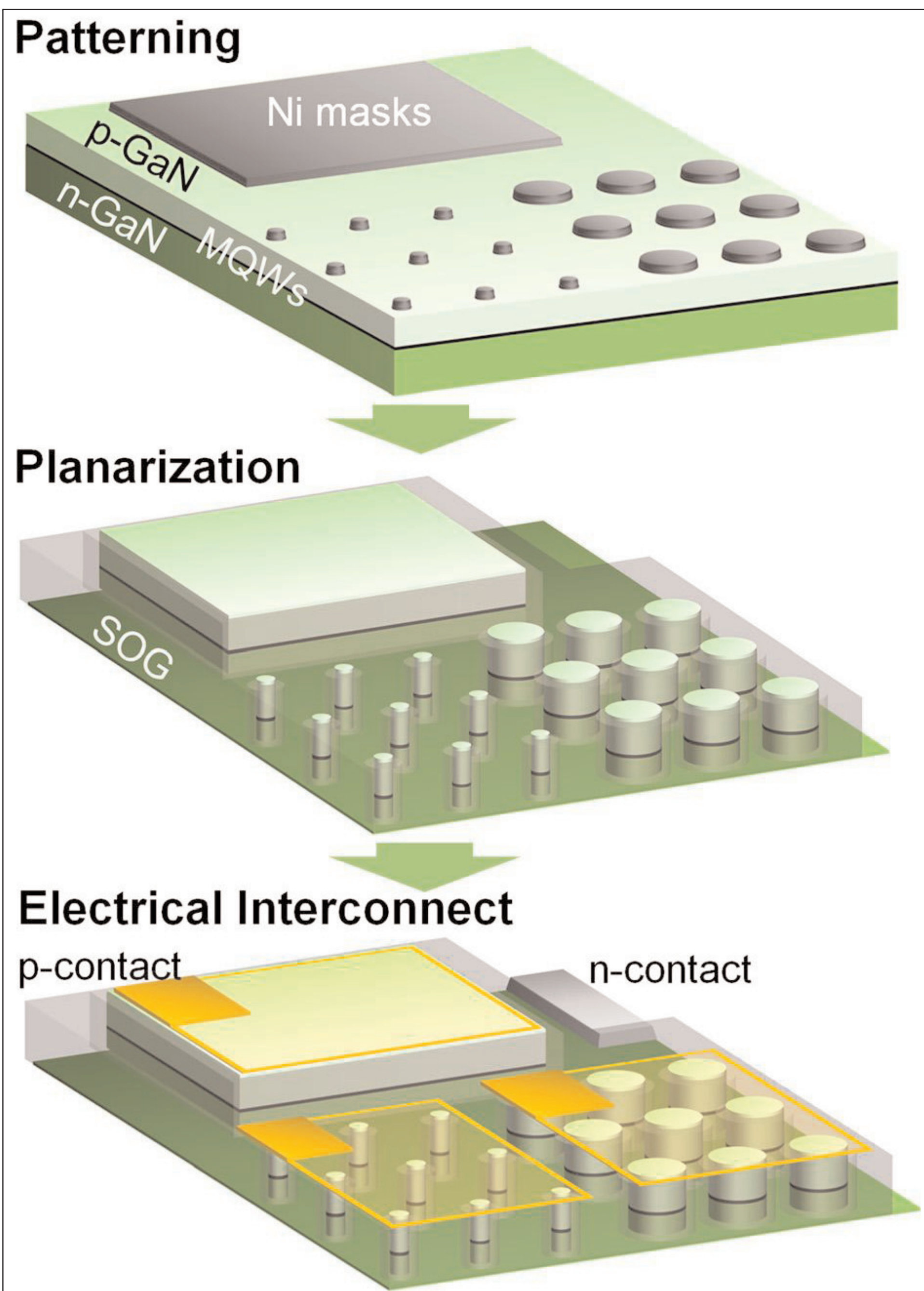

Figure 1. Schematic of fabrication process for RGB LED pixel, which includes three steps: subpixel patterning, sample planarization, and formation of electrical interconnects.

nescence with wavelength longer than 600nm. Above the MQW structures were added a 20nm aluminium gallium nitride ($Al_{0.2}Ga_{0.8}N$) electron-blocking layer and a p-GaN contact layer.

Color variations in pixels were induced by local strain engineering (Figure 1). Nanopillars of varying diameters were fabricated to relax strain in the heterostructures: 150nm for green light, and 50nm for blue. Red light came from pixels using the thin-film material as-grown. The nanopillar and other patterning was achieved using nickel masks. The nanopillars were separated by 300nm in both cases.

RGB balancing was achieved by creating different sub-pixel areas: 400μmx400μm for red, 341NPsx341NPs for green, and 434NPsx434NPs for blue. The subpixels were separated by 150μm. The areas of the respective active regions were 160,000μm^2, 2050μm^2 and 370μm^2.

The larger area for the more strained, longer-wavelength subpixels compensates for the efficiency reduction caused by the quantum-confined Stark effect, where charge polarization of the III-nitride bonds creates an electric field that tends to inhibit electron-hole recombination into photons. The electric field is increased by strain due to piezoelectric effects.

The uncooled pixels were driven with pulse-width modulation (PWM) from a Arduino microcontroller circuit. Controlling output intensity with PWM avoids wavelength shifts that arise in continuous wave operation at different current injection levels (quite apart from self-heating effects).

The bias voltages were optimized to balance the RGB output powers, starting with the red subpixel. In microdisplay applications, it would be preferred to have one bias voltage across the device. This could be achieved by suitably tuning the active region areas.

Each subpixel had a dominant wavelength, respectively, at 490nm (blue), 518nm (green) and 600nm (red). The set up enabled production of cyan, mixing blue and green, and yellow, mixing green and red (Figure 2).

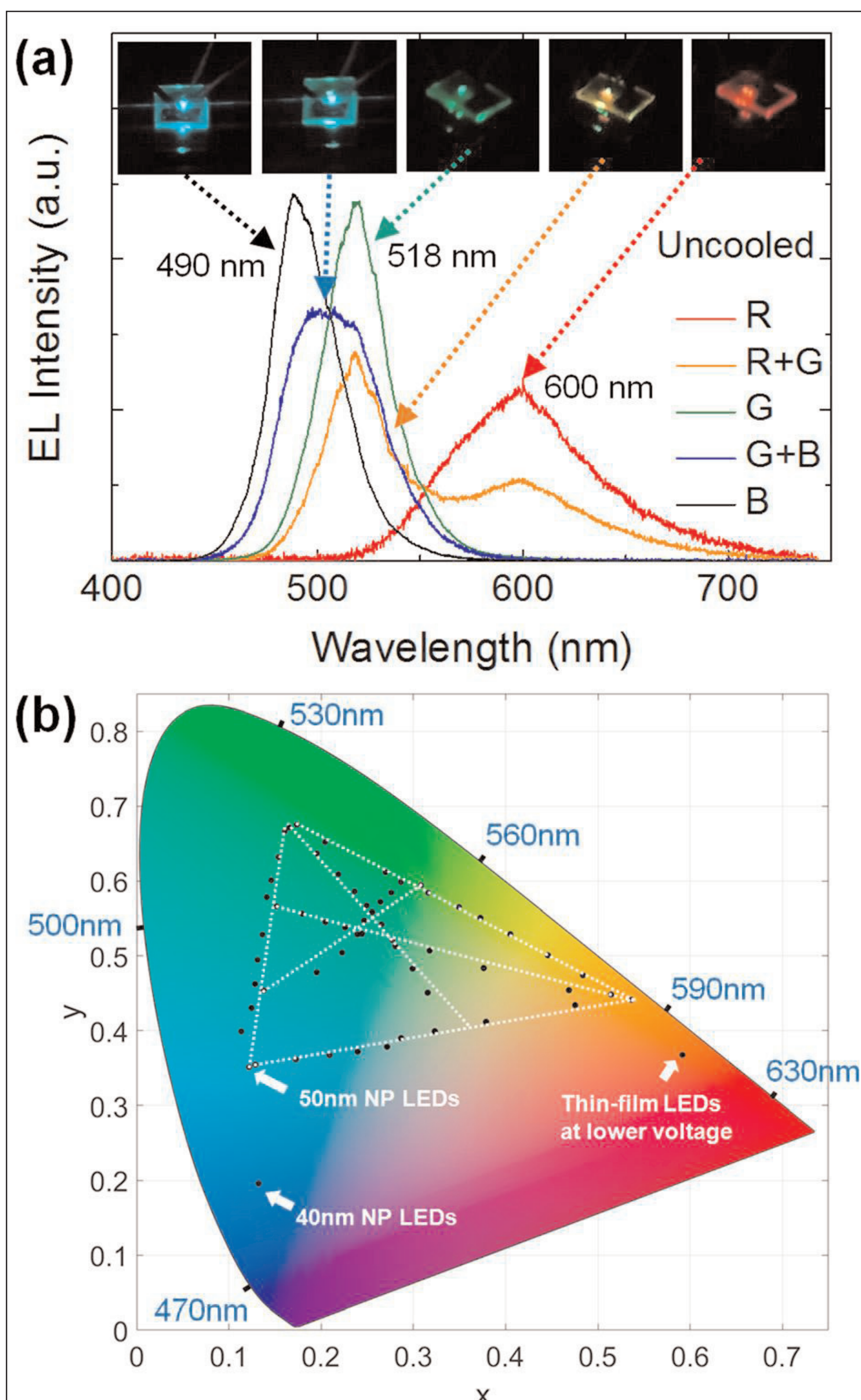

Figure 2.(a) Electroluminescence (EL) spectra and corresponding images. (b) Each EL spectrum converted into set of CIE-1931 color coordinates. White dotted lines correspond to theoretical color mixing results expected from two end points, i.e. with one or two color channels off for case of two- and three-color mixing, respectively. Also shown are color coordinates of LED devices on the same sample which were not used in the color mixing experiment due to insufficient output power.

Although the color gamut was more restricted than needed for full-color display applications, the device showed good linearity, indicating minimal crosstalk between the pixels. The researchers add that "with further improvements of the epitaxial growth and optimization of the electrical properties for small-diameter nanopillar devices, it is expected that the color gamut can approach a typical organic LED display."

Another improvement would be to extend the base wavelength of the InGaN MQW out to 650nm. ■

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Author: Mike Cooke

Near-ultraviolet laser diodes powering visible (white) light communication

Researchers achieve increased color rendering and lower color temperature with red-green-blue phosphors.

Researchers based in the USA and Saudi Arabia claim the first demonstration of the use of near-ultraviolet (NUV) laser diodes (LDs) and red-green-blue (RGB) phosphors for white visible light communication (VLC) [Changmin Lee et al, Optics Express, vol25, p17480, 2017]. The team is at University of California Santa Barbara (UCSB), King Abdullah University of Science and Technology (KAUST) in Saudi Arabia, and University of Wisconsin-Madison in the USA.

An advantage of using NUV would be reduced noise from solar radiation, compared with blue emitters. Laser diodes should have the ability be modulated at higher speed compared with light-emitting diodes (LEDs). This is because the limiting factor for laser diodes is photon lifetimes in the laser cavity, rather than electron/hole lifetimes, as for LEDs. The researchers also see potential for NUV LD-powered white-light illumination, based on high current and power density, compared with LEDs.

Potential uses of white-light VLC include light fidelity (LiFi) networks, underwater wireless optical communications (UWOC), and plastic optical fiber (POF) communications.

The 410nm laser diodes was a 4μmx1200μm ridge-waveguide device grown on semi-polar $(20\bar{2}1)$ free-standing gallium nitride. The facets were uncoated.

The laser light was used to excite a mix of RGB phosphors in silicone (Figure 1) — respectively, $CaAlSiN_3:Eu^{2+}$, $(Ba,Ca,Sr,Mg)_2SiO_4:Eu^{2+}$, and $BaMgAl_{10}O_{17}:Eu^{2+}$. The components give quantum yields to 410nm wavelength light of 74%, 78% and 78%,

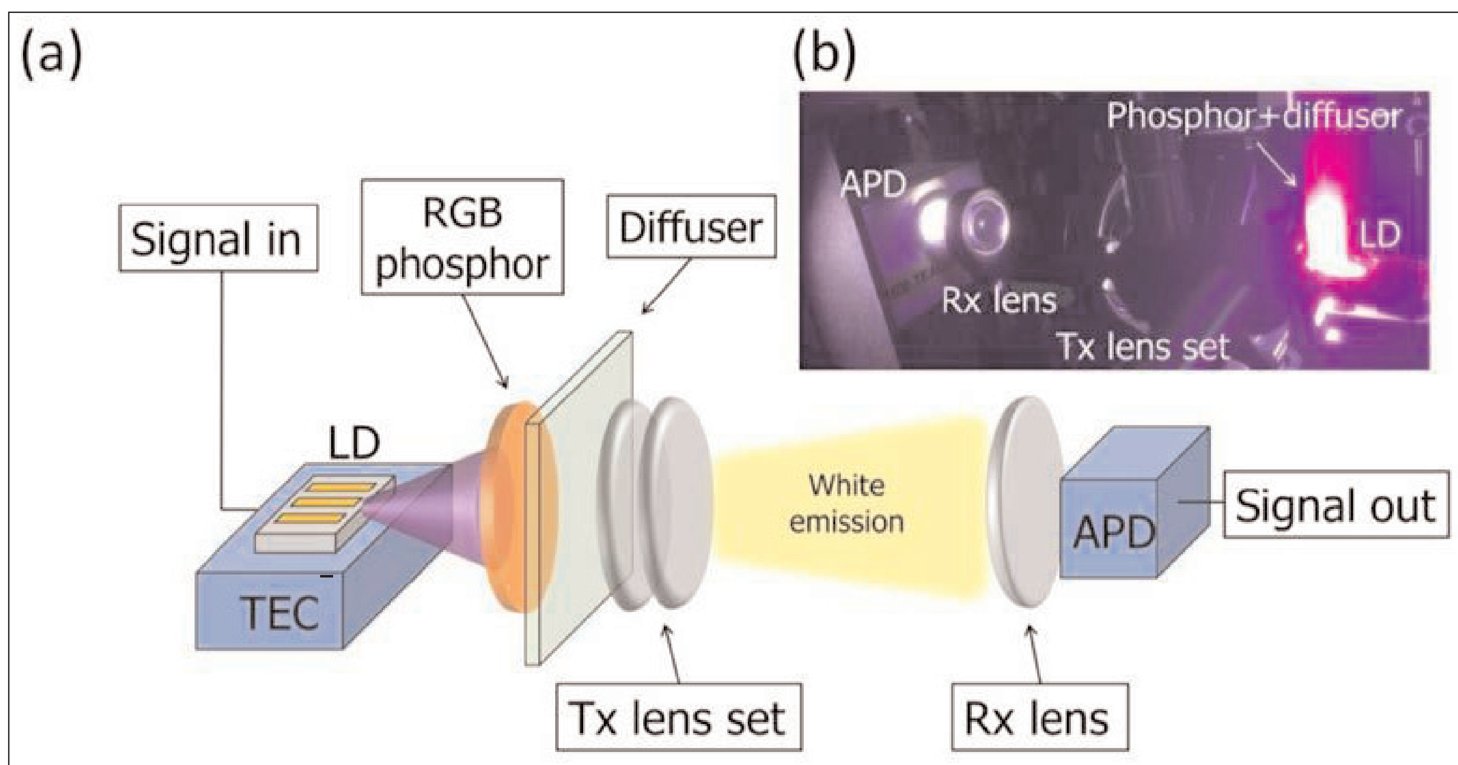

Figure 1. (a) Schematic of NUV laser-based white light communication system with RGB phosphors for color conversion, diffuser to improve uniformity of phosphor emission, transmitter (Tx) and receiver (Rx) lenses to collimate light, and 1GHz APD to collect transmitted light. (b) Photograph of setup.

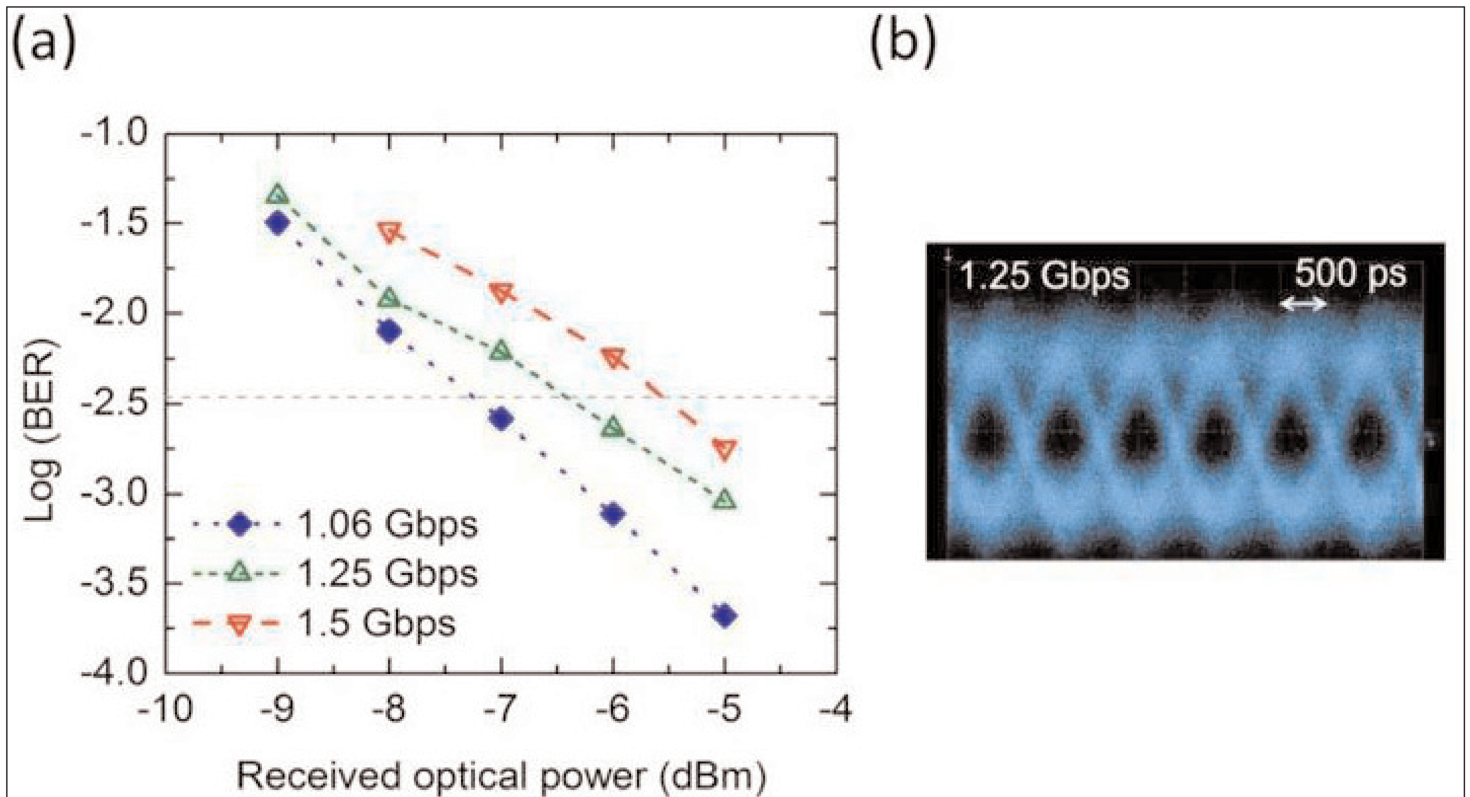

Figure 2. (a) Dependence of BER on received optical power characteristics of laser-based white light communication link at different data rates with FEC criteria shown as grey dashed line. (b) Eye diagram.

respectively. The RGB Commission Internationale de l'Eclairage (CIE) chromaticity coordinates of the phosphors were (0.65, 0.36), (0.27, 0.64) and (0.14, 0.08), respectively.

The laser diode was mounted in a microwave probe station on a heat sink and thermoelectric cooler (TEC). The distance between the laser diode and phosphor was between 1cm and 2cm.

The laser diode continuous wave (CW) 15°C threshold current and voltage were 320mA (6.67kA/cm^2) and 5.5V, respectively. The slope efficiency was 0.36W/A. The −3dB bandwidth for modulation was about 1GHz above 400mA biasing. The limited bandwidth was attributed to the avalanche photodetector (APD), since the laser diode was expected to have a bandwidth of the order 5GHz or more.

The team comments: "Higher modulation bandwidths are expected under the drive current of 400mA to 600mA for similar laser-based VLC systems with the eventual development of higher-bandwidth silicon APDs."

Higher modulation bandwidths are expected under the drive current of 400mA to 600mA for similar laser-based visible light communication systems with the eventual development of higher-bandwidth silicon avalanche photodetectors

The correlated color temperature (CCT) of the white light excited ranged from 4700K to 4050K as the injection current increased from 100mA to 600mA. The color rendering index (CRI) increased to 79 between 500mA and 600mA injection.

Previous work by some members of the team on white light generated using blue laser diodes and yellow YAG:Ce phosphor had only managed CRI values of 58. Higher CRIs (89) and lower CCT (3236K) have been obtained using blue laser diodes in combination with chemically unstable perovskite phosphor material containing lead, with associated toxicity and safety concerns limiting commercial potential.

Testing using non-return-to-zero (NRZ) on/off key (OOK) modulation with a $2^{10} - 1$ pseudo-random binary sequence (PRBS) data stream at 1.5 gigabits per second (Gbps) managed 3.8×10^{-3} forward error correction (FEC) and a bit-error rate (BER) of 1.8×10^{-3} (Figure 2). Clear open eye diagrams were demonstrated at 1.25Gbps and 570mA drive current. "Since the APD limits the system bandwidth to 1GHz, it is expected that the actual data rate is greater than 1.5Gbps," the team comments.

The researchers also hope that using schemes such as quadrature amplitude modulated orthogonal frequency division multiplexing (QAM OFDM) in combination with higher-speed photodetectors will significantly increase data rates. ■

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Author: Mike Cooke

Silicon-on-insulator substrates for compound semiconductor applications

Mike Cooke reports on research developments reaching towards high-power electronics and infrared optical communications.

Silicon-on-insulator (SOI) was developed in the silicon transistor industry to reduce parasitic capacitances in integrated circuits. As the technology developed, more applications and device structures benefiting from such substrates were demonstrated, such as micro-electro-mechanical systems (MEMS) and photonics.

In the past year, several research groups have reported on combining SOI with III-V compound semiconductors. One attractive feature is that SOI, and silicon, come in larger-diameter, lower-cost substrates than is standard for compound semiconductors. Further, combining SOI with III-V semiconductors could add new functionality to the conventional silicon complementary metal-oxide-semiconductor (CMOS) integrated circuits (ICs) that power our digital age.

Gallium nitride (GaN)-channel transistors on SOI could add high-voltage or intense power density handling capability to silicon CMOS ICs in applications such as photovoltaic inverters, electric vehicle charging, and DC power transmission.

The insulation part of the SOI structure would provide vital electrical isolation to monolithic power circuits such as half-bridge layouts with transistors biased at significantly different levels. Such isolation is difficult when devices are placed on a common conductive substrate. At present, isolation is achieved by multi-chip modules that involve increased production complexity and cost.

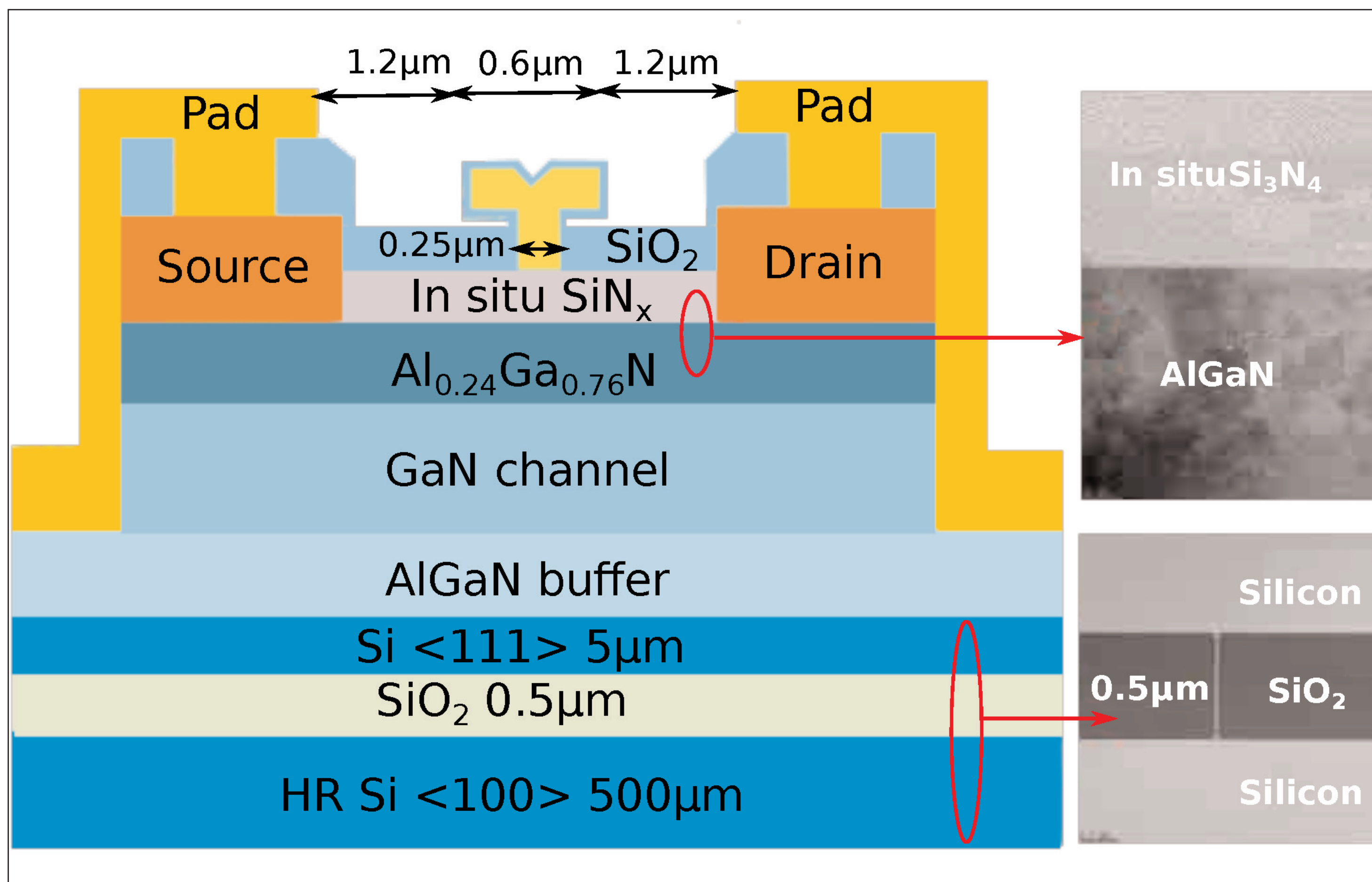

Figure 1. Cross-sectional structure of in-situ SiN_x/AlGaN/GaN MISHEMT on SOI substrate.

GaN is also used in radio frequency (RF) power devices, and again the insulator layer in SOI substrates provides opportunities for reducing power losses from currents induced in the substrate.

Both silicon and SOI have been used as the basis for photonics platforms, with the patterning of waveguides and other optical elements in advanced stages of development. The component lacking in this work is light- and laser-emitting devices. Here, integration of indium gallium arsenide phosphide (InGaAsP) alloys could lead to compact, low-cost optical communications components.

Aluminium gallium nitride transistors

Chang Gung University and Episil-Precision in Taiwan claim the first demonstration of in-situ silicon nitride (SiN_x) gate dielectric aluminium gallium nitride (AlGaN) barrier metal–insulator–semiconductor high-electron-mobility transistors (MISHEMTs) on 6-inch SOI substrates [Hsien-Chin Chiu et al, IEEE Transactions on Electron Devices, vol64, p4065, 2017].

The devices showed improved DC, dynamic and RF performance over the same structures grown on high-resistivity silicon (HR Si). The devices also included a SiN_x dielectric produced 'in-situ', immediately after the III-nitride deposition. Efficient RF performance needs resistive substrates to reduce induced power losses.

The team comments: "With some suitable thermal management solution or high-thermal sink package designs, the MISHEMT on SOI provides a high potential for millimeter-wave power amplifier applications."

Metal-organic chemical vapor deposition (MOCVD) created an epitaxial structure of a 1.75μm AlGaN buffer layer, 0.5μm GaN channel, 18nm $Al_{0.24}Ga_{0.76}N$ barrier, and in-situ 15nm SiN_x passivation. Optimization of the silane (SiH_4) and ammonia ratio ensured an atomically sharp interface between the barrier and passivation, according to the researchers. The passivation was designed to suppress surface nitrogen vacancies that degrade performance.

This structure was grown both on 500μm SOI and 1000μm HR Si substrates. The fabricated MISHEMTs (Figure 1) were mesa isolated with annealed titanium/aluminium/nickel/gold ohmic contacts and nickel/gold T-gates. The gate length was 0.25μm. The gate was centered in the 3μm source-drain gap. The devices were completed with plasma-enhanced chemical vapor deposition (PECVD) and etching of SiN_x passivation.

Hall-effect measurements showed the material on SOI to have better performance than that on HR Si (Table 1). The MISHEMT performances also suggested reduced numbers of interface traps: $1.13 \times 10^{12}/cm^2$-eV on SOI compared with $1.71 \times 10^{12}/cm^2$-eV on HR Si. The researchers attribute the improvements to higher structural quality and reduced buffer trapping.

Raman spectroscopy suggested that the GaN on SOI was strain-relaxed compared with the GaN on HR Si. X-ray analysis indicated smooth layer surfaces and abrupt interfaces between layers. Atomic force microscopy (AFM) showed a smoother SiN_x surface of 0.318nm root-mean-square roughness for the SOI sample, compared with 0.34nm for the HR Si structure.

Electrically, the use of SOI substrates improved the off-state leakage by more than one order of magnitude over the HR Si MISHEMTs. In both cases, the dominant leakage route was through the buffer. The subthreshold swing was 0.39V/decade (390mV/decade) for the MISHEMTs on SOI, compared with 0.44V/decade for HR Si. The maximum drain current and transconductance were found to be 15% and 13% higher, respectively, in the devices on SOI. The researchers attribute the improvements to the enhanced mobility on SOI. The devices were normally-on at 0V gate potential with pinch-off voltages at −6.6V and −6V for the SOI and HR Si substrates, respectively.

At increased temperature of 500K, the current flow in the MISHEMTs dropped due to scattering from lattice vibrations, according to the team.

Three-terminal breakdown measurements were made on devices with 6μm source–drain gap. The gate potential was at −12V in the pinch-off region. The MISHEMTs on HR Si had an off-state leakage five times that of the device on SOI below 200V drain bias. With a 1mA/mm leakage criterion, the breakdown (V_{BR}) was at 315V drain bias for the MISHEMT on SOI, compared with 270V for the HR Si structure.

The researchers comment: "The superior performance of the SOI can be attributed to the suppression of electrons being injected from the silicon substrate into the III-nitride/Si interface. Furthermore, the leakage current of traditional HR-Si substrates was dominated by space-charge-limited current conduction through the buffer/transition layers."

The V_{BR}^2/R_{on} figure of merit (R_{on}, on-resistance) was 11.84MW/mm for the SOI MISHEMT, while the SOI device registered 6.56MW/mm.

The SOI MISHEMT also demonstrated improved dynamic on-resistance performance under 50μs pulsed operation

Table 1. Hall-effect measurements.

Substrate	SOI	HR Si
Two-dimensional electron gas density	$1.02 \times 10^{13}/cm^2$	$9.2 \times 10^{12}/cm^2$
Mobility	$1605 cm^2/V\text{-}s$	$1533 cm^2/V\text{-}s$
Sheet resistance	392Ω/square	419Ω/square

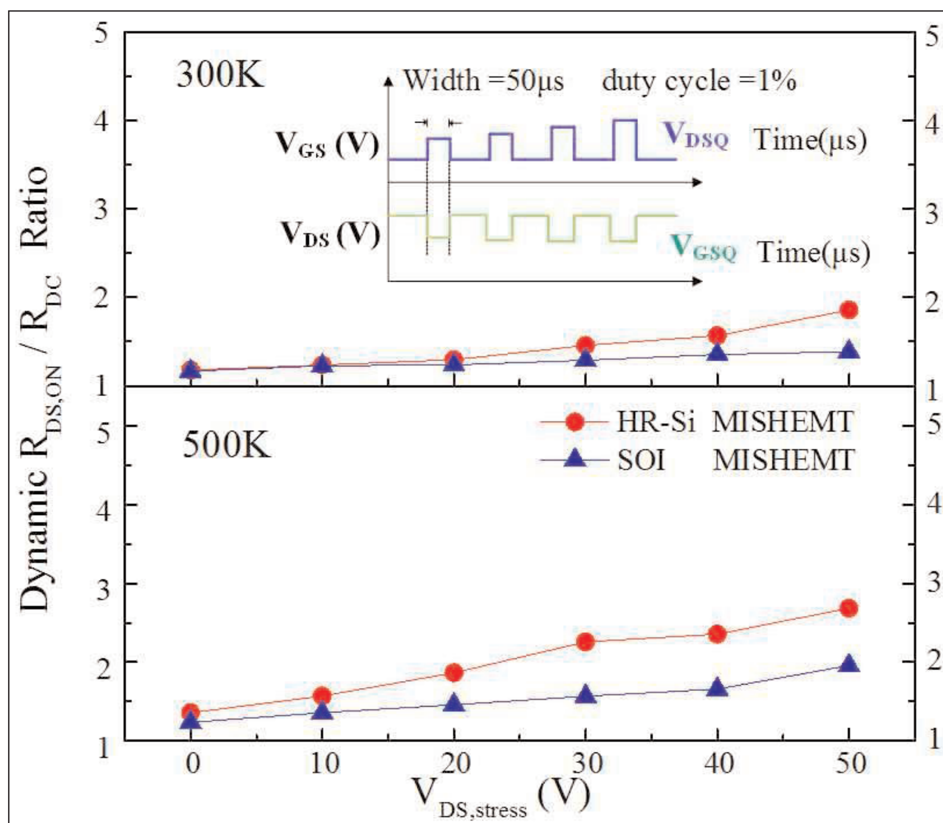

Figure 2. Dynamic switching performance determined with various stress voltages at 300K and 500K.

from the off-state (Figure 2). The increased dynamic on-resistance on HR Si was attributed to increased charge trapping in buffer states affecting performance.

Small-signal RF measurements gave cut-off/maximum oscillation (f_T/f_{max}) frequencies of 32.1GHz/51.9GHz and 18.3GHz/25.4GHz for the SOI and HR Si MISHEMTs, respectively.

Large-signal 2.4GHz RF measurements in AB-class amplifier operation gave maximum output powers of 660mW/mm and 550mW/mm for SOI and HR Si substrate MISHEMTs, respectively. The power-added efficiency (PAE) reached around 30% for SOI and 20% for HR Si. "The increase of output power and the reduction of parasitic capacitances in MISHEMT on SOI provide a significant improvement in the device linearity," the team adds.

CMOS integration

Researchers in the USA have developed GaN high-electron-mobility transistors (HEMTs) fabricated on 200mm-diameter SOI substrates with multiple crystal orientations [Ko-Tao Lee, et al, IEEE Electron Device Letters, vol38, p1094, 2017]. The team from IBM's T. J. Watson Research Center, Massachusetts Institute of Technology, Veeco Instruments Inc and Columbia University hope that the work will lead to heterogeneous integration of GaN power transistors with high-speed CMOS devices.

The substrates consisted of 750µm Si in the (111) crystal orientation, 145nm of buried oxide (SiO_2) and 80nm Si (100). The Si (111) was used for the growth of GaN, while the Si (100) gives optimum performance for CMOS devices. Thermal oxidation of the Si (100) surface reduced the 80nm layer to 40nm. The researchers point out that this is the preferred thickness for state-of-the-art 14nm-node CMOS.

Reactive ion etch (RIE) was used to expose Si (111) window regions up to 200µm x 200µm for selective GaN growth (Figure 3). The total GaN coverage was

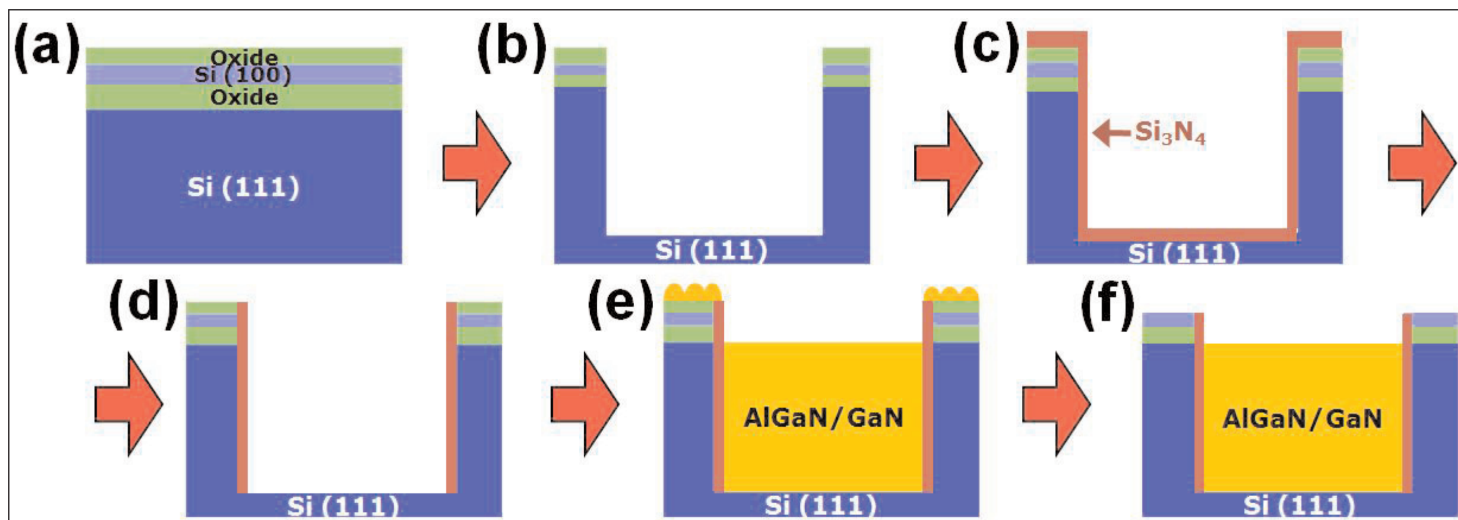

Figure 3. Hybrid-oriented SOI substrate with top Si (100) and bottom Si (111) preparation for MOCVD growth: (a) CVD-SiO_2 growth, (b) dry etching to expose Si (111) plane, (c) Si_3N_4 growth via CVD as isolation and diffusion barrier, (d) Si_3N_4 removal via dry etch to expose Si (111) plane, (e) AlGaN/GaN HEMT growth, (f) CVD-SiO_2 removal via chemical-mechanical planarization (CMP).

less than 50%, restricting bowing/warpage to within that needed for Si CMOS specifications (less than 50μm bow, for example).

The team comments: "The need for large-periphery high-power devices can potentially be achieved by combining multiple small patterned GaN devices. Once this approach is successful, this technology can extend the GaN-on-Si co-integration platform to high-power applications."

Silicon nitride (Si_3N_4) was deposited as a spacer on the window sidewalls, electrically isolating the GaN and Si (100) regions. The Si_3N_4 also provided a diffusion barrier, stopping Ga and Si atoms from doping the adjoining regions.

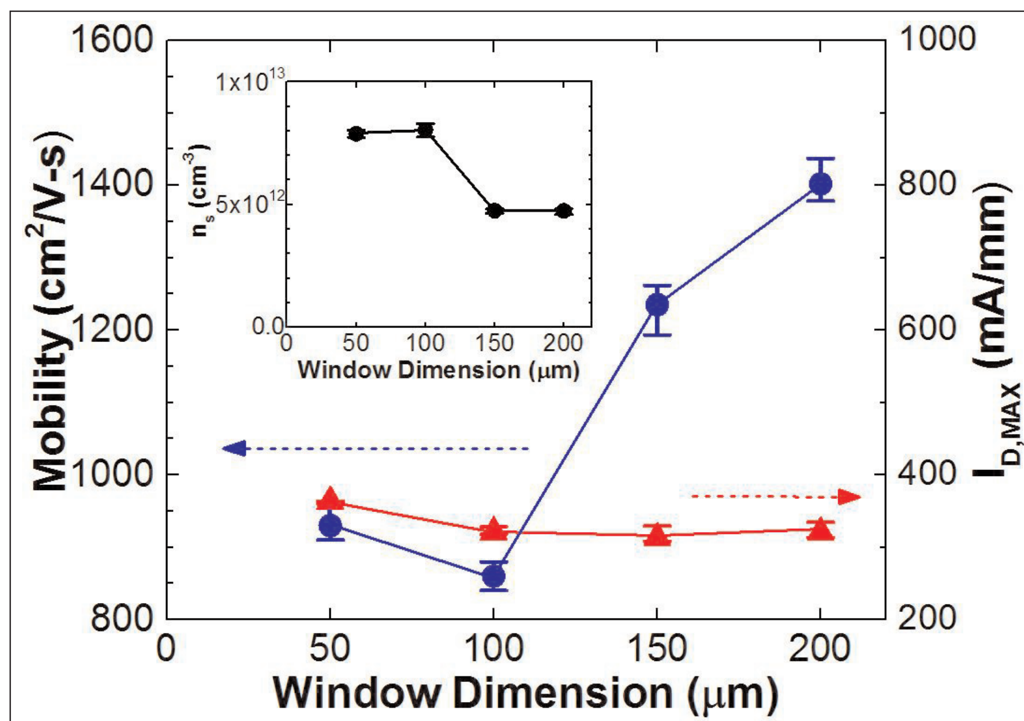

Figure 4. Electron mobility and drain current of GaN HEMTs from various window dimensions. Inset: corresponding carrier density (n_s) as function of window dimension.

The GaN and AlGaN material was grown by MOCVD: 130nm 1050ºC AlN nucleation, 1.5μm 1035ºC GaN buffer/channel, and post-growth ramp down to 985ºC to "facilitate unintentional [?] carbon doping". MOCVD for HEMTs added a 1nm AlN spacer, 20nm $Al_{0.25}Ga_{0.75}N$ barrier, and a 3nm GaN cap.

A GaN layer grown on a Si (111) control wafer under the same conditions was only 0.6μm thick, less than half that of the 1.5μm layer in the SOI Si (111) regions. The increased thickness for the selective area growth was attributed to 'micro-loading effects' from the confined space of the Si (111) regions.

Standard HEMTs were produced with 3μm gate length and 3μm spacing between the gate and source and drain regions.

While the mobility varied according to the size of the window regions, declining with reduced size, the maximum drain current for the HEMTs was roughly constant (Figure 4). "The decline in electron mobility with decreasing window dimension is believed to be related to higher strain relaxation in smaller windows," the researchers explain.

Breakdown voltage was reduced with the smallest 50μm x 50μm windows (~40V versus ~80V for larger windows), which the researchers suggest could be due to defects at the GaN/Si_3N_4 sidewalls. By contrast, current collapse increased for the largest 200μm x 200μm windows (~25% versus less than ~6% for smaller windows). The quiescent state for the collapse measurements was −3V gate potential and 10V drain bias. The pulse width was 500ns. A 100μm x 100μm window device demonstrated a collapse of less than 2%. The researchers give 25% collapse as being typical for HEMTs on 'bulk' GaN.

The researchers comment: "The current collapse appears to correlate with the strain relaxation in patterned GaN, which is lower in smaller windows. Although the exact mechanism for this phenomenon needs further investigation, we believe that an interplay between defects and strain in patterned GaN dictates the observed current collapse behavior."

Isolation

Researchers based in Belgium and Finland have used SOI substrates to improve the electrical isolation of p-type GaN HEMTs [Xiangdong Li et al, IEEE Electron Device Letters, vol38, p918, 2017].

The researchers comment: "This work demonstrates that by using GaN-on-SOI in combination with trench isolation, it is very promising to monolithically integrate GaN power systems on the same wafer to reduce the parasitic inductance and die size."

It has also been found that growing GaN on SOI can result in higher-quality material, an effect that is attributed to the more compliant nature in terms of stress and strain of the insulator component of the wafer — silicon dioxide (SiO_2).

The 200mm-diameter SOI wafer consisted of a 1070μm (100) Si handle, 1μm buried SiO_2, and a 1.5μm (111) Si device layer. The SiO_2 thickness gave a balance between high breakdown voltage and low thermal resistance.

MOCVD resulted in 200nm aluminium nitride (AlN) nucleation, a 2.6μm (Al)GaN superlattice buffer, a

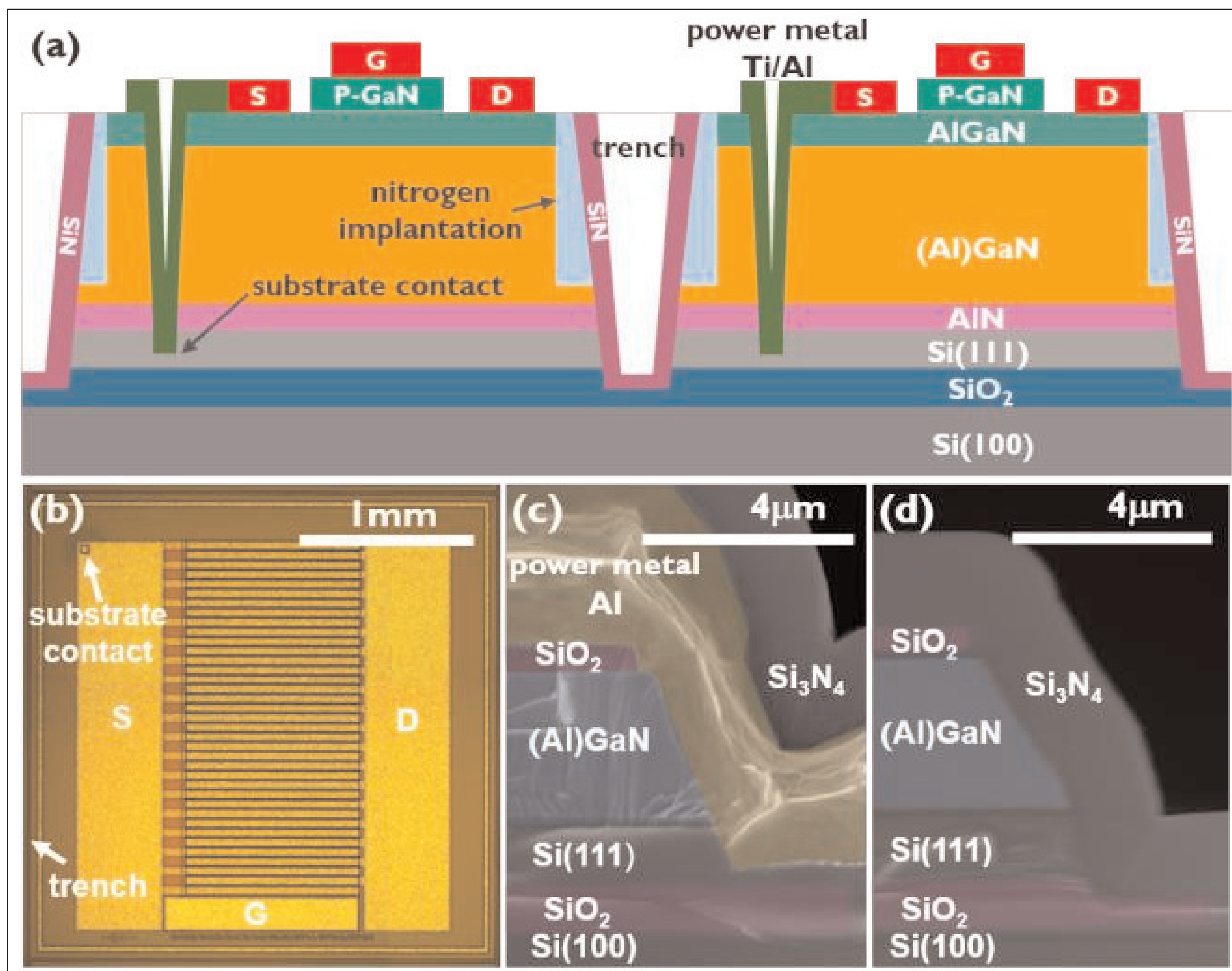

Figure 5. (a) Schematic cross section of enhancement-mode p-GaN HEMT, (b) top view of fabricated device, and cross-sectional secondary-electron micrographs of (c) substrate contact and (d) trench isolation fabricated on 200mm GaN-on-SOI.

300nm GaN channel, a 12.5nm $Al_{0.25}Ga_{0.75}N$ barrier, and 80nm of p-GaN. After deposition, the p-GaN layer was annealed in-situ in nitrogen to activate the magnesium doping, giving a hole concentration of $\sim 10^{18}/cm^3$.

The (Al)GaN buffer was designed to control stress and avoid wafer warpage (<50μm). Surface roughness was 1.4nm root-mean-square, according to atomic force microscopy.

The enhancement-mode (i.e. normally-off) p-GaN HEMTs (Figure 5) were fabricated with gold-free processing. Future integration with silicon electronic circuitry would need to eliminate gold from the production process, since the element poisons carrier transport in silicon.

The gate stack consisted of titanium nitride on p-GaN. Horizontal isolation was achieved with nitrogen ion implantation. A 50μm x 50μm substrate contact was created by etching through to the Si(111) device layer and sputtering titanium/aluminium, connecting the substrate with the ohmic source contact.

The device was completed with etching of a 20μm-wide isolation trench reaching down to the buried oxide and with deposition of a passivation layer. The trench isolation was found to have a horizontal breakdown voltage around 700V at 150ºC. The vertical breakdown of the buried oxide was around 500V at the same temperature.

The gate was 36mm wide and 0.8μm long. The distances between the gate and the source/drain were 0.75μm/6μm, respectively.

The gate threshold voltage was around +1.6V. A comparison device on non-SOI silicon had the same threshold. The comparison device did not have the substrate contact or trench isolation. The on-resistance of the comparison device was 10.6Ω-mm, and that of the SOI p-GaN HEMT was only slightly higher at 10.8Ω-mm at 0.1V drain bias and 7V gate potential.

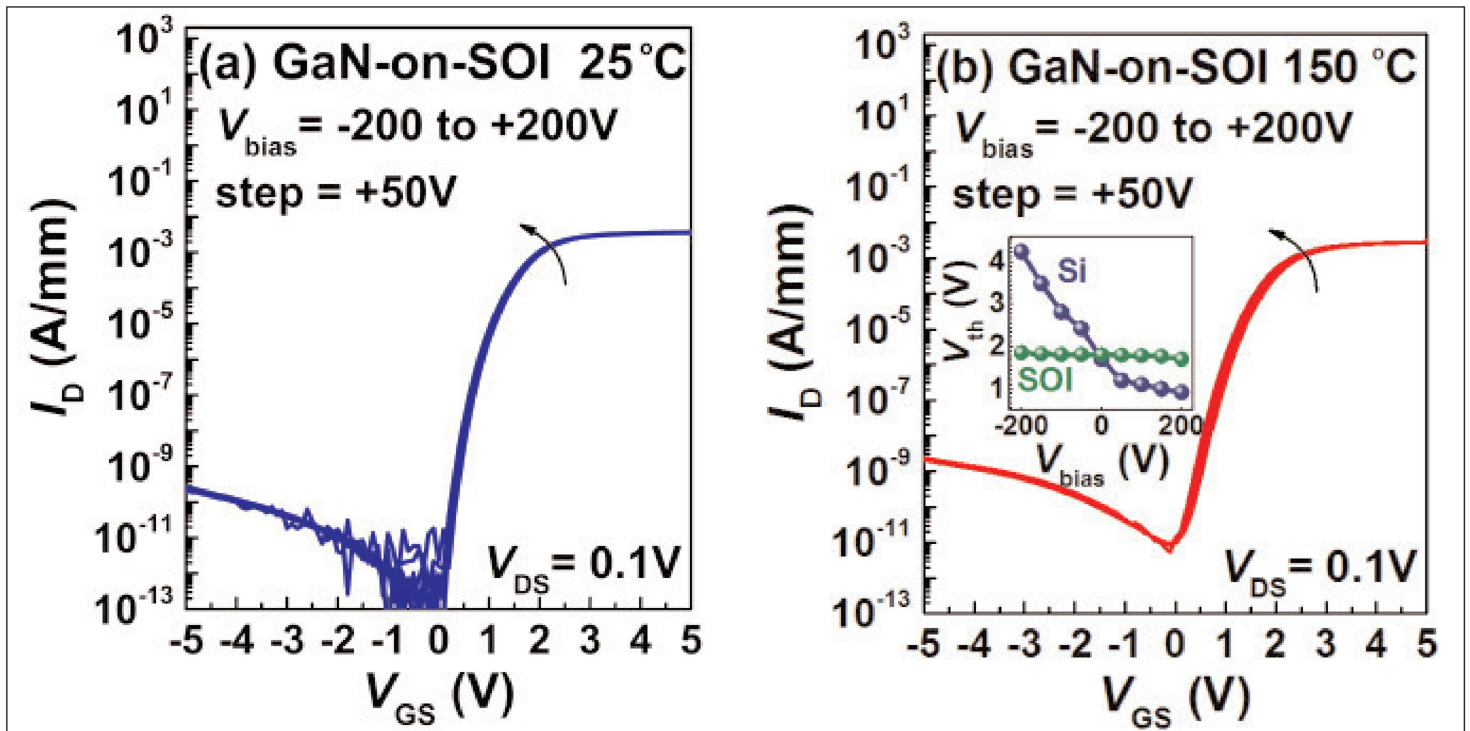

Figure 6. Evaluation of device isolation on GaN-on-SOI by measuring transfer characteristics while simultaneously biasing neighboring Si(111) device layer at different voltages at (a) 25ºC and (b) 150ºC.

The maximum drain current with 7V gate potential was 9A across the 36nm gate width, for both devices.

With the gate at 0V, the off-state breakdown for both devices was around 600V for 1μA/mm leakage. The researchers say that this gives sufficient margin for 200V-rated applications.

Where the SOI device improved on the comparison device was in the effectiveness of the electrical isolation. This was tested by biasing the substrate of the neighboring device between −200V and +200V (Figure 6). In particular, the SOI device's threshold voltage was stable over the bias range, while that of the HEMT on silicon varied by a few volts.

"With the demonstrated high-quality device isolation, it is very promising to achieve monolithic integration of GaN power system on GaN-on-SOI, and further explore the potentials of GaN in the field of high power applications," the team writes.

InGaAsP quantum wells

University of California Santa Barbara (UCSB) in the USA has developed the direct growth of InGaAsP multiple quantum well (MQW) nanowires on SOI substrates [Ludovico Megalini et al, Appl. Phys. Lett., vol111, p032105, 2017]. The target emission wavelength of the MQWs was 1550nm infrared, as favored for fiber-optic communication applications. The team looks forward to "integration of InP-based nanoridges in the SOI platform for new classes of ultra-compact, low-power, nano-electronic, and photonic devices for future tele- and data-communications applications."

SOI also has superior optical confinement properties compared to bulk silicon (Si): 13.4% confinement for SOI compared with 1.2% for silicon, according to InGaAsP nanowire simulations by the UCSB research team.

The SOI substrate used by UCSB had a 500nm lightly doped p-type Si layer on 1μm buried silicon dioxide. A 500nm PECVD silicon dioxide layer was used as a mask patterned with 3mm-long, 200nm-wide, 800nm-pitch stripes along the [110] direction. The wafer was then diced into 2cm x 2cm pieces.

The silicon device layer was etched with dilute potassium hydroxide at 70ºC to give v-grooves with {111} surfaces. A small undercut at the interface between the mask and device layer was found to be useful for trapping defects — in particular, stacking faults — in the subsequent InGaAsP growth by MOCVD.

The III-V layers consisted of 20nm of GaAs nucleation in two temperature steps of 410ºC and 430ºC, 430ºC InP nucleation, continued InP growth at 550ºC and 600ºC, and finally 650ºC growth of InGaAsP MQWs and 400nm InP cap (Figure 7). The InP nanowires were ~1.3μm thick with good height uniformity over a wide area, according to the researchers.

Photoluminescence experiments found a peak at 1555.7nm with 135nm full width at half maximum, attributed to the MQW structures. The pump power was 20.5W/cm^2. Lower pump powers gave a broader peak (Figure 8). This is attributed to saturation effects where the impact from defects becomes less significant at high excitation intensity.

The MQW layers were also non-uniform, leading to

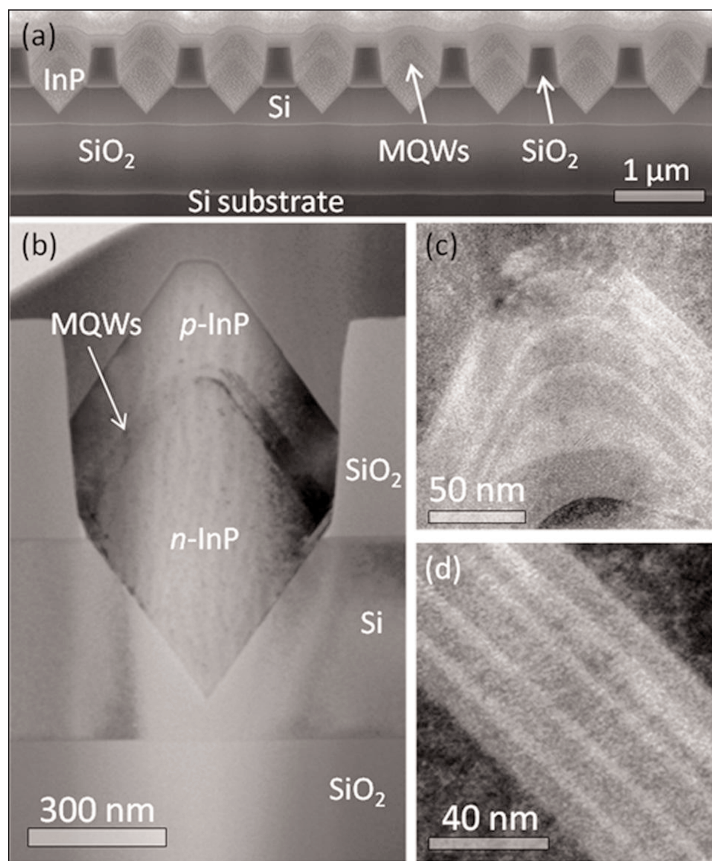

Figure 7. (a) Focused ion-beam scanning electron microscope (FIB-SEM) cross-sectional images of InP nanowires showing regular morphology. (b) Bright-field transmission electron microscope (BF-TEM) image of single nanowire with good symmetry. (c and d) BF-TEM images of QWs and barrier layers in (c) (001) surface and (d) {11-1B} facet. The dark colored layer is the barrier; the light colored layer is the quantum well.

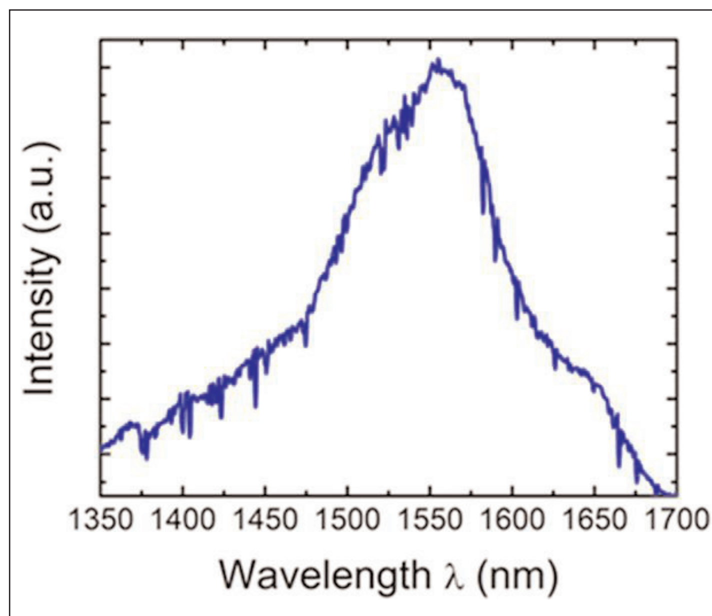

Figure 8. Photoluminescence spectrum showing emission at 1567nm from MQW structure inside indium phosphide nanowires grown on v-groove patterned SOI.

peak shifts and broadening as the excitation spot position varied over the sample. Inhomogeneous spectrum broadening could inhibit gain in laser devices. The researchers believe more uniform QWs could be achieved with careful adjustment of growth time and position within the nanowire. ■

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Controlled spalling of bulk and free-standing gallium nitride substrates

Process could be developed for material thinning and wafer reuse in power electronic applications.

IBM T. J. Watson Research Center in the USA has been exploring controlled spalling as a method for transferring thin layers of gallium nitride (GaN) from bulk and free-standing substrates [S. W. Bedell et al, J. Appl. Phys., vol122, p025103, 2017].

The researchers see the process as potentially contributing to the application in power electronics, where at present there are difficulties in thinning GaN to increase thermal conductivity due to the material's hardness and inertness. Also, the use of very expensive bulk and free-standing GaN substrates could be ameliorated by reusing the wafer and separating a number of device layers.

The researchers have previously reported the separation of epitaxial GaN light-emitting diode (LED) layers from sapphire substrates, along with applications of controlled spalling to silicon circuits and germanium- and gallium arsenide-based solar cells

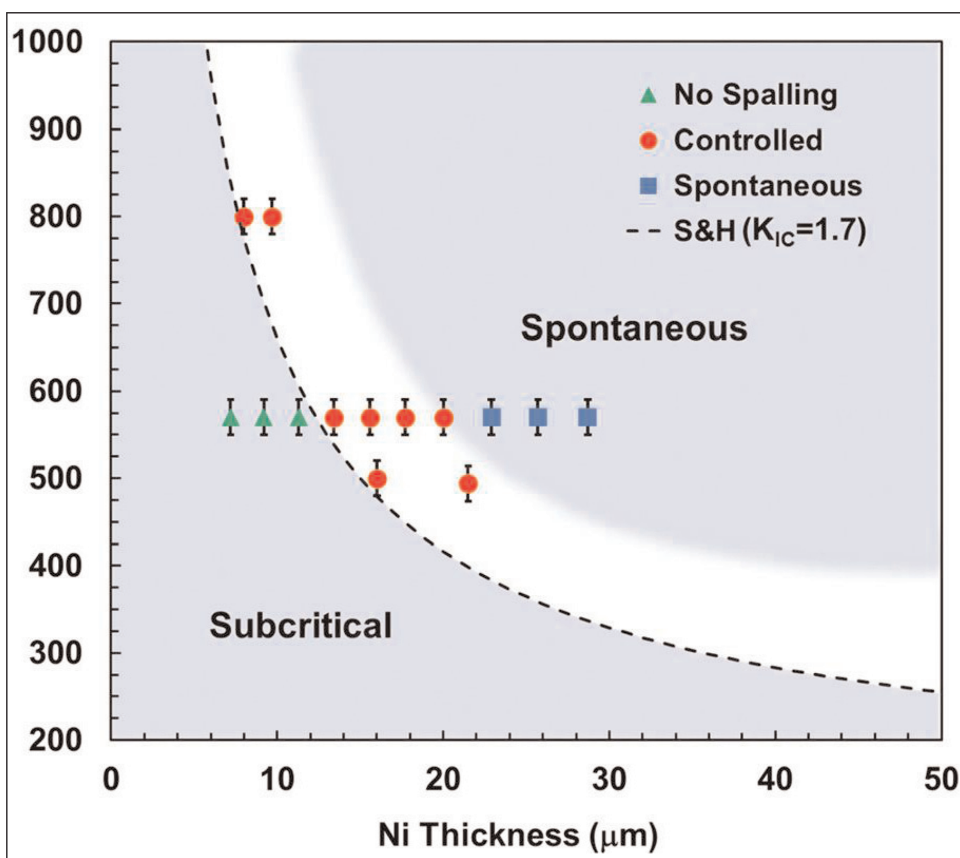

Figure 1. Plot of thickness versus stress of Ni stressor layer that defines controlled spalling regime for <0001> bulk GaN wafers.

Controlled spalling uses a tensile stressor material deposited on the surface of the GaN substrate to induce fracture inside the material that propagates across the substrate. The researchers have found nickel to be a particularly suitable stressor. The nickel can be deposited by sputtering or electro-deposition.

The substrate was 300μm-thick hydride vapor phase epitaxy (HVPE) GaN. The substrates were 2-inch diameter. The material came from various suppliers. The stressor consisted of DC magnetron sputtered layers of 90nm titanium adhesion and 1μm nickel seed for further electro-plating at room temperature. The electro-deposition used a solution containing nickel chloride ($NiCl_2$) and boric acid (H_3BO_3). The nickel was applied to both sides of the substrate.

The tensile stress in the nickel was around 450MPa to 500MPa, independent of thickness from 16μm up to 30μm (Figure 1). Adding ammonium chloride (NH_3Cl) to the electro-deposition solution increased the stress to 800MPa, allowing spalling to begin at 8μm thickness.

To perform the spalling, a 25μm-thick polyimide tape was roll applied to the surface. Lifting one edge of the tape was found to initiate the fracture that could be propagated across the substrate (Figure 2).

The researchers report: "This manual method of guiding fracture does not require any additional 'pulling' force on the handle layer; once the crack is initiated at the wafer edge, the mechanical energy to propagate fracture is contained in the Ni stressor layer."

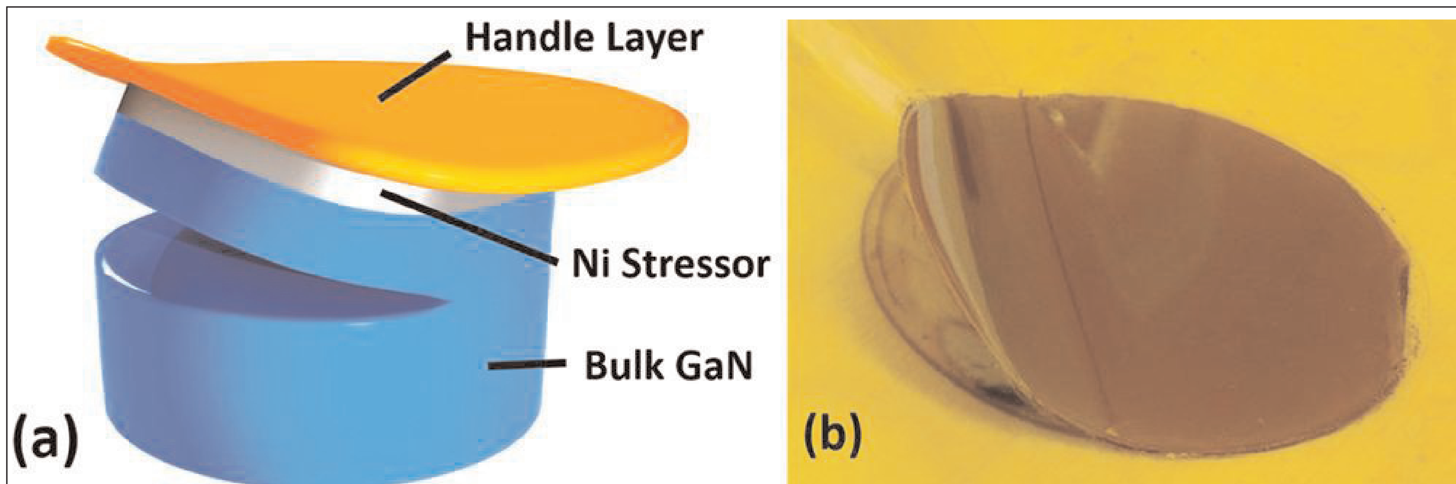

Figure 2. (a) Controlled spalling of bulk GaN substrate and (b) image of 2-inch bulk GaN wafer during process.

There was variation in the thickness of the spalled GaN between 18μm and 25μm, "primarily dependent on the Ni film uniformity, although local fracture perturbations can cause spalling depth variation," the team reports.

Transmission electron microscopic (TEM) analysis gave the defect density as below the detection limit of mid $10^7/cm^2$.

One problem is that the [0001] c-planes are not natural cleavage directions in GaN. The researchers comment: "Recent work suggests that the m- and a-planes permit proper cleavage and, therefore, spalling of semi-polar and non-polar GaN wafers may have much lower as-spalled roughness."

The researchers report: "Although we have demonstrated that controlled spalling can be used to remove thin surface films from bulk GaN substrates without generating defects or cracks in either the film or the remaining wafer, the surface artifacts presently make wafer reclaim challenging."

The surface artifacts were seen when the spalling process was started and stopped. The artifacts presented as depth perturbations of order 1–2μm. The team suggests that improvement in the technique for wafer reclaim would require constant velocity fracture propagation or new higher-speed grinding and lapping.

Double-side-polished GaN wafers allowed spalling from the N-face. The researchers found no difference in spalling characteristics between Ga- and N-faces. ■

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Gallium nitride on silicon in-plane gate field-effect transistors

Researchers see prospects for high-frequency high-power devices using small gate capacitance, high carrier density and high breakdown field.

Giovanni Santoruvo and Elison Matioli of École Polytechnique Fédérale de Lausanne in Switzerland have combined in-plane gate field-effect transistors (IPGFETs) with gallium nitride (GaN) on silicon technology with a view to high-frequency power applications [IEEE Electron Device Letters, published online 9 August 2017]. The IPGFET (Figure 1) uses gate electrodes etched from the same level as the channel to control current flow. There is no need for dielectrics since the gate is insulated from the channel by air.

Santoruvo and Matioli comment: "High-frequency devices require a small gate capacitance in addition to a large gm [transconductance], which is an intrinsic advantage of IPGFETs."

Although IPGFETs have been realized in other compound semiconductor materials, Santoruvo and Matioli claim that their work is the first to use III-nitrides to produce high-performance IPGFETs.

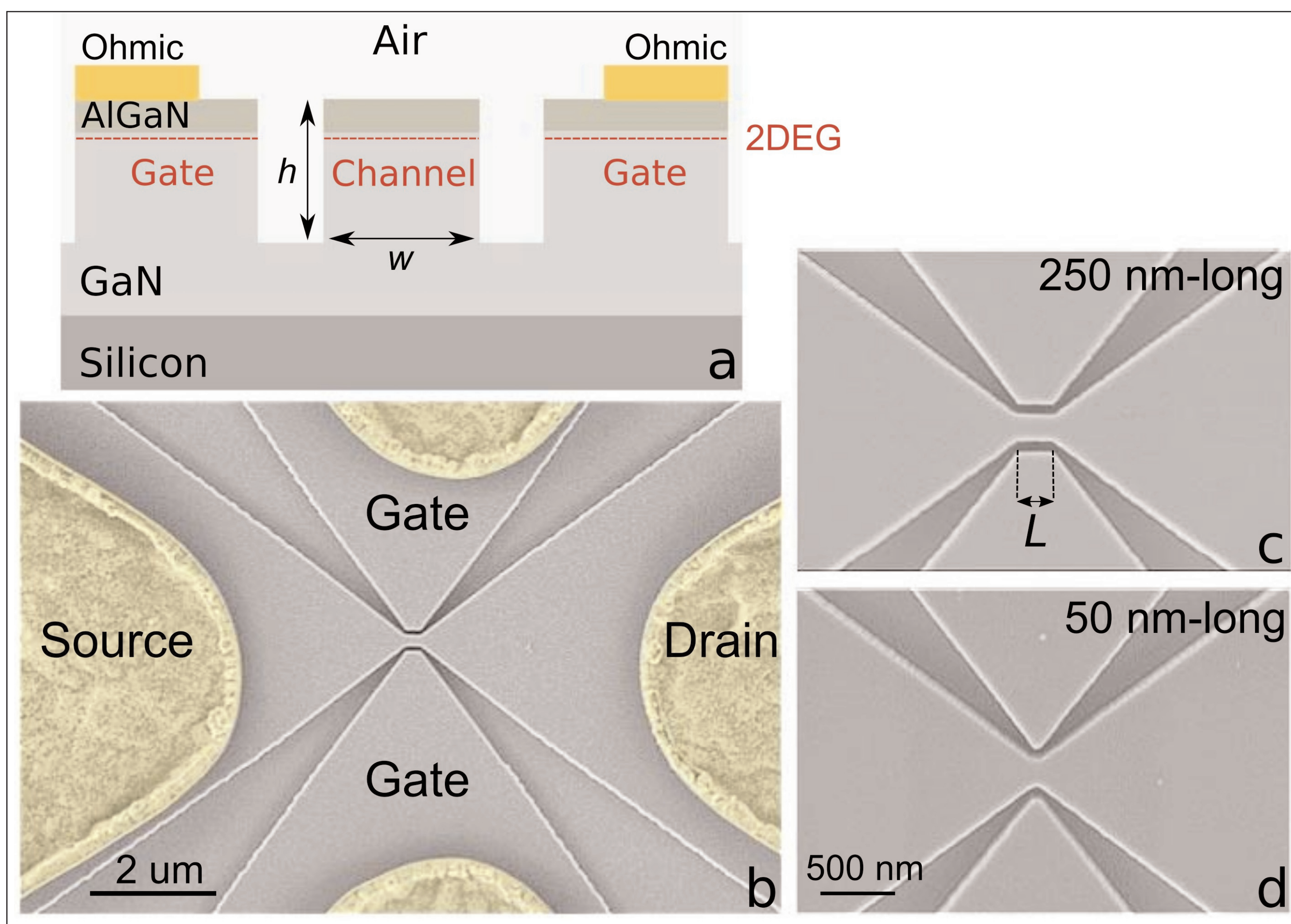

Figure 1. (a) Schematic and (b) top-view scanning electron microscope (SEM) image of 165nm-wide, 250nm-long IPGFET. Zoomed top-view SEM of 250nm-long (c) and 50nm-long (d) IPGFETs.

III-nitride should enable access to high carrier density and high breakdown voltages.

The III-nitride semiconductor material consisted of a silicon substrate, 3.75μm GaN buffer, 300nm GaN channel, 8nm aluminium nitride (AlN) spacer, and 23.5nm $Al_{0.25}Ga_{0.75}N$ barrier. The two-dimensional electron gas formed at the top GaN interface with the spacer/barrier had $1.05 \times 10^{13}/cm^2$ carrier concentration, $1690cm^2/V\text{-}s$ mobility, and 350Ω/square sheet resistance.

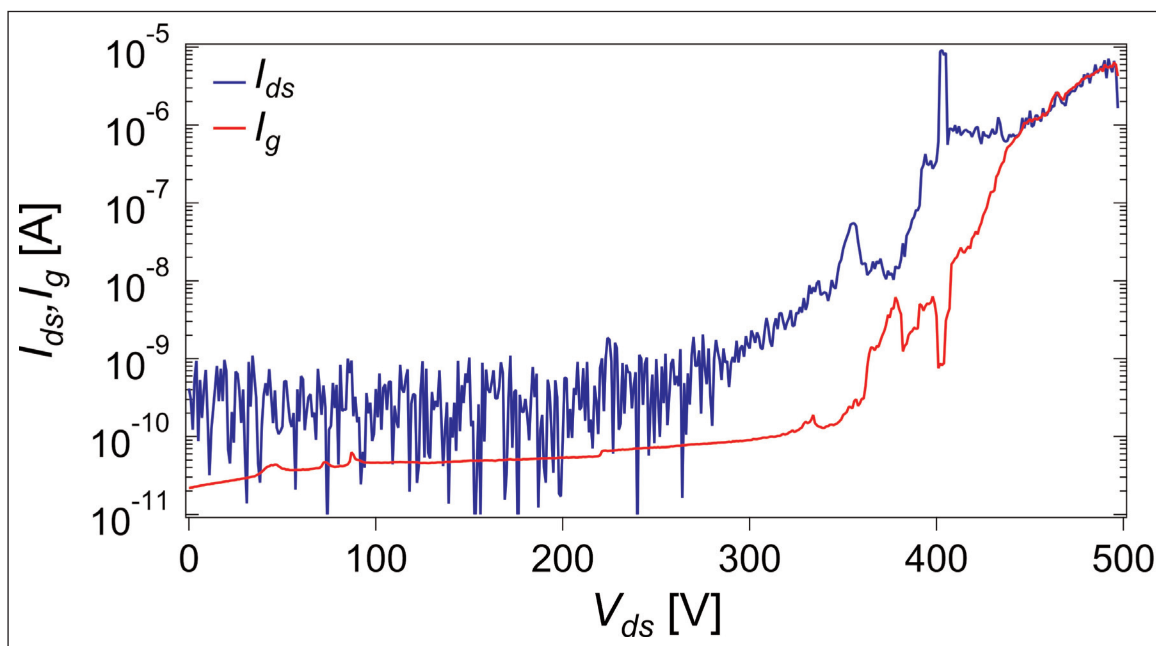

Figure 2. Drain and gate currents for 165nm-wide, 250nm-long IPGFET in −11V gate off-state.

The channel, source, drain and gate were fabricated using electron-beam lithography and inductively coupled plasma etch. Devices with varying parameters were defined. Annealed ohmic contacts to the source, drain and gate consisted of titanium/aluminium/titanium/nickel/gold.

This essentially two-step fabrication results in transistors with self-aligned gates. No insulation oxides or passivation layers were used. Such additions to improve performance are suggested as future work by Santoruvo and Matioli.

Wide-channel devices had larger maximum drain current and threshold voltage magnitude. The devices were normally-on, so the threshold was negative. The wider channels naturally had lower resistance. However, the narrower-channel devices had a further effect increasing resistance — strain relaxation in the AlGaN barrier, decreasing carrier density due to reduced piezoelectric effects. Reducing the channel length also reduced resistance, giving similar increases in drain current and threshold.

The on/off current ratio was of the order 10^7 with less than 10pA leakage current for 210nm deep trench etching. Shallower trench etching to 140nm gave a slightly higher leakage, but still less than 100pA.

The shallower trenches also gave devices with more positive thresholds — i.e. the magnitude was smaller. This is attributed to an increase in gate capacitance for the shallower trenches.

Santoruvo and Matioli estimate the total effective capacitance of 0.7—3.9aF (where aF = atto-Farads = 10^{-18}F) for deep IPGFETs of widths 20–85nm. The corresponding values for shallow transistors were in the range 2.2–9.4aF. "These are extremely small values of gate capacitance, which are very promising for high-frequency applications," the researchers comment.

On the basis of these values, they estimate potential for up to 0.89THz cut-off frequencies, although the reported devices were not designed or tested for high-frequency performance.

A 50nm-long, 85nm-wide shallow IPGFET achieved a drain current of 1.4A/mm, which is 9x the value reported for similar structures using indium gallium arsenide (InGaAs) quantum well material. The improvement for GaN IPGFETs is credited to much larger carrier densities and very small sidewall depletion in III-nitrides.

Shallow 50nm-channel-length IPGFETs also demonstrated higher transconductance, which increased over a broader range of gate potentials with channel width. Normalized by channel width, the peak transconductance was 335mS/mm for 85nm-wide channels and 665mS/mm for 20nm. The latter value is 5x that of previous reports. The increase in normalized transconductance for narrower channels is attributed to improved modulation by the gate.

In the −11V gate potential 'off' state, leakage was maintained at a low level up to 300V (less than 1nA drain and 100pA gate current), breaking down at 500V (Figure 2). This performance trend was independent of channel width. "The similar behavior of I_{ds} and I_g suggests that at large voltages the leakage current flows entirely through the semiconductor buffer layers, not through the nanowires, since both the drain and gate contacts are ohmic," Santoruvo and Matioli write. ■

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Author: Mike Cooke

High-breakdown slanted tri-gate gallium nitride power transistors

Researchers claim record figure of merit, reflecting high breakdown and low on-resistance.

Jun Ma and Elison Matioli of the École Polytechnique Fédérale de Lausanne in Switzerland have used slanted tri-gate structures to enhance the breakdown voltage of gallium nitride (GaN) metal-oxide-semiconductor high-electron-mobility transistors (MOSHEMTs) by 500V [IEEE Electron

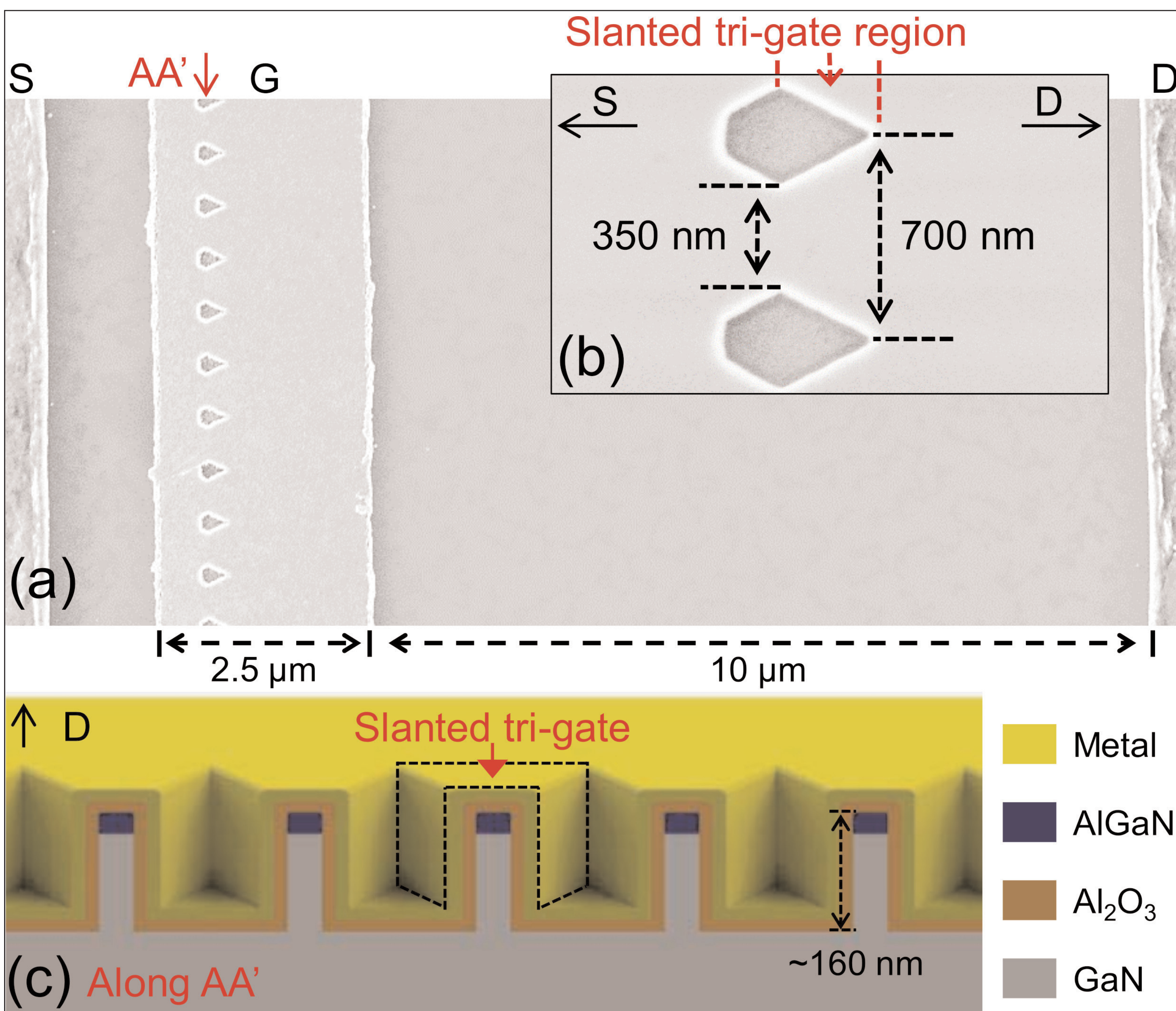

Figure 1. Scanning electron microscope top-view of slanted tri-gate MOSHEMT (a) with and (b) without gate dielectric and metal. (c) Cross-sectional schematic of slanted tri-gate along arrow AA'.

Device Letters, published online 25 July 2017]. They claim a record 1.2GW/cm^2 high-power figure of merit.

The fabricated transistors (Figure 1) consisted of etched nanowires with slanted width within the gate region. The etch depth was 160nm into the aluminium gallium nitride (AlGaN) barrier on gallium nitride channel on silicon structure. The slant gave a 350nm width on the source side and 700nm on the drain side.

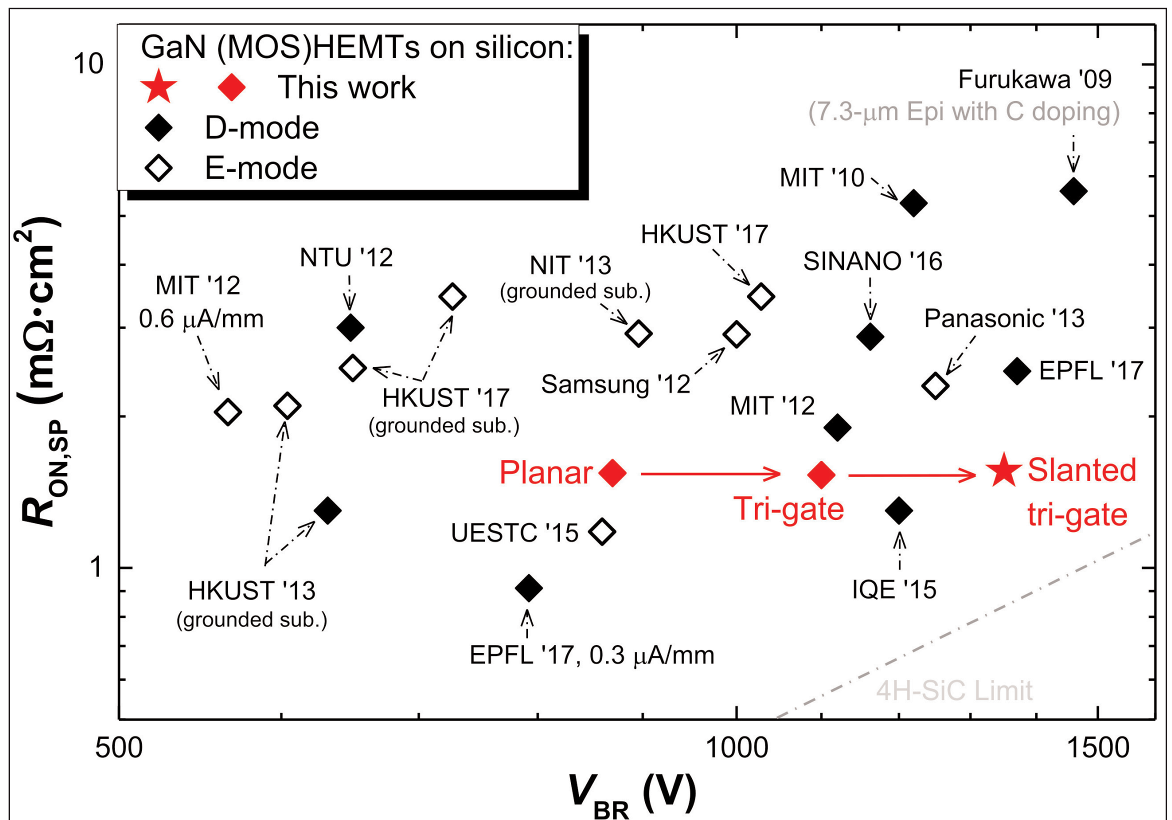

Figure 2. $R_{ON,SP}$ versus V_{BR} benchmark of slanted tri-gate MOSHEMTs against state-of-the-art GaN enhancement-mode and depletion-mode (MOS)HEMTs on silicon with breakdown criterion of 1µA/mm. $R_{ON,SP}$ based on 1.5µm transfer length for each ohmic contact. V_{BR} for all reference devices re-calculated based on 1µA/mm criterion.

The gate stack consisted of 20nm atomic layer deposition (ALD) aluminium oxide (Al_2O_3) and metal wrapped around the channel. The source and drain planar sides of the gate were 0.5µm and 1.5µm, respectively. The total gate length was 2.5µm. The source-gate and gate–drain distances were 1.5µm and 10µm, respectively.

Since the researchers were interested in the raw effect of slant gates, they did not use conventional field plates or passivation. In fact, the team sees the tri-gate structure as converting the planar part of the gate towards the drain side into an effective field plate. The slant structure allows the pinch-off potential to vary in such a way that the electric field is kept below critical. The varying potential is mainly achieved by strain relaxation in the AlGaN/GaN nanowires along with the increased electrostatic control offered by the sidewall gates of the tri-gate structure.

Without field plates, or the slant tri-gate structure, the electric field tends to peak at the gate edge on the drain side. However, while field plates require complex processing, tri-gates can be achieved with just one extra etch step.

Even introducing an unslanted tri-gate into the planar transistor improved the breakdown voltage from 877V to 1100V with a 1µA/mm leakage criterion. Slanting the tri-gates increased the breakdown further to 1350V, close to the buffer limit, even with a gate–drain distance as low as 10µm.

The off leakage current (I_{OFF}) at lower drain biases were higher in the slanted tri-gate structure, compared with the planar and unslanted tri-gate MOSHEMTs. The researchers comment: "The larger I_{OFF} of the slanted tri-gate device at small voltages is likely due to its much smaller effective gate length, since the three devices have the same buffer leakage current as they were fabricated on the same chip, and exhibited small gate leakage currents ≤ 2nA/mm at 750V."

The leakage dependences on bias voltage were similar above 750V up to near the respective breakdowns.

Beyond breakdown characteristics, the slanted tri-gate structure also exhibited a high on/off current ratio of more than 10^9 and high transconductance up to 72mS/mm at 5V drain bias. The transconductance of the planar device was lower, at 66mS/mm. The on-resistance of the devices was similar, at about 9Ω-mm.

The researchers also compared the slanted tri-gate device with transistors produced by other groups (Figure 2). They point out that their breakdown voltage was comparable with the best reported value of 1460V. At the same time, the specific on-resistance ($R_{ON,SP}$) was 3.6x lower due to the 14µm shorter gate-drain distance in the slanted tri-gate MOSHEMT.

A widely used power transistor figure of merit, $V_{BR}^2/R_{ON,SP}$, was 1.2GW/cm^2, claimed as a record value. ■

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Author: Mike Cooke

Aluminium nitride Schottky barrier diodes with breakdown more than 1kV

Arizona State University has claimed the first demonstration of high-performance 1kV-class AlN Schottky barrier diodes on sapphire substrates.

Arizona State University (ASU) in the USA claims the first demonstration of 1kV-class aluminium nitride (AlN) Schottky barrier diodes (SBDs) [Houqiang Fu et al, IEEE Electron Device Letters, 5 July 2017].

AlN has a wide bandgap of 6.2eV. Wide bandgaps are associated with the large critical fields (12.5MV/cm in AlN), which are needed in compact power handling devices. Other semiconductor materials used in or proposed for power devices have narrower bandgaps: 3.3eV for silicon carbide, 3.4eV for gallium nitride, 4.8eV for beta-gallium oxide, and 5.5eV for diamond. AlN also has a large thermal conductivity of 340W/mK, which is also an attractive feature for power applications.

AlN's advantages have not led so far to commercial devices since there are material and fabrication challenges.

ASU's AlN material was grown by metal-organic chemical vapor deposition (MOCVD) on single side-polished (0001) sapphire substrate off-cut 0.2°. The SBD structure (Figure 1) included 1µm unintentionally doped (UID) AlN underlayer (UL), 300nm silicon-doped n-AlN, and 2nm UID gallium nitride cap.

According to the researchers, the device structure mimics silicon-on-insulator (SOI) technology, with a thin n-AlN epilayer active region on the thick resistive AlN underlayer. The purpose of the cap was to protect the underlying layers from oxidation, which can negatively impact device performance.

The researchers report that the AlN material demonstrated among the narrowest reported full-width at half maximum (FWHM) x-ray peaks for MOCVD AlN on sapphire — 46.8arcsec for the (0002) rocking curve and 159.1arcsec for (20$\bar{2}$4). These figures suggest dislocation densities of the order 10^8/cm^2.

The Schottky barrier diode was fabricated with 20nm/100nm/20nm/50nm titanium/aluminium/titanium/gold (Ti/Al/Ti/Au) ohmic and 30nm/120nm platinum/gold (Pt/Au) Schottky contacts. The ohmic metal was patterned as a 400µm-diameter circular disk.

Two types of Schottky contact were made: a 100µm-diameter circular disk and 100µm-side square. The distance between the contacts was 200µm. Surface passivation consisted of 200nm plasma-enhanced CVD silicon dioxide (SiO_2). There was no edge termination structure.

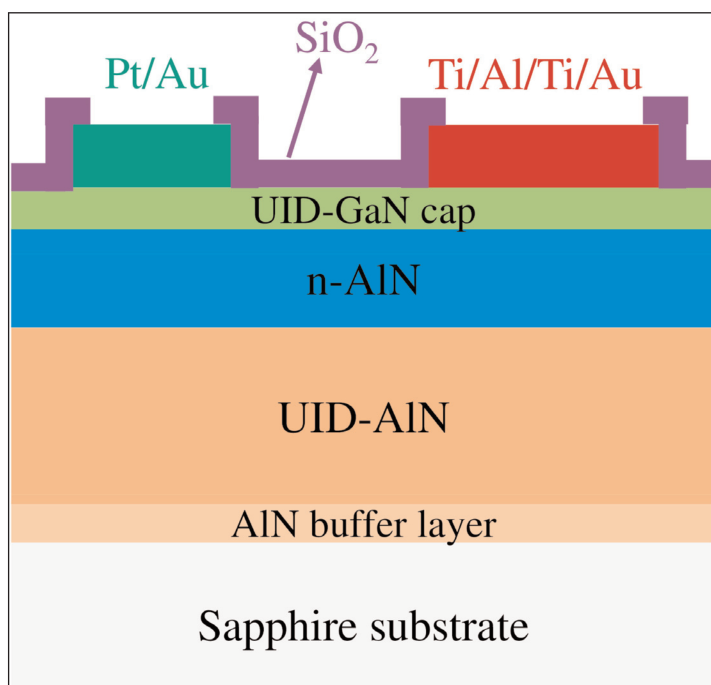

Figure 1. Schematic view of fabricated AlN Schottky barrier diodes on sapphire by MOCVD. Ohmic and Schottky contacts are in red and green, respectively.

The ~10^5 on–off ratio of the devices is described by the team as being comparable to AlN devices on AlN substrates. The turn-on voltage of 1.2V (1.1V for square contacts) is smaller than previously reported values (more than 2V), according to ASU.

The temperature dependence of the device performance suggests that the forward current was limited by thermionic emission. The Schottky barrier height increased from 0.9eV to 1.6eV between 20°C (room temperature — RT) and 200°C. At the same time, the ideality decreased from 5.5 (5.3 for square contact) to 2.2. Previous reported idealities of AlN Schottky barrier diodes have been greater than 8.

The researchers attribute the ideality behavior to

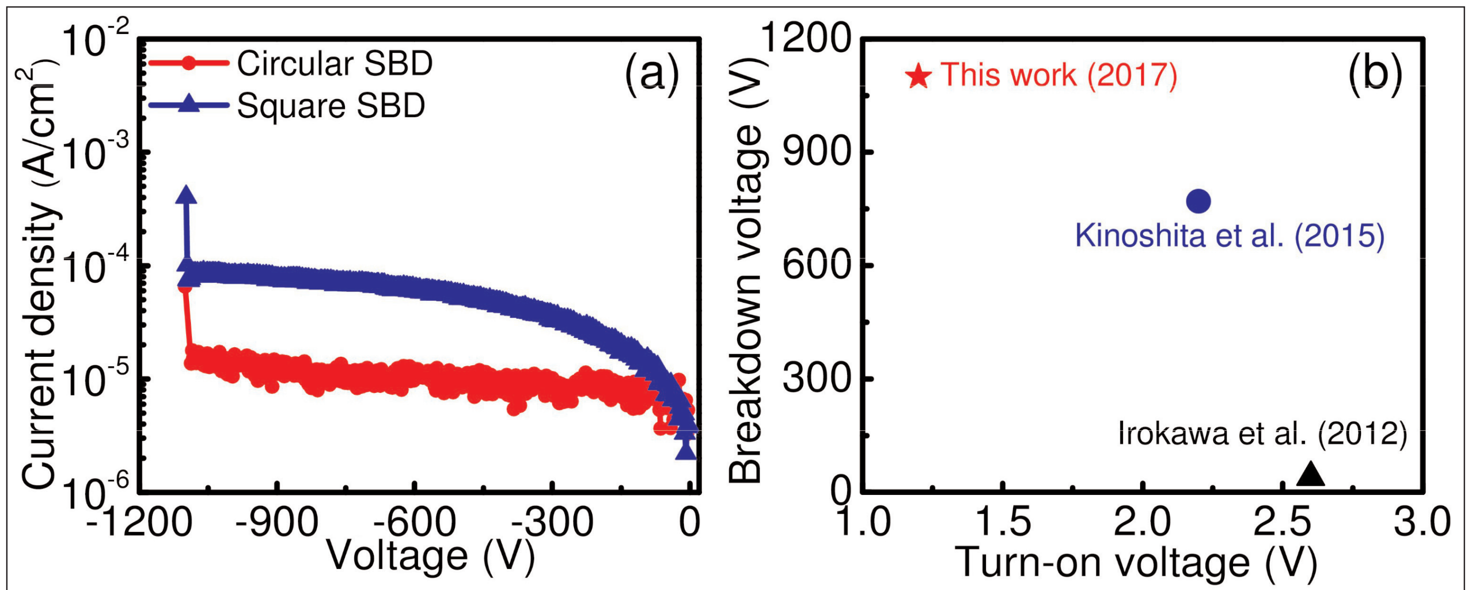

Figure 2. (a) Reverse current-voltage characteristics of circular and square AlN SBDs. (b) Comparison of breakdown and turn-on voltages of reported AlN SBDs.

'lateral inhomogeneity of the Schottky barrier interface'. They add: "Note that the RT ideality factors (n = 5.5 and 5.3 for circular and square SBDs, respectively) obtained in this work were 2~3 times smaller than previous results, possibly due to improved material quality and metal/semiconductor interface."

Under reverse bias, the Schottky barrier diodes broke down only after 1kV, beating previous reports of ~700V for devices produced on free-standing AlN substrate by Japanese and US researchers (Figure 2). The ASU devices showed catastrophic damage at the edge of Schottky contacts that was attributed to edge electric field crowding.

The team comments: "Improvement in the breakdown capability of the devices can be further expected by employing field plate and/or edge termination. In addition, improving the material quality of n-AlN, increasing the resistivity of the UID AlN UL by Fe or C doping and optimizing the passivation strategies can also help to increase the breakdown voltage of the devices."

Reverse bias leakage was generally less than 1nA. ■

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SiC power device market to grow at 40% CAGR from 2020 to more than $1bn in 2022, after tipping point in 2019

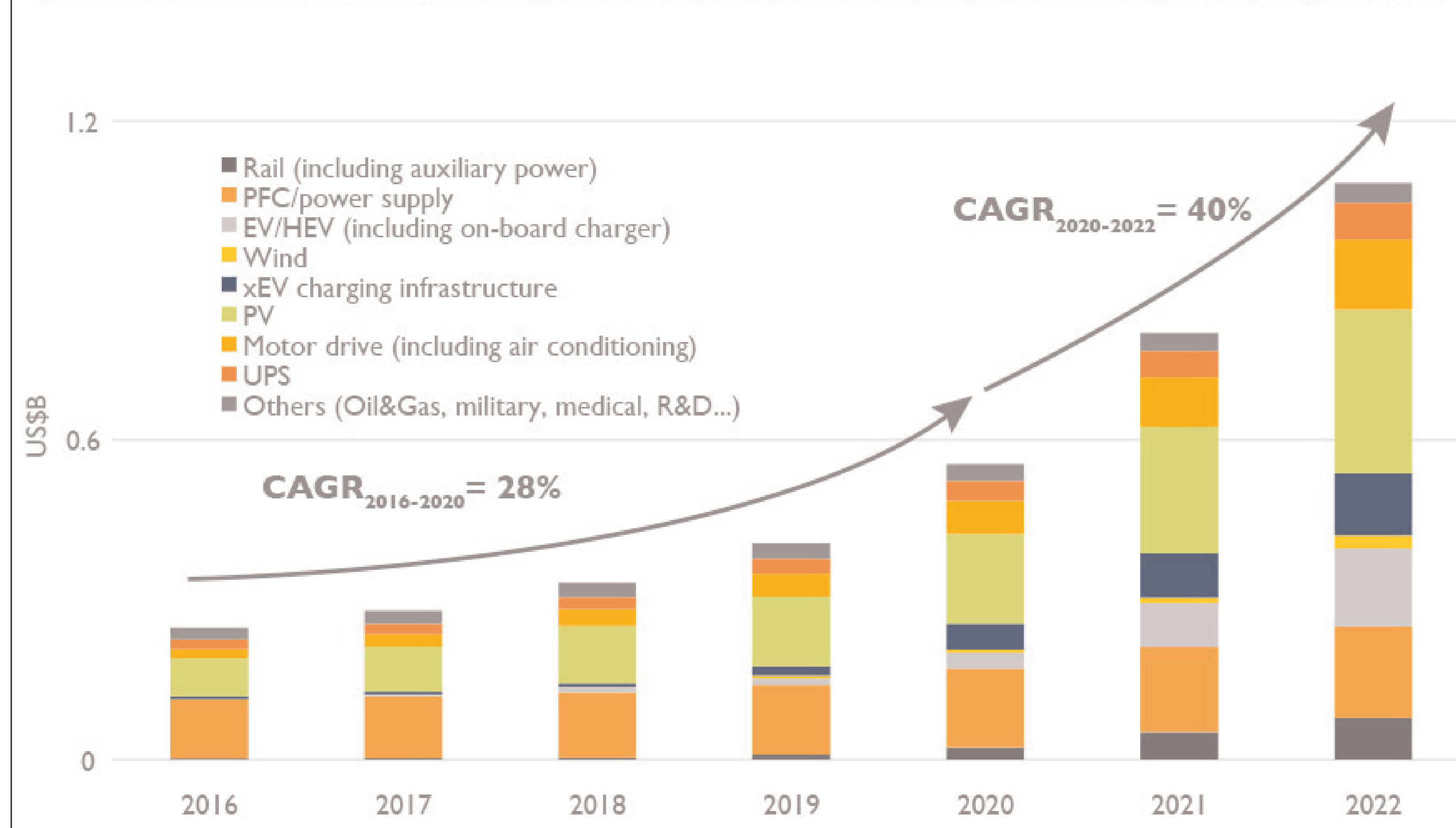
PFC, PV and xEV driving adoption; supply chain evolving, with SiC modules coming

The SiC power business is concrete and real, with a promising outlook," said Yole Développement in 2016. The trend has not changed in 2017, and the SiC industry is going even further as industrial players have increasing confidence about the SiC power market, adds the market analyst firm in the third edition of its SiC technology & market analysis: 'Power SiC 2017: Materials, Devices, Modules, And Applications'. End users were once simply curious about SiC, but they are now coming to try it, building prototypes for concrete projects that could drive volumes in coming years.

"SiC technology's added value is today widely understood and accepted by the power electronics community," comments technology & market analyst Dr Hong Lin. "We are gradually going from the customer awareness and education stage to the customer trial and adoption stage. And this is especially true for SiC transistors."

Besides the general positive feedback, multiple other signals reveal that the market adoption of SiC power devices is going to accelerate.

The power factor correction (PFC)/power supply segment is still the leading SiC application. However,



its market share is expected to decrease gradually because of the penetration of new applications of SiC.

Photovoltaic (PV) applications seem are broadly adopting SiC products. Indeed, SiC solutions offer a better performance/cost ratio at the system level for string PV inverters. Yole has identified players that are already using SiC MOSFETs and diodes.

In the future, electric vehicle (xEV)-related applications, rail and others are also expected to contribute to the market evolution.

The leading Chinese xEV manufacturer BYD has confirmed that it is using SiC in its on-board chargers. SiC is now on the road, not only on trial. While the on-board charger is embracing SiC technology, the pre-2020 market volume for SiC devices in automotive applications will mainly be limited to on-board chargers.

On the other hand, for the main inverters the situation remains the same as 2016: almost all the OEMs and tier-1 firms are testing SiC devices. Some pioneers like Toyota, Nissan and Honda will probably launch SiC-based solutions around 2020. After 2020, due to the high power rating of the main inverter, even a low adoption rate will contribute to significant revenue after 2020, forecasts Yole.

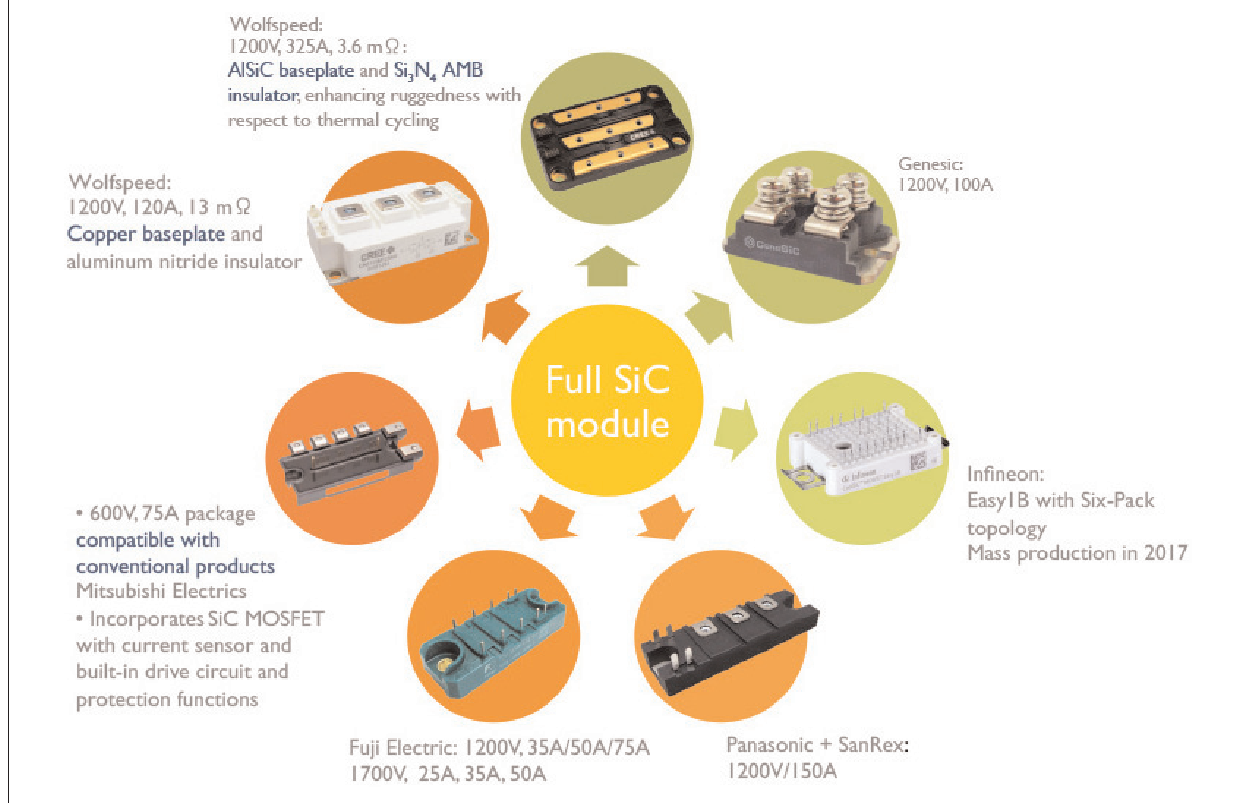
Together with the development of the xEV market, the charging infrastructure market is emerging. Globally, charging infrastructures are rapidly being deployed in the European Union (EU), USA and Japan, which will contribute to growth in SiC power device markets. Various players have confirmed adoption of their devices in xEV charging infrastructure. However, the development is especially impressive in China.

In this context, for a third time since 2014, Yole has increased its forecast for the SiC power device market, in particular for the post-2020 period after 2019 represents a tipping point in SiC adoption. While the market is growing at a 28% CAGR from 2016 to 2020, it will accelerate to 40% CAGR for 2020-2022, exceeding $1bn.

An established but evolving SiC power device supply chain

Looking back 16 years to the beginning of the commercialization of the first SiC power devices, only two companies offered them: Infineon and Cree (whose power and radio-frequency device business has since been spun out as Wolfspeed). The device market landscape did not really evolve for the next 10 years, as SiC struggled to prove itself to the industry.

The situation has taken a sharp turn since 2009–2010, with ever more device players supplying SiC diodes. As of July, the total number of diode suppliers is up to 23. The total number of SiC transistor suppliers is also increasing. In particular, it is worth highlighting that from 2016 to 2017 the number of SiC MOSFET



Full SiC module examples
(Source: Power SiC: Materials, Devices, Modules, and Applications report, Yole Développement, August 2017)

suppliers has doubled. That number will undoubtedly further increase in the coming years, believes Yole.

As the device market has developed, an industrial supply chain has been established, from wafer to epitaxy, chip manufacturing, and module packaging and finally reaching system end users with different business models, for example:

- Wolfspeed and Rohm Semiconductor are vertically integrated from substrate to module;
- Mitsubishi Electric and Fuji Electric are vertically integrated from chip to end system;
- many other players occupy part of the supply chain.

This industrial supply chain is constantly evolving, with newcomers and quitters. In 2016–2017 in particular, Yole notes the following:

- At the wafer level, Dow Corning has been restructured after being acquired by Dow. The merger of Dow and Dupont now puts a question mark over the future of Dow Corning's SiC wafer business (one of the main SiC suppliers). Also notable is the acquisition of Norstel by Chinese capital: the firm is now constructing a new factory in Fujian, China to expand its capacity.
- Despite the fact that Raytheon stopped its SiC foundry service in 2017, a foundry model is clearly in operation. This is helping fabless/fab-lite SiC companies to launch their products and make SiC technology more accessible to the industry. The model is currently driven by X-Fab, which is supported by Power America. Yole is expecting other foundries to enter the market too.

The total number of diode suppliers is up to 23. From 2016 to 2017 the number of SiC MOSFET suppliers has doubled

SiC modules are coming

As of 2017, the SiC power market is still dominated by discrete devices, including both discrete diodes and transistors. But that situation will change, reckons Yole. Hybrid modules are already penetrating some applications, such as PV, and full SiC modules are coming.

SiC transistors are especially advantageous for high-voltage, high-power-rating applications. Markets that are going to drive SiC include rail, motor drives, xEV and inverters, which all prefer modules. Yole therefore expects modules to gain market share. Indeed, SiC power semiconductor suppliers are taking action. Developments in the 2016–2017 period included the following:

- Number-one power semiconductor manufacturer Infineon has entered mass production of full SiC modules; and
- GE has teamed up with Danfoss for SiC module production.

Module players are not only launching products but also doing what they can to facilitate market adoption. For example, the launch of new modules is frequently associated with the release of driver electronics, assisting designers in surmounting the difficulties linked to the driver. Additional integrated 'plug-and-play' solutions (power stacks, power assemblies or power blocks) are appearing on the market. These help those end users who want to implement SiC modules in their products but do not have internal design resources or capabilities, notes Yole. ■

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SiC MOSFET with record power efficiency for 1200V-class power device

Extra region in source area controls series resistance, reducing short-circuit current and simplifying protection circuitry

At the International Conference on Silicon Carbide and Related Materials (ICSCRM 2017) in Washington DC (17–22 September), Tokyo-based Mitsubishi Electric Corp unveiled a silicon carbide (SiC) metal-oxide-semiconductor field-effect transistor (MOSFET) with what is believed to be record power efficiency for a 1200V-class power device.

Semiconductor power devices are key components of the power electronics equipment used in a wide range of applications such as home electronics, industrial machinery and railway trains. Mitsubishi Electric achieves high energy efficiency ratings by utilizing SiC MOSFETs, meeting the requirements for higher energy efficiency and reduced size that are essential in those fields.

Short circuits in power electronics equipment can cause large overcurrent flows into semiconductor power devices, which may lead to damage or failure. Excess current must therefore be interrupted as quickly as possible. Because the resistance of a SiC MOSFET is lower than that of a silicon device, any overcurrent tends to be large, resulting in a reduction in the short-circuit time (the length of time a device can

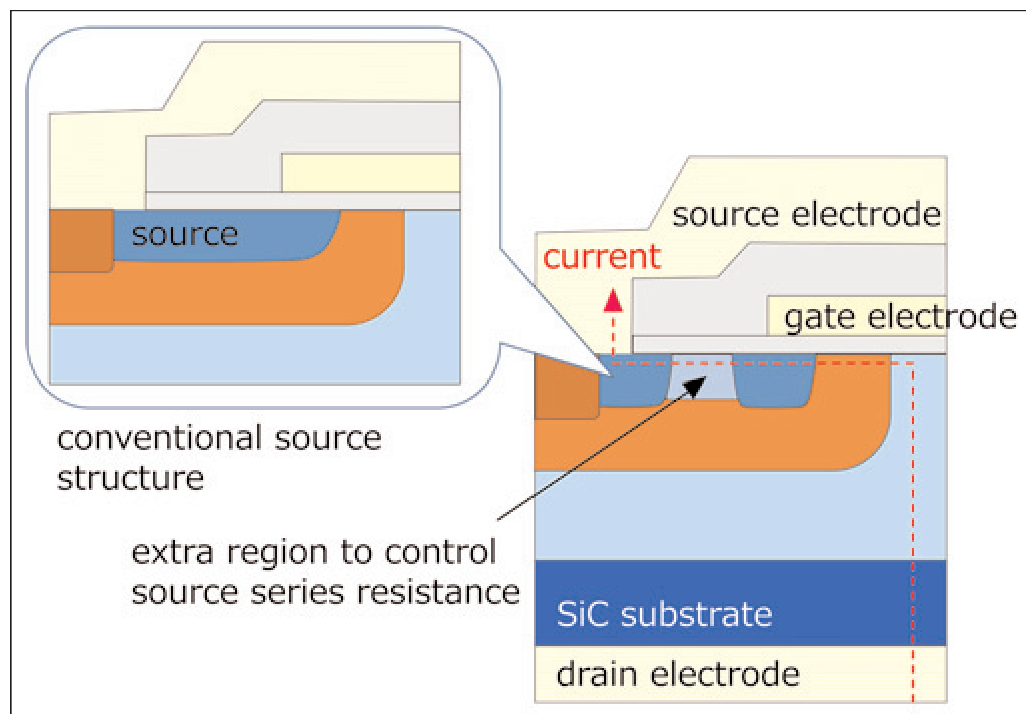

Figure 1. Cross-sectional schematic of the new SiC MOSFET structure.

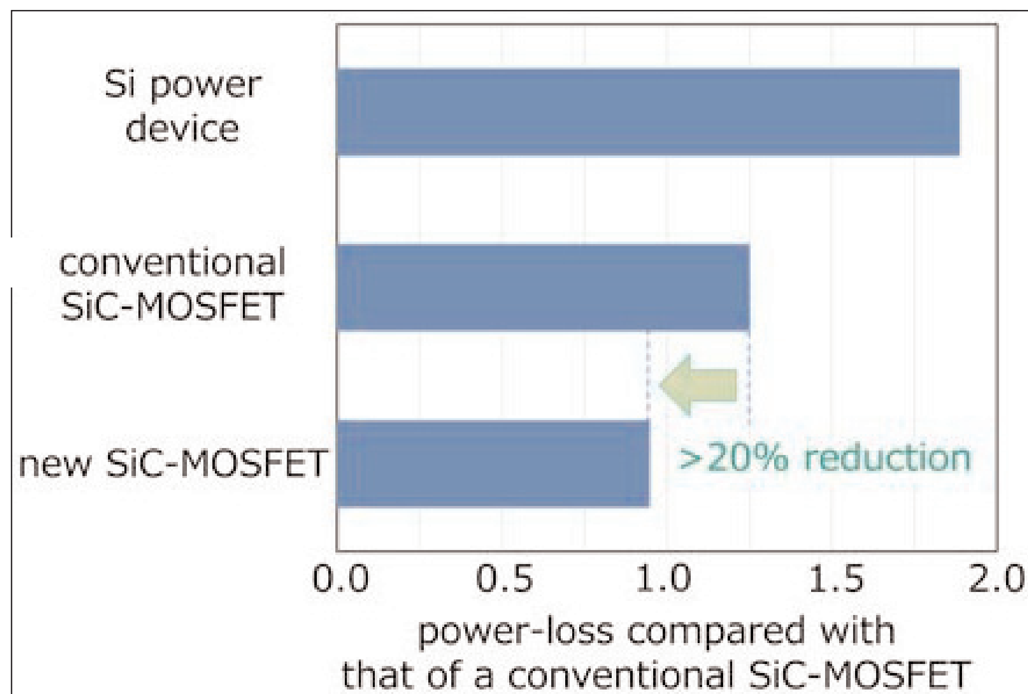

Figure 2. Reduction in power loss through adoption of the new structure.

withstand any overcurrent). To protect SiC MOSFETs from damage, overcurrent must be terminated more quickly than with a silicon device, usually by including special protection circuits.

There is also a trade-off between the short-circuit time and on-resistance. A long short-circuit time requires high on-resistance and a large chip size. Improvements in this trade-off have been in demand for a long time.

In conventional MOSFETs, the source area is formed as a single region. However, Mitsubishi Electric has introduced an additional region in the source area to control the source series resistance of the SiC MOSFET (see Figure 1). Adopting this structure reduces the incidence of excessive current flows caused by short circuits.

With a short-circuit time exceeding 8μs, Mitsubishi Electric's new device does not require a high-speed protection circuit to interrupt supply when excess current is detected. The structure of the new SiC power device reduces the short-circuit current as a result of the increased resistance resulting from the temperature rise induced by the short circuit, while at the same time keeping the on-resistance low at normal operating temperatures. As a result, on the basis of the general short-circuit time used for silicon power semiconductor devices, the on-resistance of the SiC MOSFET (at room temperature) is reduced by 60% compared with regular silicon power semiconductor devices and by 40% compared with conventional SiC MOSFET devices, while power loss is reduced by more than 20% (see Figure 2).

This technology can hence improve the trade-off between short-circuit time and on-resistance. As a result, a SiC MOSFET with the new structure can simultaneously offer high reliability, high energy efficiency and reduced size.

Due to the long short-circuit time precluding the need for special protection circuitry, the simplified circuit design allows the technology to be applied across SiC MOSFETs with various ratings for blocking voltage. Also, established circuit technology (used to protect silicon power semiconductor devices from short-circuit damage) can hence be applied to SiC MOSFETs without any need for modification. Mitsubishi Electric says that this guarantees easy implementation of protective functionality in power electronics equipment using SiC MOSFETs.

The firm says that its development teams will further refine the new device, aiming to make it available commercially from 2020. ■

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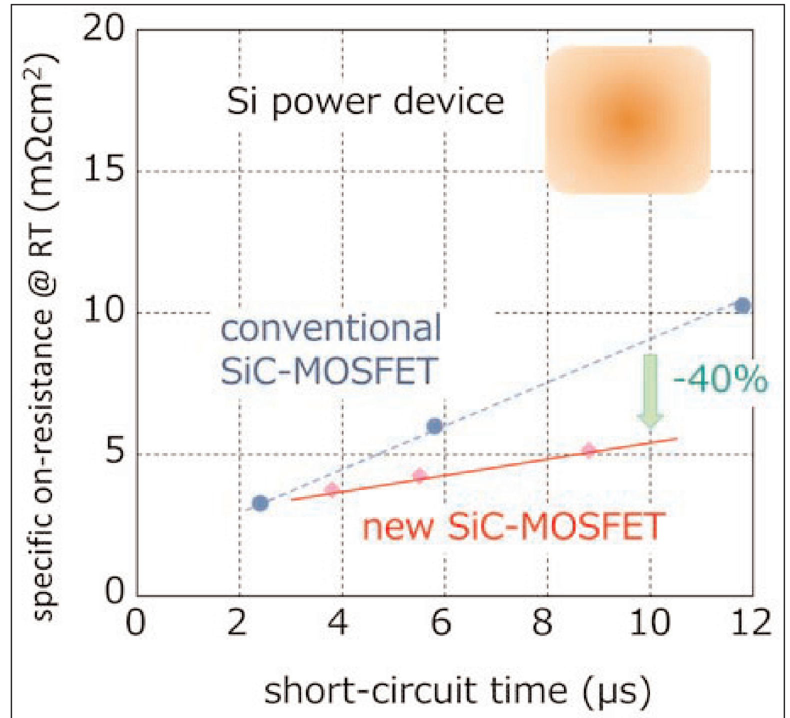

Figure 3. On-resistance at room temperature versus short-circuit time.

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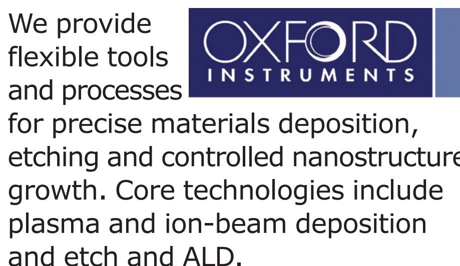

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Kulicke & Soffa Industries
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PA 19034,
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Tel: +1 215 784 6000
Fax: +1 215 784 6001
www.kns.com

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

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

17 Assembly/packaging foundry

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

18 Chip foundry

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

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

19 Facility equipment

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

20 Facility consumables

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

21 Computer hardware & software

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

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

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

22 Used equipment

Class One Equipment Inc
5302 Snapfinger Woods Drive,
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Fax: +1 770 808 8308
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23 Services

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Brownlow House, 50–51
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M+W Zander Holding AG
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Germany
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Fax: +49 711 8804 1950
www.mw-zander.com

24 Consulting

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

25 Resources

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7140 San Jose, CA 95126, USA
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www.alshuktz.com

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San Jose, CA 95134, USA
Tel: +1 408 943 6900
Fax: +1 408 428 9600
www.semi.org

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1–5 October 2017
2017 IEEE Photonics Conference (IPC), 30th Annual Conference of the IEEE Photonics Society
Orlando, FL, USA
E-mail: i.donnelly@ieee.org
www.ipc-ieee.org

1–5 October 2017
ECCE 2017: 9th Annual IEEE Energy Conversion Congress & Exposition
Duke Energy Convention Center, Cincinatti, OH, USA
E-mail: ecce@courtesyassoc.com
www.ieee-ecce.org/2017

9–10 October 2017
12th European Microwave Integrated Circuits Conference (EuMIC 2017), part of European Microwave Week (EuMW 2017)
Nuremberg, Germany
E-mail: friedel.gerfers@tu-berlin.de
www.eumweek.com/conferences/eumic.html

15–18 October 2017
NAMBE 2017: 33rd North American Conference on Molecular Beam Epitaxy
Hilton San Luis Resort Spa & Conference Center on Galveston Island, Galveston, TX, USA
E-mail: info@nambe2017.org
www.nambe2017.org

22–25 October 2017
IEEE Compound Semiconductor Integrated Circuit Symposium (CSICS 2017)
Miami, FL USA
E-mail: l.lelong@ieee.org
https://csics.org

24–26 October 2017
BIT's 7th Annual World Congress of Nano Science & Technology (Nano S & T-2017)
Hilton Fukuoka Sea Hawk Hotel, Japan
E-mail: linhui@bitlifesciences.com
www.bitcongress.com/Nano2017

26–28 October 2017
International Conference on Advanced Materials and Nanotechnology
Osaka, Japan
E-mail: l.lelong@ieee.org
http://advancedmaterials.conferenceseries.com/events-list/photonics-and-semiconductor-nanophysics

30 October – 1 November 2017
5th IEEE Workshop on Wide Bandgap Power Devices and Applications (WiPDA 2017)
Hyatt Regency Tamaya Resort, Albuquerque, NM, USA
E-mail: rjkapla@sandia.gov
www.wipda.org

7–9 November 2017
Wide Bandgap Devices and Applications Short Course
PowerAmerica Offices, Raleigh, NC, USA

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E-mail: poweramerica@ncsu.edu
www.poweramericainstitute.org/shortcourse

14–17 November 2017
SEMICON Europa 2017
Messe München, Germany
E-mail: SEMICONEuropa@semi.org
www.semiconeuropa.org

4–6 December 2017
63rd IEEE International Electron Devices Meeting (IEDM 2017)
San Francisco, CA USA
E-mail: info@ieee-iedm.org
www.ieee-iedm.org

5–7 December 2017
9th PV Performance Modeling and Monitoring Collaborative Workshop 2017 (PVPMC-9)
Solar Research Institute of HIT, Weihai, China
E-mail: pvpmc@hitwh.edu.cn
http://pvpmc.hitwh.edu.cn

6–9 December 2017
48th IEEE Semiconductor Interface Specialists Conference (SISC 2017)
San Francisco, CA USA
E-mail: pmcintyre@ieeesisc.org
www.ieeesisc.org

13–15 December 2017
SEMICON Japan 2017
Tokyo Big Sight, Tokyo, Japan
E-mail: jcustomer@semi.org
www.semiconjapan.org

27 January – 1 February 2018
SPIE Photonics West 2018
Moscone Center San Francisco, California, USA
E-mail: customerservice@spie.org
http://spie.org/SPIE-PHOTONICS-WEST-conference

4–8 February 2018
IEEE International Solid-State Circuits Conference (ISSCC 2018)
San Francisco, CA, USA
E-mail: melissa@widerkehr.com
www.isscc.org

4–8 March 2018
IEEE Applied Power Electronics Conference and Exposition (APEC 2018)
San Antonio, TX, USA
E-mail: apec@apec-conf.org
www.apec-conf.org

14–16 March 2018
LASER World of PHOTONICS CHINA 2018
Shanghai New International Expo Centre, China
E-mail: info@world-of-photonics-china.com
www.world-of-photonics-china.com

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

13–17 May 2018
30th IEEE International Symposium on Power Semiconductor Devices and ICs (ISPSD 2018)
Palmer House Hilton Hotel, Chicago, IL USA
E-mail: info@ispsd.org
www.ispsd2018.org

5–7 June 2018
PCIM Europe (Power conversion and Intelligent Motion) 2018
Nuremberg Messe, Germany
E-mail: daniela.kaeser@mesago.com
www.mesago.de/en/PCIM/main.htm

18–22 June 2018
2018 IEEE Symposium on VLSI Technology and Circuits
Hilton Hawaiian Village, Honolulu, HI, USA
E-mail: vlsi@vlsisymposium.org
www.vlsisymposium.org

24–29 June 2018
IEEE 45th Photovoltaic Specialists Conference (PVSC 2018)
Washington, DC, USA
E-mail: info@ieee-pvsc.org
www.ieee-pvsc.org

9–11 July 2018
IEEE Photonics Society's 2018 Summer Topicals Meeting Series
Waikoloa, Hawaii, USA
E-mail: i.donnelly@ieee.org
www.sum-ieee.org

23–28 September 2018
13th European Microwave Integrated Circuits Conference (EuMIC 2018), part of European Microwave Week (EuMW 2018)
IFEMA, Madrid, Spain
www.eumweek.com/conferences/eumic.html

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