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COMPOUNDS & ADVANCED SILICON

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III-Vs on silicon for optical communications

GaAsP on silicon photovoltaics

Rubicon closing Malaysia plant • 4WDM MSA Group formed • Stacked perovskite/CIGS solar module hits record 17.8%

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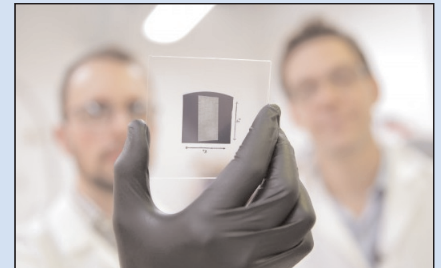
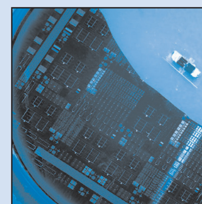
p25 Gallium nitride film deposited on a silicon substrate at 27°C using electron-enhanced ALD, developed at University of Colorado Boulder.



p90 University of Wisconsin–Madison researchers have created the first carbon nanotube transistors that outperform state-of-the-art silicon transistors.

p80 Intel's new Silicon Photonics 100G PSM4 QSFP28 optical transceiver, integrating III-V light-emitting material on silicon.



Cover: A team at MIT and the Masdar Institute of Science and Technology in Abu Dhabi has developed a solar 'step cell' combining two different layers of absorbing material (GaAsP on silicon) in a stepped configuration (to harvest more solar energy), made using a novel, low-cost manufacturing process. **p64**

Developments in III-V laser integration on silicon photonics

As previewed last issue, in this issue we cover the launch in August at the 2016 Intel Developer Forum in San Francisco of Intel's first Silicon Photonics 100G optical transceiver products (see pages 80–85)

Intel has been developing silicon photonics for 16 years, and it now sees opportunities for optoelectronic integration driven by cloud computing and enterprise data centers, along with Ethernet switch, router, and client-side telecom interfaces. Intel's 'hybrid silicon laser' technology involves indium phosphide (InP)-based active light-emitting III-V epitaxial layers bonded to a silicon photonics substrate containing low-loss waveguides etc.

We report this amongst a more general article on the integration of III-V light-emitting material with silicon photonics. This includes work by Intel's partner University of California Santa Barbara (UCSB) such as integrating quantum cascade lasers on silicon. Meanwhile, IBM has been developing the coupling of InP-based lasers into silicon photonic circuits using self-aligned flip-chip assembly. Also, at March's Optical Fiber Communications conference (OFC 2016), Kaiam Corp reported what it claimed was the first 100Gb/s CWDM4 silicon photonics transceiver, incorporating InP lasers with micro-electro-mechanical coupling into glass-based planar lightwave circuits (PLCs), which connect to a silicon photonics IC via grating couplers.

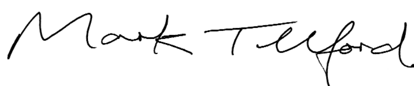
Further to Intel's work on hybrid integration (by wafer bonding), we also report direct integration of III-V materials on silicon by Imec and Ghent University in Belgium, specifically using aspect ratio trapping (ART) techniques to reduce defect density in InGaAs multiple quantum wells (MQWs) grown on 300mm-diameter silicon in a ridge format that could be used in future laser diodes. Ghent/Imec have also worked with X-Celeprint to claim "the first III-V optoelectronic components transfer printed on and coupled to a silicon photonic integrated circuit" as a stepping stone towards the cost-effective integration of III-V optoelectronic components (separated from the InP substrate) onto silicon photonic integrated circuits, including lasers, semiconductor optical amplifiers and electro-absorption modulators.

On pages 78–79 we report how researchers in Russia have developed an InGaAs quantum well laser on (001) germanium-on-silicon 'virtual substrate' without an offcut angle. Continuous-wave (cw) lasing at a wavelength of 941nm was possible at 77K, and room-temperature lasing at 992nm was restricted to pulsed mode. However, the researchers aim to extend the wavelength into the >1100nm transparency range needed for use with silicon waveguides.

Meanwhile, a team in China has achieved cw lasing at room temperature from indium gallium nitride InGaN) grown directly on silicon (pages 76–77). "With further improvements in the material quality, device performance and life-time, GaN-on-Si technology holds great promise for commercializing III-nitride laser diodes on large-diameter and cost-effective substrates," says the team. They add that, by growing GaN upon Si(111)-on-insulator-Si(100), InGaN-based lasers could be a useful alternative on-chip light source for monolithic-integrated silicon photonics.

Finally, see pages 49–59 for news on September's European Conference on Optical Communications (ECOC 2016) in Düsseldorf, Germany.

Mark Telford, Editor
mark@semiconductor-today.com



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

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

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

Original design Paul Johnson
www.higgs-boson.com

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

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

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Power amplifier market growing at 14% CAGR to 2020

Growth driven by increasing wafer size, adoption of CMOS by start-ups and need for high-speed amplifiers in defense sector

The global power amplifier market will increase at a compound annual growth rate (CAGR) of nearly 14% from 2016-2020, according to a report from Technavio that provides an analysis of the most important trends expected to impact the market.

The development of multi-band and multi-mode mobile computing devices that incorporate wireless communication systems (such as Bluetooth, wireless local-area networks, near-field communication, LTE and GPS) has led to greater demand for power amplifiers, primarily because amplifiers are compatible with higher-frequency bands, and are considered to be ideal for advanced RF requirements in new mobile devices.

According to Technavio's hardware and semiconductor research analysts, the top three emerging trends driving the power amplifier market are: increasing wafer size; the adoption of CMOS technology by start-ups; and the growing need for high-speed amplifiers in the defense sector.

Increasing wafer size

Over the last 40 years, the semiconductor industry has seen an increase in wafer diameter, with gallium arsenide (GaAs) wafers growing from 50mm to 150mm, since this reduces the cost of manufacturing by at least 20–25%. The industry is now predominantly at 150mm for IC and power amplifier manufacturing. The use of 150mm wafers is expected to continue till late into the forecast period due to the heavy investments made by manufacturers such as Taiwan's WIN Semiconductors toward the upgrade and new construction of fabs for this wafer size.

The industry is moving toward the development 200mm (8 inch) wafer technology, and pilot production is expected toward the end of 2018. Researchers at Stanford University are working on making the production process for 200mm GaAs wafers less expensive, so that they can compete directly with silicon wafers currently on the market at a much lower price. This will create demand for wafer fabrication equipment (including mask inspection equipment), notes Technavio.

Adoption of CMOS technology by start-ups

Power amplifiers are required for communications in smartphones and many Internet of Things (IoT) connected products, and start-ups like ACCO Semiconductor are increasingly adopting complementary metal-oxide-semiconductor (CMOS) technology. The firm has raised $35m to invest in the technology to improve its CMOS-based RF power amplifier business. It is relying on the growing opportunity for RF power amplifiers for cell phones and IoT products by focusing on power amplifiers manufactured using CMOS process technology.

The vast majority of power amplifiers are fabricated using silicon germanium (SiGe) or GaAs technology rather than CMOS. However, CMOS-based power amplifiers will help to achieve efficient performance at low cost, reckons Technavio, so the adoption of CMOS technology will increase during the forecast period.

Growing need for high-speed amplifiers in defense sector

The military sector needs more efficient use of spectrum and more mobile devices to be connected, hence it has a requirement for high-speed power amplifiers, notes Technavio. The US Defense Advanced Research Projects Agency (DARPA) has made some progress in this regard with the Terahertz (THz) Electronics Program. Aerospace and defense technology company Northrop Grumman has developed solid-state power amplifiers and the traveling-wave tube amplifiers, which are the only two types of devices operating at terahertz frequencies.

"THz frequency-based power amplifiers can be used in a lot of applications such as high-resolution security imaging, high-data-rate communications, collision-avoidance radar, and remote detection systems for dangerous chemicals and explosives, where high-speed amplifiers are a necessity for the faster function of these devices," notes Sunil Kumar Singh, a lead analyst at Technavio specializing in research on embedded systems sector.

www.technavio.com/report/global-embedded-systems-global-

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Technavio details top four drivers of RF IC market

The global radio frequency (RF) IC market will increase at a compound annual growth rate (CAGR) of nearly 12% from 2016 to 2020, forecasts a report by Technavio.

Asia-Pacific (APAC) is expected to be the main demand-generating region and is expected to be the major contributor to the market due to the growing demand for RF ICs in the consumer electronics segment and the increasing need for logic and multipoint control units (MCUs) in the automotive segment in the region. The presence of major buyers such as Samsung Electronics, LG Electronics and Toyota Motor has led to the increasing RF IC consumption.

Increased demand for electronics from countries such as China and India is driving the market in APAC. China's massive demand for electronics exceeds the production levels in the country. Despite the phenomenal growth, only a small share of semiconductor demand in China is actually produced domestically.

Technavio's hardware and semiconductor analysts highlight the following four factors that are contributing to growth of the global RF IC market: deployment of next-generation LTE wireless networks; the advent of carrier aggregation; the use of new materials for manufacturing RF devices; and the growing traction of RF technology for remotes.

Deployment of next-generation LTE wireless networks

The increase in data consumption has resulted in the adoption of next-generation LTE networks such as 3G and 4G. The growing consumption has resulted in the growth of commercial networks, making LTE the fastest-developing mobile technology. Although specific bands have been designated for LTE, they vary from carrier to carrier.

"LTE-based computing devices allow consumers to upload and download music and photographs, play games online with minimum signal interference, and watch online TV shows uninterrupted," says Sunil Kumar Singh, one of the lead embedded systems research analysts at Technavio. "This has created an opportunity for manufacturers of transceiver chips to offer solutions that address the consumer needs for faster and smoother access to mobile data."

Advent of carrier aggregation

Carrier aggregation combines a wide range of the available spectrum at the same time to increase download and upload speeds, and results in an increase in RF content in smartphones and tablets. Although carrier aggregation is not a widespread concept currently, it has already been implemented in South Korea.

"RF signals are transmitted and received using transceiver chips, which are integrated into RF modules as a component," says Sunil. "The advent of carrier aggregation will compel transceiver chip manufacturers to improve and upgrade their offerings according to the requirements of the OEMs."

Use of new materials for manufacturing RF devices

The manufacture of RF devices such as power amplifiers (PAs) incurs huge costs for vendors because of the high cost of raw materials. This has resulted in vendors searching for new materials that can reduce the expenditure. The development of materials such as gallium arsenide (GaAs) and indium phosphide (InP) will ramp up the production of RF power amplifiers. GaAs RF power amplifiers use high saturated electron velocity and electron mobility to function, especially at high frequencies.

Carrier aggregation will compel transceiver chip manufacturers to improve and upgrade their offerings

These materials offer integration with other electronic components such as switches being fabricated in silicon on sapphire or other silicon-on-insulator (SOI) processes. Meanwhile, surface acoustic wave (SAW) filters and duplexers are being fabricated with piezo-effective materials such as lithium tantalate and lithium niobate. Therefore, companies such as Murata and TriQuint are aiming to use cost-effective and superior-performing materials to manufacture RF power amplifiers.

Growing traction of RF technology for remotes

RF remotes accounted for 13% of the global remote market in 2015 and are expected to see increased adoption, accounting for more than 20% by 2020. One of the main contributing factors is the decrease in development costs for RF technology-based products. Moreover, RF remotes are expected to gain market traction because of advantages compared with infrared (IR) remotes. RF remotes have lower power consumption, longer range, and do not need line-of-sight to control the device.

The RF remotes segment will see high demand, considering the demand for advanced TVs such as 3D smart TVs and 4k UHD smart TVs. Consumers demand visually aesthetic TVs that deliver a unique experience in terms of picture quality, viewing angle, and internet connectivity. With such advanced features, remote manufacturers are also manufacturing advanced and sophisticated RF remotes. RF has benefits such as out-of-line and sight communication and control, two-way communication, the incorporation of gesture recognition and voice controls, and enhanced bandwidth compared to IR.

Technavio lists the key vendors in the market as Infineon Technologies, Qualcomm, Avago Technologies, Qorvo, Skyworks Solutions, NXP Semiconductors, STMicroelectronics and Renesas Electronics.

www.technavio.com/report/global-embedded-systems-global-rf-ic-market-2016-2020

GaN devices to grow at 17% CAGR to $3438.4m in 2024

The global gallium nitride (GaN) device market is largely consolidated, with the top four companies collectively commanding more than 65% market share in 2015, states Transparency Market Research (TMR) in the report 'GaN Semiconductor Devices Market — Global Industry Analysis, Size, Share, Growth, Trends and Forecast, 2016–2024'. The dominant firm Efficient Power Conversion Corp (EPC) accounted for 19.2% of the market, followed by NXP Semiconductors N.V., GaN Systems Inc, and Cree Inc.

Regarding on-going R&D activities, efforts to eliminate issues related to the reliability of GaN semiconductors are expected to be a focus of key vendors in the near future. TMR forecasts the GaN device market will rise at a compound annual growth rate (CAGR) of 17% over 2016–2024, increasing from $870.9m in 2015 to $3438.4m in 2024. Of the key end-use industries utilizing GaN, the aerospace & defense sector dominates, accounting for over 42% of the market in 2015.

Broadening applications and focus on R&D to boost demand in North America and Europe

North America and Europe are expected to remain the dominant regional markets for GaN devices over the next few years. The rising focus of the Europe Space Agency (ESA) on the increased usage of GaN across space projects and the use of GaN-based transistors in the military and defense sectors in North America will help the GaN device market to gain traction.

In the past few years, GaN technology has seen rapid advances and vast improvement in its ability to work under operating environments featuring high frequency, power density and temperature with improved linearity and efficiency. These advances have boosted the usage of GaN devices across an increased set of applications and have played an important role in the market's overall growth, notes the report.

In addition, the increased usage of GaN devices in the defense sector has emerged as a key market driver. The continuous rise in defense budgets of developing and developed countries as well as the demand for inclusion of the most advanced products in the arsenal of national and international military will propel the market in the near future.

High cost to hinder growth

Compared with silicon-based devices, GaN-based devices are relatively expensive due to the high production costs, including the high cost of fabrication, packaging and support electronics. Silicon-based semiconductors have seen a significant decline in their costs over the past few years, making the high cost of GaN a challenge that could hinder its large-scale adoption.

The issue can be tackled by producing GaN in bulk. However, there is currently no widespread method that can be used for this purpose due to the necessity for high operating pressure and temperature as well as the limited scalability of the material, concludes the report.

www.transparencymarketresearch.com

GaAs wafer market growing at 12.69% CAGR to 2020

The gallium arsenide wafer market is rising at a compound annual growth rate (CAGR) of 12.69% over 2016–2020, forecasts Technavio.

In the report 'GaAs Wafer Market Trends, Size, Analysis and Forecast To 2020', Technavio lists the following companies as the key players in the global GaAs wafer market: AWSC, GCS and WIN Semiconductors. Other prominent vendors are AXT, Century Epitech, Freiberger Compound Materials, Intelligent Epitaxy Technology, IQE, OMMIC, Xiamen Powerway Advanced Material, Qorvo, Sumitomo Electric Semiconductor Materials, UMS¸ and Visual Photonics Epitaxy Co (VPEC).

"Shutdown of 2G network will be a key trend for market growth," says Technavio. "High-speed 3G or 4G Internet services are easily available worldwide. The data speed of a 4G connection is, on average, ten times more than the speed of a 3G connection. High-speed Internet connectivity leads to faster streaming of videos, quicker web browsing and better performance of GPS. Hence, many countries are opting for 3G and 4G connectivity, which will result in the shutdown of the 2G mobile network by the end of 2016, with its bandwidth being allocated to 3G and 4G mobile networks."

One of the key growth drivers will be demand for increased network bandwidth. The growth in Internet bandwidth is fueled by two factors: the proliferation of mobile computing devices with advanced capabilities (such as smartphones, tablets and wearables) and the emergence of disruptive technologies that shift the bandwidth usage by altering the way users access the network. With the emergence of new mobile telecom standards such as 4G and 5G, consumers are now opting for higher-bandwidth applications and services, notes Technavio.

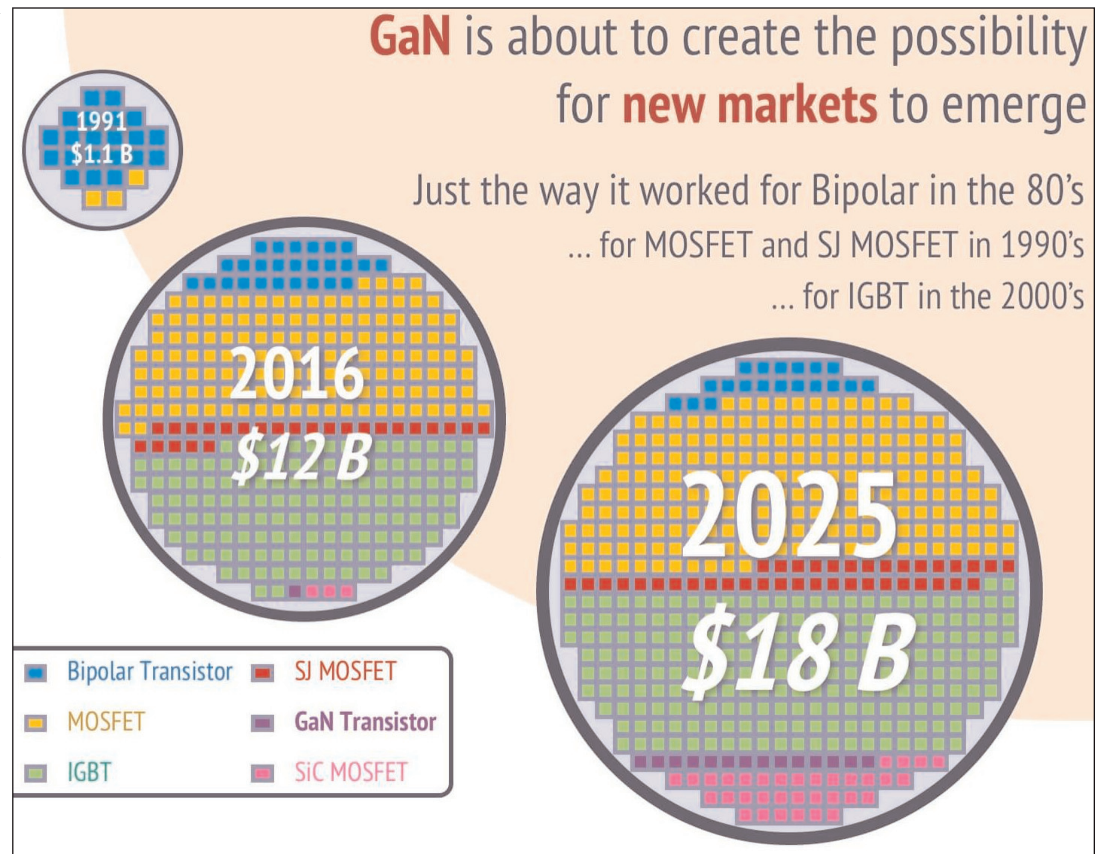
Further, the report states that slowing growth in smartphone shipments (a CAGR of about 10% to 2020, rather than a previous forecast of more than 11%) will be a challenge for the market. Slow growth can be attributed to China, which has joined North America and Western Europe in a more developed growth pattern. However, gradually falling average selling prices (ASPs) will propel steady growth through the end of the forecast period, with global shipments reaching more than 2 billion units in 2020. China remained the focal point of the global smartphone market in 2015, although shipments declined compared with previous years.

https://marketreportscenter.com/

Consumer electronics chargers to comprise 30% of GaN market in 2022

Industrial and energy applications to adopt GaN later, due to greater lifetime and warranty demands

The launch in late August by Dialog Semiconductor plc — a fabless provider of highly integrated power management, AC/DC power conversion, solid-state lighting (SSL) and Bluetooth low-energy technology — of a gallium nitride (GaN) power IC targeting consumer charger applications adds to the list of recently released GaN devices, which are all power ICs targeting that consumer market segment, forming a trend noted in the report 'Applications & Markets for GaN in Power Electronics' by Point The Power. The first market for GaN in power electronics is consumer power supplies, led by laptop and electronic device chargers, it adds. Consumer electronics chargers could comprise 30% of the GaN market in 2022, it forecasts.



"Consumer systems do not require the same lifetime and warranty as industrial systems," comments Alex Avron, principal market analyst at Point The Power. "Industry or energy segments like PV [photovoltaic] inverters need a minimum expected lifetime of 10 sometimes 15 years, while the lifetime of a laptop charger is 5 years at most," he adds. "It's a perfect playground for innovation and new product releases," Avron continues. "Many start-ups have taken advantage of this, such as California-based companies FinSix and Avogy or Canada-based Appulse Power."

Point The Power notes that the laptop and smartphone charger markets are perfect for testing and trialing wide-bandgap devices and new topologies, due specifically to the comparatively short lifetime required; the fact that size reduction is a main driver; and lower price sensitivity.

Consumer systems do not require the same lifetime and warranty as industrial systems. The laptop and smartphone charger markets are perfect for testing and trialing wide-bandgap devices and new topologies, due specifically to the comparatively short lifetime required; the fact that size reduction is a main driver; and lower price sensitivity.

According to Point The Power, gallium nitride will remain in direct competition with super-junction MOSFETs, which are already the most used devices for consumer power supplies of all kinds — with a total market of more than $800m this year.

The market research firm reckons that GaN will enable new applications to emerge for power converters, just as IGBTs and MOSFETs have done in the past; i.e. not replacing bipolar junction transistors (BJTs) but, in fact, facilitating new applications. "Each time a new device has arrived on the market, it did not eat its competing devices' market share, but rather enlarged the overall market size through new applications," says Avron.

According to the report, GaN for consumer power supplies is just the beginning of a bigger trend to offering new, smaller and more efficient charging and powering systems.

www.pointthepower.com

Skyworks appoints new chief financial officer as Donald Palette retires

Skyworks Solutions Inc of Woburn, MA, USA (which manufactures analog and mixed-signal semiconductors) says that Kris Sennesael has joined it as senior VP & chief financial officer.

Sennesael was most recently chief financial officer for semiconductor-based energy solutions provider Enphase Energy. Prior to that, he was chief financial officer at Standard Microsystems, a designer of mixed-signal connectivity solutions. Previously, he held increasingly responsible financial positions at ON Semiconductor, AMI Semiconductor and Alcatel Microelectronics. Sennesael holds bachelor's and master's degrees in economics from the University of Ghent, Belgium, as well as an MBA from the Vlerick Management School.

Skyworks is embarking on its next key growth phase driven by ubiquitous mobile connectivity and the Internet of Things, says president & CEO Liam K. Griffin. "His unique combination of financial expertise, operational acumen and industry knowledge will be valuable assets as we build upon our market leadership and take Skyworks to the next level of financial outperformance," he adds.

"Skyworks is embarking on its next key growth phase driven by ubiquitous mobile connectivity and the Internet of Things," says president & CEO Liam K. Griffin

Donald Palette, who has been chief financial officer since 2007, will serve in an advisory role for a transitional period. "We appreciate Don's leadership and counsel over the last nine years, particularly as we reshaped our business, outpaced our competition, substantially improved our degree of profitability and strengthened our balance sheet," comments Griffin. "Skyworks has benefited from the strong financial foundation set by Don."

www.skyworksinc.com

Skyworks powering LG's Online Connectivity Units in VWs

Skyworks says that several of its semiconductor solutions (including its SkyHi multimode modules and switches) are powering LG Electronics Inc' latest Online Connectivity Units (OCU) being leveraged across Volkswagen automobiles to enhance connectivity and convenience. According to PwC's Strategy& 2015 study, Volkswagen ranked first for connected car innovation for both safety and infotainment.

The OCUs offer drivers seamless access to features such as smart home and location-based services from their vehicles. With more than a quarter of global vehicles expected to be connected to the internet by 2020, Skyworks is capitalizing on the need for next-generation wireless devices addressing this growing market opportunity. Specifically, LG is leveraging eight Skyworks products, including analog control ICs and integrated front-end modules.

"Our automotive design wins with LG demonstrate how Skyworks is leveraging its mobile connectivity expertise, partnerships and scale to expand our reach across the Internet of Things," says Skyworks' VP of product marketing John O'Neill.

"As connected car technology continues to push the performance envelope and application boundaries, we rely on innovators like Skyworks to enable vital wireless connectivity for our next-generation platforms," comments JS Kim, head of LG telematics research & development. "With Skyworks' advanced mobile communications solutions, we are revolutionizing the way drivers interact with their vehicles."

www.skyworksinc.com/Market/17/Automotive
www.LGnewsroom.com

Skyworks launches front-end module for smart energy and Internet of Things applications

Skyworks has introduced a highly integrated 470–510MHz front-end module (FEM) that is suitable for smart energy, smart metering (electric, gas, water, heat), security, RFID, industrial and other Internet of Things (IoT) applications.

The SKY66115-11 FEM operates over a wide variety of supply voltages at low power consumption, and comes in a small 4mm x 4mm x 0.9mm, 16-pin multi-chip module (MCM). Its extended range more than doubles that of a standalone system-on-chip solution.

To enhance the range and RF performance for solutions addressing Internet of Things applications, Texas Instruments and Skyworks have partnered, combining the SKY66115-11 with TI's CC1310 wireless MCU to address customers' needs for long-range, low-power and cost-effective solutions.

www.skyworksinc.com/Product/3138/SKY66115-11
www.ti.com/product/cc1310

Qorvo smart home gateway platform earns first ZigBee 3.0 certification

Qorvo Inc of Greensboro, NC and Hillsboro, OR, USA (which provides core technologies and RF solutions for mobile, infrastructure and defense applications) says that its Low Power Wireless business unit (formerly GreenPeak Technologies until its acquisition in April) is first in the industry to receive the ZigBee 3.0 certification for its smart home gateway platform. A certified ZigBee 3.0-ready platform enables software developers to quickly integrate the standard into their smart home applications.

ZigBee 3.0 combines the best capabilities of the existing ZigBee smart home profiles in a single unified protocol. It also includes ZigBee Green Power, which supports battery-less, energy-harvesting devices. ZigBee 3.0 facilitates communication and interoperability among a wide variety of smart devices for home automation, light control, building automation, retail services, healthcare and telecom services.

"Certified platforms are important tools for ZigBee 3.0 developers," comments Lee Ratliff, principal analyst for connectivity and the Internet of Things (IoT) at market research firm IHS Markit. "Platforms such as this allow more companies to participate in the ZigBee ecosystem by reducing complexity and shortening time-to-market for developers. This is especially important for the newly revised ZigBee 3.0 standard which helps address the pent-up demand from developers eager to introduce compliant products," he adds.

"Our ZigBee 3.0 Software Development Kit (SDK) for smart home gateways allows software developers to use a mature and well documented model to deliver solutions quickly and cost effectively," says Cees Links, general manager of Qorvo's Low Power Wireless business unit. "Together, our SDK and Qorvo's multi-channel and multi-protocol GP712 communication chip enable gateways to handle a variety of different connectivity standards. Developers can now plug in different application protocols as needed," he adds. "Multiple leading gateway manufacturers have started the development of a ZigBee 3.0 gateway with Qorvo's GP712."

The new ZigBee 3.0 SDK for smart home gateways provides an optimized design template enabling a quick system integration. Developers can focus on building a system without needing to dig into the details of the ZigBee 3.0 standard. By incorporating the GP712 radio communication controller chip in the new ZigBee 3.0 SDK for smart home gateways, multi-channel radio support is guaranteed. It allows seamless communication with various sensors, controllers and systems. Its multi-stack protocol capability and the scalable software architecture enable application developers to smoothly integrate current and upcoming standards.

www.qorvo.com

Qorvo adds control products for DOCSIS 3.1 to CATV portfolio

Qorvo Inc of Greensboro, NC and Hillsboro, OR, USA (which provides core technologies and RF solutions for mobile, infrastructure and aerospace/defense applications) has rounded out its CATV product portfolio to include two new control products — a digital step attenuator (DSA) and RF absorptive single-pole double-throw (SPDT) switch — designed for DOCSIS 3.1 cable networking, giving cable operators greater network design flexibility to enhance upstream and downstream bandwidth while reducing power consumption.

"The addition of these high-performance control products to the industry's most comprehensive CATV product portfolio creates a one-stop-shop for DOCSIS 3.1 CATV networks," says Kellie Chong, director of CATV and Broadband Access products. "This enables Qorvo to simplify our customers' efforts related to design and production while reducing their time-to-market."

The new control components use silicon-on-insulator (SOI) process technologies with what is claimed to be proven performance and reliability for network control applications.

Addition of these high-performance control products to the industry's most comprehensive CATV product portfolio creates a one-stop-shop for DOCSIS 3.1 CATV networks

Operating from 45MHz to 2GHz, the QPC3624 is a 6-bit DSA with high linearity and low insertion loss that also allows glitch-free attenuation and faster switching speed. The QPC3024 RF absorptive switch operates from 5MHz to 3GHz and allows fast switching speed of 250ns typical performance. Both the QPC3624 and QPC3024 are DOCSIS 3.1-ready.

Samples and evaluation boards for both the QPC3624 and QPC3024 are available now, with limited production release in October and November, respectively. Both products were showcased at the Society of Cable Television's (SCTE) Cable-Tec Expo in Philadelphia, PA, USA (26–29 September).

http://expo.scte.org

www.qorvo.com

Anokiwave appoints director of Asia-Pacific sales

Anokiwave Inc of San Diego, CA, USA, which provides highly integrated silicon core chips and III-V front-end integrated circuits for millimeter-wave (mmW) markets and active electronically scanned array (AESA)-based terminals, has added to its leadership team and expanded into the Asia-Pacific region with the appointment of Alan Chang as director of Asia-Pacific sales.

Chang joined Anokiwave in June. With over 18 years of sales and engineering experience, he has a proven track record of establishing new markets, building distributor relations, and leading sales growth in Asia-Pacific for companies such as WIN Semiconductor, Weltrend Semiconductor, ASML, and most recently MACOM (where he was country manager for Taiwan and South East Asia). Chang will be responsible for expanding Anokiwave's AESA Core IC solutions into new markets in the Asia-Pacific.

"Alan's presence in Asia further strengthens our capability in this high-growth region," says chief operating officer Carl Frank. "His leadership and skills will accelerate our sales growth in the region and globally. He will work directly with customers and partners to help anchor our presence and increase share in Asia's 5G, SatCom and radar markets."

Chang holds Bachelor and Master of Electrical Engineering degrees from National ChiaoTung University in Taiwan and a Master of Business Administration degree from TiasNimbas Business School in The Netherlands.

www.anokiwave.com

Taiwan GaAs IC foundry AWSC announces stock buyback

Taiwan gallium arsenide IC foundry Advanced Wireless Semiconductor Company (AWSC) plans to repurchase 5 million shares (3.56% of its outstanding stock) at between NT$36 (US$1.13) and NT$78 per share from 1 September to 31 October, according to Digitimes. The bought-back shares will be distributed to staff.

AWSC saw its July revenue fall to the lowest levels since March 2014. Cumulative 2016 revenue through July of NT$1.66bn is down 33.7% year-on-year.

For first-half 2016, AWSC reported net profits of NT$310m, down 38% year-on-year. Earnings per share (EPS) were NT$2.21, down from NT$3.66 in first-half 2015.

www.awsc.com.tw

MACOM amends credit agreement securing $250m

MACOM Technology Solutions Inc of Lowell, MA, USA has entered into an amendment of its existing credit agreement dated 8 May 2014, in which the firm secured incremental term loans (bearing an interest rate of LIBOR plus 3.75%) in an aggregate principal amount of $250m.

"Access to incremental capital at favorable terms as part of this amended credit agreement provides MACOM with additional flexibility for general corporate purposes," says president & CEO John Croteau. "In addition, this capital enables us to continue being opportunistic as we consider potential future acquisitions."

www.macom.com

Peregrine expands patent portfolio by 50% to over 280 issued and pending patents since Murata acquisition

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 it has expanded its intellectual property (IP) portfolio to over 280 issued and pending patents. Since its acquisition by Japan's Murata in December 2014, Peregrine has increased its patent portfolio by 50% and is on track to exceed 300 issued and pending patents by the end of 2016.

The firm says that, as it further strengthens its IP portfolio, it has established more robust internal processes to protect its RF and power advances: 70% of Peregrine's design and process engineers are directly involved in the patent process.

"Peregrine has an over 25-year history of industry-leading innovation, and most of our patents have a large number of claims, which is indicative of the inventions' scope," says Dan Nobbe, VP of corporate research & IP development. "We remain committed to pursuing many foundational patents based on our groundbreaking work in RF SOI," he adds.

Peregrine's patent portfolio protects product and technology inventions for its two business units — mobile wireless solutions (MWS) and high-performance analog (HPA). The portfolio has patents granted by both the US Patent & Trademark Office and by the national patent office of select other countries.

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MACOM showcasing DC–100GHz MMICs at EuMW

At European Microwave Week (EuMW 2016) in London, UK (4–6 October), MACOM Technology Solutions Inc of Lowell, MA, USA (which makes semiconductors, components and subassemblies for analog RF, microwave, millimeter-wave and photonic applications) is debuting the industry's broadest and most advanced MMIC product and technology portfolio.

Along with its new portfolio of monolithic microwave integrated circuits (MMICs), MACOM will feature its Gen 4 gallium nitride-on-silicon (GaN-on-Si) portfolio for RF energy applications, and other high-performance products at the show.

MACOM is exhibiting the following new product solutions optimized for test & measurement (T&M), SatCom, aerospace & defense (A&D), wired broadband and industrial, scientific & medical (ISM) applications, including giving live demonstrations:

- wideband GaAs power amplifier: new 2W GaAs power amplifier covering DC–22GHz for T&M/A&D applications;
- wideband voltage-controlled oscillator: demonstrating the performance and functionality of MACOM's new platform of wideband VCOs, including octave band frequencies, lower phase noise, stable power over temperature and improved sensitivity for T&M/ISM applications; and
- 300W Gen 4 GaN power transistor: demonstrating MACOM's Gen 4 GaN-on-Si for RF energy in both solid-state cooking and plasma lighting RF applications.

Also, MACOM's experts are presenting papers and posters and participate in a workshop on the latest in RF & microwave technology:

Papers:

3 October

- EuMIC15-04 'Development and Verification of a Scalable GaAs pHEMT FEM Thermal Model', Bryan Schwitter (presented by Simon Mahon);
- EuMIC10-05 'Characterization of Trapping in a GaN HEMT by Performing Isothermal Three-Stage Pulse Measurements', by Bryan Schwitter (presented by Simon Mahon).

4 October

- EuMIC17-04 'EM Analysis of Ka-Band Multi-Throw PIN Diode MMIC Switches' by Andrzej Rozbicki/Jim Brogle; and
- EuMIC18-05 'Dependence of a Hybrid 125W S-Band Switch-Limiter Receiver Protector's Performance on Packaging Technique' by Jim Brogle.

Posters:

3 October

- EuMIC Poster 01-14 'A 6–46GHz, High Output Power Distributed Frequency Doubler using Stacked FETS in 0.25um GaAs pHEMT' by Thu Nguyen; and

6 October

- EuRAD Poster 01-13, 'Migrating SPAR to Higher Frequencies' by Tim Boles.

Workshop:

4 October

- National Instruments Workshop (AWR Design Forum (ADF)/NI AWR Software User Group Meeting), 'Advanced GaN on Silicon Transistor Modelling for High Power MMIC Design' by Jonathan Leckey.

www.macom.com/wirelessinfra
www.eumweek.com

MACOM launches high-power DC–22GHz MMIC power amplifiers for test & measurement, electronic warfare and radar

MACOM Technology Solutions Inc of Lowell, MA, USA (which makes semiconductors, components and subassemblies for analog RF, microwave, millimeter-wave and photonic applications) has launched the MAAP-011247 and MAAP-011248 distributed power amplifiers. Operating from DC to 22GHz, they can be used as a power amplifier stage or as a driver stage in higher-power applications, and are suitable for test & measurement (T&M), electronic counter measures (ECM) and radar applications.

The MAAP-011247, a 2W amplifier, features 12dB of linear gain, 33dBm of saturated output power and what is claimed to be the industry's highest output power for a monolithic microwave integrated circuit (MMIC) amplifier covering DC–22GHz. The device is fully matched across the band and provides 42dBm of OIP3 (output third-order intercept point) linearity.

The MAAP-011248, a 1W amplifier, offers 12.5dB of linear gain, 30dBm of saturated output power and can be operated over a drain voltage of 9–12V for optimization of RF power versus DC power dissipation. The device provides 41dBm of OIP3 linearity.

Both devices offer an integrated temperature-compensated output power detector, and are available as bare die (measuring 2.99mm x 1.5mm x 0.1mm) or in 5mm 32-lead QFN packages.

"The MAAP-011247 and MAAP-011248 are the first of four new distributed amplifiers designed to deliver high gain and power in compact bare die or QFN packaged solutions," says Graham Board, senior director, Multi-Market Products. "Two additional distributed amplifiers with _W and _W output power are scheduled for release over the next two quarters. This complete family of distributed amplifiers will offer customers a full range of power levels to solve their most challenging wideband test & measurement and mission-critical aerospace & defense system requirements."

www.macom.com/products/product-detail/MAAP-011247
www.macom.com/products/

MACOM expands MMIC portfolio with family of 75Ω amplifiers spanning 5–1218MHz for DOCSIS3.1 cable TV infrastructure

MACOM Technology Solutions Inc of Lowell, MA, USA (which makes semiconductors, components and subassemblies for analog RF, microwave, millimeter-wave and photonic applications) has introduced five monolithic microwave integrated circuit (MMIC) amplifiers covering the downstream 45–1218MHz cable band, with two of them (MAAM-011162 and MAAM-011163) also covering the upstream 5–1218MHz band. Designed specifically for DOCSIS 3.1 infrastructure applications, the devices are a subset of MACOM's new high-performance MMIC portfolio launched at European Microwave Week (EuMW 2016) at ExCel London, UK (4–6 October).

MACOM says that, as one of the few remaining pure-play RF, microwave and millimeter-wave suppliers, it designed the amplifiers to meet demanding requirements for small- to medium-signal 75Ω amplifiers in new and legacy HFC (hybrid fiber coax) networks.

The MAAM-011220 is an 18.5dB gain, high-linearity, low-noise-figure gain block operating at 45–1218MHz. It is provided in an industry-standard 3-lead SOT-89 plastic package and can be biased at either 8V or 5V (depending on available voltage rails and system requirements).

The MAAM-011194 is a differential, 3-stage VGA (variable-gain amplifier) in a 5mm x 7mm PQFN package operating at 45–1218MHz. The VGA delivers 36dB gain, 2.5dB noise figure and ACPR (adjacent channel power ratio) at output levels of +7dB above Cable Labs downstream radio frequency interference (DRFI) specifications.

MACOM designed the amplifiers to meet demanding requirements for small- to medium-signal 75W amplifiers in new and legacy hybrid fiber coax networks

The MAAM-011162 is a single-ended high-linearity, low-noise-figure amplifier covering both upstream and downstream bands of 5–1218MHz. The device is assembled in a 3-lead SOT-89 plastic package and provides 18dB of flat gain in both upstream and downstream applications.

The MAAM-011163 is a differential amplifier covering both the upstream and downstream 5–1218MHz band. Assembled in a SOIC-8EP plastic package, it has 19dB gain, what is claimed to be excellent S11 and S22 match, high linearity and 1.4dB at noise figure at 45MHz.

The MAAL-011136 is a broadband, ultralow-noise-figure amplifier operating at 45-1218MHz. It provides 20dB of flat gain and low distortion with 16dB S22, making it suitable as an input stage for low-cost fiber-to-the-x (FTTx) optical receivers and other 75Ω infrastructure applications.

Samples and reels of the MAAM-011220, MAAM-011194, MAAM-011163, MAAM-011162 and MAAL-011136 are available now.

www.eumweek.com

MACOM expands MMIC portfolio with current-adjustable, fully matched surface-mount wideband amplifiers

MACOM Technology Solutions Inc of Lowell, MA, USA (which makes semiconductors, components and subassemblies for analog RF, microwave, millimeter-wave and photonic applications) has added to its growing portfolio of high-performance monolithic microwave integrated circuits (MMICs) with two fully matched, current-adjustable surface-mount wideband amplifiers (sampling now).

The MAAM-011206 is a versatile broadband Darlington amplifier operating from DC to 15GHz. Compared with competing devices, it is said to have superior frequency range, higher gain of 14.5dB, improved return loss of >15dB and higher output power drive of 20dBm P1dB (output power at 1dB compression point). Housed in a small, 1.5mm x 1.2mm 6-lead PDFN plastic SMT package, the MAAM-011206 is compatible with standard pick & place assembly equipment. Functional operation is achieved with single bias from +3V to +5V and has the option for current adjustment with an external bias resistor. The new amplifier is said to offer real-estate-constrained users greater versatility for test & measurement, land mobile radios, and wireless and satellite communications.

The MAAM-011229 is a 3-5V broadband low-noise amplifier (LNA) covering the frequency range 0.05–4GHz. The 50Ω LNA provides flat gain (of 19dB) and what are claimed to be excellent return losses to 3.25GHz and out to 4GHz with a 1.2dB roll off while keeping noise figure below 2dB. Simple matching and a bias circuit, along with active bias, enables the 2mm 8-lead PDFN-packaged MAAM-011229 to act as a multi-market amplifier.

"These two devices are just a fraction of MACOM's expanding product portfolio that ranges from DC–100GHz," says Graham Board, senior director, RF and Microwave.

www.macom.com/mmics

NCSU's SiC-based inverter achieves 12.1kW/L, close to DOE's target of 13.4kW/L by 2020

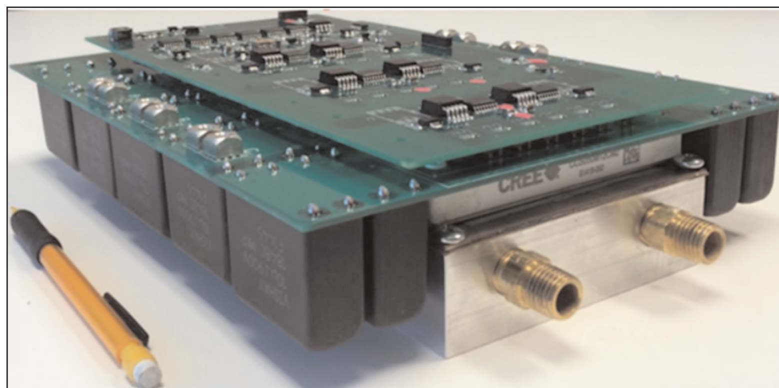
In-house-developed ultra-high-density SiC power components to get closer to target

Researchers at the Future Renewable Electric Energy Distribution and Management (FREEDM) Systems Center at North Carolina State University (NCSU) have used off-the-shelf silicon carbide (SiC)-based components to develop an inverter with greater efficiency in a smaller, lighter package that could improve the fuel-efficiency and range of hybrid and electric vehicles (HEV/EV).

"Our silicon carbide prototype inverter can transfer 99% of energy to the motor, which is about 2% higher than the best silicon-based inverters under normal conditions," says FREEDM Center director Iqbal Husain, ABB Distinguished Professor of Electrical and Computer Engineering at NC State. "Equally important, the silicon carbide inverters can be smaller and lighter than their silicon counterparts, further improving the range of electric vehicles," adds Husain, who co-authored two papers related to the work. "New advances we've made in inverter components should allow us to make the inverters even smaller."

A major factor limiting public acceptance of electric vehicles is 'range anxiety' (fear of not being able to travel very far or getting stuck at the side of the road). The new SiC-based inverter is able to convey 12.1 kilowatts of power per liter (kW/L) — close to the US Department of Energy (DOE) goal of developing inverters that can achieve 13.4kW/L by 2020. In comparison, a 2010 electric vehicle could achieve only 4.1kW/L.

"Conventional, silicon-based inverters have likely improved since 2010, but they're still nowhere near 12.1kW/L," Husain notes. "But, frankly, we are pretty sure that we can improve further on the energy density that we've shown with this prototype," he adds. That's because the new inverter prototype was made using off-the-shelf SiC components, and FREEDM researchers have recently made new, ultra-high-density SiC power components that they expect will allow them to get closer to the DOE's 13.4kW/L target once it's incorporated into next-generation inverters.



The new inverter. Photo courtesy of Iqbal Husain.

In addition, the design of the new power component is more effective at dissipating heat than previous versions. This could allow the creation of air-cooled inverters, eliminating the need for bulky (and heavy) liquid cooling systems. "We predict that we'll be able to make an air-cooled inverter up to 35kW using the new module, for use in motorcycles, hybrid vehicles and scooters," Husain says. "And it will boost energy density even when used with liquid cooling systems in more powerful vehicles."

The existing SiC inverter prototype was designed to go up to 55kW — the sort of power you'd see in a hybrid vehicle. The researchers are now in the process of scaling it up to 100kW — akin to what you'd see in a fully electric vehicle — using off-the-shelf components. They are also in the process of developing inverters that make use of the new, ultra-high-density SiC power component that they developed on-site.

A paper on the inverter 'Design Methodology for a Planarized High Power Density EV/HEV Traction Drive using SiC Power Modules' was presented at the IEEE Energy Conversion Congress and Exposition (ECCE) in Milwaukee (18–22 September). Lead author is Ph.D. student Dhrubo Rahman, and co-authors are Ph.D. students Adam Morgan, Yang Xu and Rui Gao, plus research professors Wensong Yu and Douglas Hopkins of NC State's Department of Electrical and Computer Engineering, along with Husain.

A paper on the new ultra-high-density SiC power component 'Development of an Ultra-high Density Power Chip on Bus Module' was also presented. Lead author is Yang Xu, and co-authors are Yu, Husain and Hopkins, as well as Harvey West, a research professor in NC State's Edward P. Fitts Department of Industrial and Systems Engineering.

The research was performed with the support of the PowerAmerica Institute, a public-private research initiative housed at NC State and funded by the DOE's Office of Energy Efficiency and Renewable Energy under award number DE-EE0006521. FREEDM, a National Science Foundation (NSF) Engineering Research Center (ERC), aims to facilitate the development and implementation of new renewable electric-energy technologies.

https://news.ncsu.edu/2016/09/inverters-boost-ev-range-2016

ABB's SiC-based battery charger for trains shrinks size tenfold and cuts weight by 80%

At the InnoTrans trade show in Berlin, Germany (20–23 September), ABB of Zurich, Switzerland launched a next-generation battery charger based on silicon carbide (SiC) power semiconductors for use in all rail applications.

Train batteries provide power for critical systems such as control and lighting. The new compact battery charger in the BORDLINE BC series complements ABB's large standalone auxiliary converter product family and is compatible with all standard train battery voltages. With a footprint of 360mm x 220mm (the size of a shoebox) it is about 10 times smaller and 80% lighter compared to previous generations. The new device also has a high power density of 1kW per liter and per kg (an improvement on previous generations by a factor of 15).

Modern trains have varying requirements for power electronics components. In local transportation (such as trams), the components need to be as lightweight as possible to improve overall system energy efficiency. The need in long-distance and high-speed transportation is for compact and powerful yet reliable devices.

The BORDLINE BC battery charger employs ABB's proven modular platform design while incorporating SiC technology for the first time. Due to its conductivity characteristics, SiC power semiconductor technology enables power density and performance not possible with conventional silicon power semiconductors. Mastering SiC technology translates into dramatically reduced size, weight and cooling requirements, and increased system efficiency, all critical factors for rail operators, says ABB.

"The new battery charger leverages all the benefits available from SiC and soft switching technologies to allow for a new performance level of power electronics in railway," says Sami Atiya, president of ABB's Discrete Automation and Motion division. "ABB has a long history of providing innovative and energy-efficient technologies to the rail industry and we will continue innovating for the transportation sector, a key growth area in our Next Level strategy."

The technology will be used to equip the new high-speed trains by Stadler operated by the Swiss Federal Railways (SBB) on the new transalpine Gotthard base tunnel route between Zurich and Milan.

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1	1394	25.4mm	P
22	2483	25.4mm	Undoped
500	444	50.8mm	P
267	446	50.8mm	N

Wolfspeed releases highest-power 50V L-band radar gallium nitride HEMT

At European Microwave Week (EuMW 2016) in London, UK (3–7 October), Wolfspeed of Research Triangle Park, NC, USA — a Cree Company that makes gallium nitride on silicon carbide (GaN-on-SiC) high-electron-mobility transistors (HEMTs) and monolithic microwave integrated circuits (MMICs) — launched what is claimed to be the highest-power 50V GaN HEMT demonstrated to date.

Delivering a minimum of 800W of pulsed power at 1.2–1.4GHz and 50V operation with better than 65% drain efficiency, the CGHV14800 features high efficiency, high gain and wide-bandwidth capabilities, making it suitable for L-band radar amplifier applications including air traffic control (ATC) radar, penetration radar, anti-missile system radar, target-tracking radar, and long-range surveillance radar.

Internally matched on input and output, the 900W, 50V GaN HEMT also exhibits 14dB power gain and <0.3dB pulsed amplitude droop. The CGHV14800 is supplied in a ceramic/metal flange package that can be shipped individually, or alongside or installed on a test board.

"We demonstrated the CGHV14800 at this year's International Microwave Symposium," says RF & microwave director Jim Milligan. "Our comprehensive and continually expanding radar product portfolio enables state-of-the-art RF amplifier performance critical for the development of the next-gen defense, aerospace and commercial radar applications," he claims.

Wolfspeed says that, compared with conventional silicon (Si) and gallium arsenide (GaAs) devices, its 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. In addition to L-band radar power amplifiers, the firm's GaN-on-SiC RF devices are also enabling next-generation broadband, public safety, and ISM (industrial, scientific & medical) amplifiers; broadcast, satellite, and tactical communications amplifiers; unmanned aerial vehicle (UAV) data links; cellular infrastructure; test instrumentation; and two-way private radios.

www.wolfspeed.com/cghv14800

Wolfspeed completes C-band radar range with 70W GaN HEMT pre-driver operating at 4.5–5.9GHz

Wolfspeed of Research Triangle Park, NC, USA — a Cree Company that makes gallium nitride on silicon carbide (GaN-on-SiC) high-electron-mobility transistors (HEMTs) and monolithic microwave integrated circuits (MMICs) — has announced its complete lineup of high-efficiency, high-gain and wide-bandwidth devices for C-band radar systems with the introduction of its CGHV59070 GaN HEMT at European Microwave Week (EuMW 2016) in London, UK (3–7 October).

Designed to operate at 4.5–5.9GHz from a 50V rail, the new 70W GaN HEMT is suitable as a driver for the 350W CGHV59350 GaN HEMT for 5.2–5.9GHz operation (launched in May 2015), which is claimed to be the highest-power C-band radar device on the market. Delivering 90W typical P_{OUT} at 50V, in addition to 55% drain efficiency at high 14dB power gain, the internally matched CGHV59070 offers a general-purpose broadband solution for RF and microwave applications, and is especially suitable for use in linear and compressed amplifier circuits in marine radar, weather monitoring, air & maritime vessel traffic control, and port security applications.

"First demonstrated at this year's International Microwave Symposium [IMS 2016 in late May], the market release of the new 70W CGHV59070 pre-driver completes Wolfspeed's C-band radar lineup of pre-drivers, drivers and output stages, enabling 1kW, all-GaN SSPAs [solid-state power amplifiers] for C-band radar applications," says RF & microwave director Jim Milligan. "This latest introduction also further extends our comprehensive radar product portfolio, which helps designers achieve smaller, lighter and higher-power RF amplifiers that are critical for the development of the next-gen military, aerospace and commercial radar applications."

The CGHV59070 can be supplied in a ceramic/metal flange or pill package, and can be shipped either individually or alongside or installed on a test board.

www.wolfspeed.com/RF
www.wolfspeed.com/cghv59070

Northrop Grumman delivering first GaN-based G/ATOR systems under latest LRIP award

Northrop Grumman Corp of Redondo Beach, CA, USA has received a contract from the US Marine Corps (USMC) for an additional nine AN/TPS-80 Ground/Air Task-Oriented Radar (G/ATOR) low-rate initial production (LRIP) systems.

This is the second LRIP order placed by the USMC, but the first order in the upgraded gallium nitride (GaN)-based configuration. Northrop Grumman's initial contract was to provide six G/ATOR LRIP systems — in a gallium arsenide (GaAs)-based configuration — the first of which will be delivered in February 2017 (to support testing and fielding G/ATOR Block 1 and Block 2 initial operational capability in 2018).

These nine additional systems and all subsequent G/ATOR systems incorporate GaN technology, providing the Marine Corps with nearly $2m in life-cycle cost savings per system. GaN technology also provides performance benefits including lower input power needs, higher efficiency and higher output power. This higher output power can substantially increase threat detection and tracking ranges for all four G/ATOR mission capabilities: air surveillance, weapon cueing, counter-fire target acquisition and air traffic control.

The GaN-based G/ATOR Ground/Air Task-Oriented Radar system.

"There are no other GaN ground-based active electronically scanned array (AESA) radars in production today," says Roshan Roeder, director, mission solutions, Northrop Grumman. "G/ATOR is the first DoD [Department of Defense] ground-based AESA system to incorporate GaN in a production program. We proposed this technology as a cost-savings measure for the government and funded risk reduction internally to ensure a seamless insertion into the G/ATOR system," he adds. "We are continuing to look at future technology insertions to continue providing the best capability out there to our warfighters at an affordable cost."

As a developer of AESA radar systems, Northrop Grumman is also on contract to develop and test high-performance, short- and medium-range radars for additional DoD ground- and ship-based applications. The firm's family of ground radar systems includes the AN/APG-83 Highly Adaptable Multi-Mission Radar (HAMMR) AESA system as well as the solid-state AN/TPS-78 and TPS-703 systems.

www.northropgrumman.com

Telcodium partners with Transphorm on first redundant power supplies using GaN FETs

Power supply design firm Telcodium of Boucherville, QC, Canada, in collaboration with Transphorm Inc of Goleta, near Santa Barbara, CA, USA — which designs and manufactures JEDEC-qualified 650V gallium nitride (GaN)-based devices for high-voltage power conversion applications — has released what are claimed to be the first redundant power supplies using GaN field-effect transistors (FETs).

Telcodium's AC Series replaces a typical three-module power supply architecture — two power supply bricks and one intermediate bus converter (IBC) — with a single power module with redundant AC feeds. The firm's power module operates at 94% true system efficiency (TSE, i.e. power supply module efficiency plus IBC efficiency) or higher — reducing average energy loss by 13% or more. To achieve the same TSE with the typical three-module power supply, the bricks and IBC would each need to yield 97% efficiency, which exceeds the 80Plus Titanium specification and has yet to be demonstrated by any power supply manufacturer.

Further, the new module is reckoned to be 30% smaller than the two bricks and eliminates the standalone IBC, freeing considerable, critical space inside a host system.

The high TSE and size reduction are made possible by Telcodium's design, which pairs patented front-end circuitry with what is said to be the market's only JEDEC-qualified 650V GaN FET (from Transphorm). The resulting AC Series enables data-center, server and telecom manufacturers to develop smaller, high-performing systems that can virtually eliminate power-supply-related failures, it is reckoned. Such features can potentially reduce an average system's total cost of ownership by 19%.

The AC Series' universal form factor (260mm x 100mm x 40mm) is lightweight (1.36kg) and fits common equipment developed by data center, server and telecom manufacturers. Products are available now, and short delivery windows average in-stock to 6 weeks.

www.telcodium.com
www.transphormusa.com

VisIC launches 1200V family of GaN power switching devices with integral iso-driver

At the IEEE Energy Conversion Congress and Exposition (ECCE2016) in Milwaukie, WI, USA (18–22 September), VisIC Technologies Ltd of Nes Ziona, Israel — a fabless developer of power conversion devices based on gallium nitride (GaN) metal-insulator-semiconductor high-electron-mobility transistors (MISHEMTs) founded in 2010 — launched a family of high-voltage GaN devices for switching power electronics designs.

With a 1200V rating, the GaN modules have typical on-resistance ($R_{DS(ON)}$) down to just 0.04Ω. Target applications are power converters for motor drives, three-phase power supplies and other applications requiring current switching up to 50A (current limit at the first line of products).

The GaN devices are based on VisIC's ALL Switch (Advanced Low Loss Switch) second-generation HEMT technology, which combines high levels of cell integration with optimized cell design, says chief technology officer Gregory Bunin. "This technology supports reduced gate charge and capacitances without losing the benefits of low $R_{DS(ON)}$, with our GaN devices offering an ultra-low maximum switching energy down to 140μJ."

Switching losses are 3–5 times lower compared to SIC MOSFETs counterparts, it is reckoned. The isolated gate driver is integrated in an isolated DIP power package.

The new GaN devices represent high-voltage supplements to VisIC's existing ALL Switch line-up of 650V GaN devices.

www.ieee-ecce.org

VisIC launches low-$R_{DS(ON)}$ 650V GaN switch product line in bottom-side-cooled package for switching up to 12A

VisIC Technologies has launched a new product with an on-resistance ($R_{DS(ON)}$) rating of just 0.080Ω and a reduced external components requirement using a simplified driving scheme, offered in a smaller package with bottom-side cooling.

The new 650V GaN power switch is a member of the company's ALL-Switch (Advanced Low Loss Switch) family, designed for bridge converters in motor drives, power supplies, chargers, UPS (uninterruptible power systems), Inverters and other circuits requiring high efficiency and currents up to 12A.

VisIC claims that its designs operate with lower gate charge and capacitance than competing products while providing the benefits of low $R_{DS(ON)}$. Offered in low-inductance packaging, the ALL-Switch family is able to deliver high efficiency, adds the firm. For comparison, ALL-Switch's switching losses are 3–5 times lower than comparable silicon carbide (SiC) MOSFET transistors operating at the same frequency, it is reckoned.

VisIC says that the V80N65B meets the demand of customers for a bottom-side-cooled package in their designs after they have experienced ALL-Switch's low switching losses.

The V80N65B bottom-side-cooled power switch supplements VisIC's existing ALL Switch top-side-cooled product line of 650V GaN devices (the V22N65A, V22S65A and V18G65A).

www.visic-tech.com

TMD exhibiting GaN-based microwave power module at UAE electronic warfare conference

Exhibiting for the first time at an electronic warfare (EW) exhibition in the United Arab Emirates (UAE), at the Electronic Warfare GCC Conference (EW GCC 2016) in Abu Dhabi (25–26 October) UK-based TMD Technologies Ltd (TMD) — which designs and manufactures specialized transmitters, amplifiers, microwave power modules (MPMs), high-voltage power supplies and microwave tubes for radar, EW and communications applications — is showcasing a selection of products for electronic warfare.

Exhibiting at EW GCC 2016 is "a direct result of our planned on-going expansion into the Middle Eastern markets," says sales & business development director Jane McAlister. "The EW GCC event is supported by the region's elite intelligence and military community."

The products on show include TMD's newest microwave power modules, namely the recently launched traveling wave tube (TWT)-based PTX8807 and the solid-state PTS6900.

Optimized for EW/ECM systems and employing gallium nitride (GaN) monolithic microwave integrated circuit (MMIC) technology, the PTS6900 MPM operates over the 2–6GHz frequency range, with 150W output power and adjustable 55dB gain. The device is said to have a very high predicted mean time between failure (MTBF) for an airborne uninhabited fighter environment.

www.tmd.co.uk

EpiGaN adds Brussels/Beijing-based private equity fund ACAPITAL as investor

Investment to aid expansion into Asian markets

EpiGaN nv of Hasselt, near Antwerp, Belgium, which supplies commercial-grade 150mm- and 200mm-diameter gallium nitride on silicon (GaN-on-Si) epitaxial wafers for 600V high-electron-mobility transistor (HEMT) power and RF devices, says that the Brussels/ Beijing-based European private equity fund ACAPITAL has joined its initial investors to fund expansion, in particular to Asian markets.

Incorporated in 2010, EpiGaN was founded by chief executive officer Dr Marianne Germain, chief technology officer Dr Joff Derluyn and chief operating officer Dr Stefan Degroote as a spin-off of nanoelectronics research center Imec of Leuven, Belgium. The founders jointly developed GaN-on-Si technology at Imec, part of which has been licensed to EpiGaN.

In 2011, EpiGaN was joined by start-up investment firms Robert Bosch Venture Capital, Capricorn CleanTech Fund and LRM to enable the installation of its wafer production facility. In June, Beijing/Brussels-based Euro-Asia private equity fund A Capital joined the initial investors to fund expansion of EpiGaN's sales and support base to Asian markets. EpiGaN is now undertaking volume production and wafer characterization at its Research Campus Hasselt in the Eindhoven–Leuven–Aachen high-tech triangle. In January, the firm signed a global representation agreement for its 150mm and 200mm GaN-on-Si power semiconductor product solutions with silicon substrate maker SunEdison Semiconductor of St. Peters, MO, USA.

EpiGaN offers GaN-on-Si and GaN-on-SiC material solutions aimed at the next generation of efficient power electronics, RF power and sensor devices and systems. Allowing drastic savings in energy loss as well as more compact and lighter power conversion systems such as consumer power supplies, photovoltaic inverters and industrial sensors, GaN technology is also in demand for its superior performance in wireless communications and more generally all products linked with the Internet of Things (IoT). Also, EpiGaN offers unique solutions for epitaxial GaN layer structures on 150mm and 200mm silicon substrates, in particular via its in-situ silicon nitride (SiN) passivation, which enables more robust high-performance devices. The firm's product portfolio spans solutions for low-loss power switching, RF/mobile communication power and sensor applications.

"We believe ACAPITAL is the right partner to support the expansion of our business activities into Asia, where we see great opportunities right now," comments Germain. "Our initial investors stay in place to support the continuous growth of the company," she adds.

"EpiGaN has developed a unique expertise in gallium nitride-on-silicon technology for semiconductors," comments ACAPITAL's founder & managing partner Andre Loesekrug-Pietri. "Applications are massive: power electronics, Internet of Things, smart-grid applications, mobile communications and electric mobility — most areas linked with Industry 4.0 and Energy Transition, which are core investment areas for ACAPITAL," he adds. "EpiGaN is uniquely positioned to grasp a significant share of these high-growth markets. We look forward to help scale EpiGaN internationally and in Asia and China in particular, the largest market in the world."

www.epigan.com

Mitsubishi Electric sampling 220W GaN HEMT for 2.6GHz-band 4G base transceiver stations

Tokyo-based Mitsubishi Electric Corp has developed a 220W-output gallium nitride high-electron-mobility transistor (GaN-HEMT) with what is claimed to be world-leading drain efficiency of 74% (in load-pull measurements) for 2.6GHz-band base transceiver stations (BTS) of fourth-generation (4G) mobile communication systems. Samples of the 2.5–2.7GHz MGFS53G27ET1 will be released from 1 November.

High-speed 4G mobile communication systems including long-term evolution (LTE) and LTE-Advanced are being equipped with progressively smaller base transceiver stations for macro-cells to increase data capacity and to reduce power consumption.

High efficiency results in a simpler cooling system, which reduces BTS size and power consumption. In addition, launching 220W models for 2.6GHz-band macro-cell BTS has involved Mitsubishi Electric expanding its GaN-HEMT lineup to add a flangeless ceramic package, reducing the size of the device itself as well as related power amplifier modules. Hence, Mitsubishi Electric says that, through transistor optimization, its highly efficient new GaN HEMT for 2.6GHz-band macro-cell BTS will help to realize an even smaller and lower-power BTS.

Mitsubishi Electric says that, going forward, its GaN HEMT range will be further expanded with products for different outputs and frequencies, as well as adapted for mobile communication systems beyond 4G.

www.MitsubishiElectric.com

SAGE Satcom delivers compact, lightweight 12W linear Ka-band GaN block-up converter

SAGE SatCom of San Diego, CA, USA (part of telecoms solutions provider REMEC Broadband Wireless), which manufactures power amplifiers for the satellite industry, has added an ultra-compact, efficient, low-power-consumption gallium nitride (GaN)-based 12W linear Ka-band block-up converter (BUC) to its high-transmit-power Ka-band lineup for next-generation satellite data communications.

SAGE SatCom says that its GaN solid-state technology allows significant power consumption and size savings compared with widely used gallium arsenide (GaAs) technology, without compromising RF performance or reliability. The overall size improvement enables simplified installation directly on the antenna feed arm, without the need for pedestal mounting. SAGE SatCom claims that its Ka-band BUC products offer the highest linear power levels in the most compact and lightweight package on the market.

SAGE says that it has deployed many hundreds of its earlier-generation 12W linear Ka-band BUCs in the most demanding

customer environments. The new GaN-based 12W linear Ka-band BUC joins its Ka-band portfolio of products, which includes a GaN-based 20W linear Ka-band BUC and a 5W linear Ka-band BUC. Utilizing GaN technology, SAGE has further reduced the size and weight of its 12W linear BUC to a size and power consumption similar to 5W linear Ka-Band BUCs based on GaAs technology. The 12W linear Ka-band BUC measures only 7.5″x5.3″x4″ and consumes just 155W at 12W linear output power.

"No longer are 1W and 2W transceivers the only options for mission-critical deployments in the Ka-band space," says Sherman Su, director, global sales. "The SAGE 12W linear power Ka-band BUC is the world's lightest and smallest-form-factor, high-transmit-power BUC and can easily mount on the feed assembly of any Ka-band terminal," he claims. "Deployments on the edge of a beam, as well as mission-critical applications anywhere in the zone, can be assured of increased transmission qualities with this powerful unit."

"Within the Ka-band space, this new 12W linear unit is also refined for specific use in specialty applications," Su continues. "In fact, all SAGE products can be engineered for emerging applications. SAGE BUCs exhibit high linear power, have solid-state reliability, consume very little power, are compactly packaged, and extend our lead as the de facto standard for reasonably priced, high-powered amplifiers for the industry's fastest-growing space."

The new SAGE SatCom products were displayed on the Sematron stand at IBC in Amsterdam, The Netherlands (9–13 September) and on the BridgeWave stand at GITEX 2016 in Dubai.

www.sagesat.com

e2v to supply GaN Systems' 100V and 650V hi-rel GaN transistors to global aerospace & defense industry

A master supply agreement has established e2v inc of Milpitas, CA, USA (which provides solutions, sub-systems and components to the medical & science, aerospace & defense and commercial & industrial markets) as the global supplier of 100V and 650V high-reliability GaN transistor products (and customer care) of GaN Systems Inc of Ottawa, Ontario, Canada, a fabless developer of gallium nitride (GaN)-based power switching semiconductors for power conversion and control applications, to the aerospace & defense (A&D) market.

e2v will utilize its infrastructure and 30 years of experience in this area to support the hi-rel market with GaN Systems' transistors and evaluation boards. The firm will offer power management solutions that respond directly to the hi-rel market's growing SWaP (size, weight and power) demands.

"Our A&D customers must increase system power density, while reducing size and weight," notes e2v's VP of business development Mont Taylor. "This global partnership with GaN Systems allows us to extend our A&D portfolio and offer new power technologies to meet these requirements," he adds.

"Power designers are routinely reducing the volume and weight of their systems by 4–6 times by using GaN transistors as a replacement for silicon devices," says GaN Systems' VP of sales & marketing Larry Spaziani. "Partnering with e2v enables our solutions to reach, supply and support hundreds of A&D electronic systems designers. e2v's heritage within the A&D market will allow us to extend the availability of our SWaP-conscious power solutions and give our A&D customers the specialist support they deserve."

www.gansystems.com
www.e2v.com/semis

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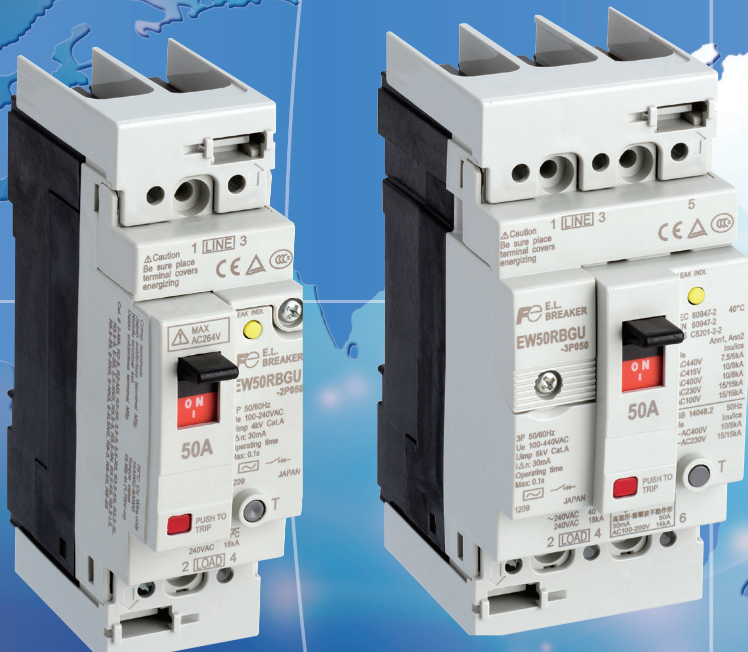

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Evince secures £0.75m in new equity investment for diamond-based electronics

Firm to accelerate technology development program while strengthening patent portfolio

Evince Technology Ltd of Netpark, Sedgefield, County Durham, UK, which is developing technologies to enable the manufacture of synthetic diamond-based electronics, has closed its largest funding round to date, amounting to £750,240 in new equity investment from business angels and other private investors. A quarter of the total (£189,000) was raised via Syndicate Room in just 10 days, resulting in the round being over-funded by £100,000 (the maximum agreed by the company at the outset).

This latest investment, together with a £230,000 award from UK Government agency Innovate UK (formerly the Technology Strategy Board) secured in late 2015, will allow Evince to accelerate key aspects of its technology development program while continuing to strengthen its patent portfolio.

"Following extensive due diligence, our investor group believes Evince has a unique practical approach to realizing electronics using synthetic diamond," comments lead investor James Morton. "Diamond offers the potential to yield devices that are up to 100x faster than silicon and could therefore revolutionise electronics across a broad range of industries and multi-billion dollar markets. Our investment decision was based amongst other things on the professionalism of the company's approach, its passion and determination to succeed, and in particular its rigorous development program to deliver first prototype solid-state diamond electronic devices," he adds.

"This latest funding round is a major milestone in the company's development," says Evince's chairman Phil Cammerman. "It is the largest new investment since Evince restructured its business in 2013 and a significant endorsement for the company's strategy and technology," he adds. "Our aim is to work more closely with partners across a wide range of target applications where we believe our novel diamond technology has the potential to deliver the quantum leap in performance over silicon that the industry is urgently looking for."

Evince was re-launched in 2013 to focus on developing a robust core technology and to expand its target applications, whereas previously the firm had planned to develop and market its own products for the power and energy sectors. The new strategy will see the firm work with partners to define products and target applications, then licence its patented synthetic diamond processing technologies to semiconductor manufacturing partners.

www.evincetechnology.com

RASIRC renews funding for ALD research at UCSD

RASIRC Inc of San Diego, CA, USA (whose products purify and deliver ultra-pure liquids and gases) has renewed its funding agreement with the University of California, San Diego (UCSD) for on-going semiconductor processing research. The gift donation supports one student for one year. RASIRC made a similar gift donation last year. RASIRC manufactures BRUTE hydrogen peroxide and hydrazine vaporizers for emerging atomic layer deposition (ALD) applications.

"Our ongoing research focuses on solving difficult materials problems associated with emerging semiconductor technology," says professor Andrew Kummel of the Department of Chemistry. "Financial and technical support from RASIRC aids our efforts to create new films and passivation layers for continuous shrinkage of semiconductor devices."

As part of the agreement, RASIRC provides BRUTE Peroxide and BRUTE Hydrazine materials for experimentation. The UCSD team has produced and published findings from these materials during the previous year of research. Chemists and engineers from both organizations regularly collaborate on research and share their findings. Research covers the passivation of silicon germanium (SiGe) channel materials and development of new low-temperature deposition methods for metal nitrides.

"UCSD is a great partner and we look forward to working with the team to perfect novel new chemistries that solve very difficult problems where traditional methods do not work," says RASIRC's chief technology officer Daniel Alvarez.

Kummel's group is focused on understanding and imaging chemical processing at the atomic level. Current projects include:
(1) in-situ cleaning and functionalization of SiGe, Ge and InGaAs for defect-free interfaces on FinFET sidewalls and contacts;
(2) selective etching and ALD on semiconductors and insulators;
(3) non-covalent functionalization of two-dimensional semiconductors;
(4) nano-scale synthesis of silica nanoshells for tumor ultrasound imaging and ablation.

http://kummelgroup.ucsd.edu
www.rasirc.com/lp/brute-peroxide-gas-for-water-free-ald.htm
www.rasirc.com/lp/brute-hydrazine-for-low-temperature-nitridation.htm

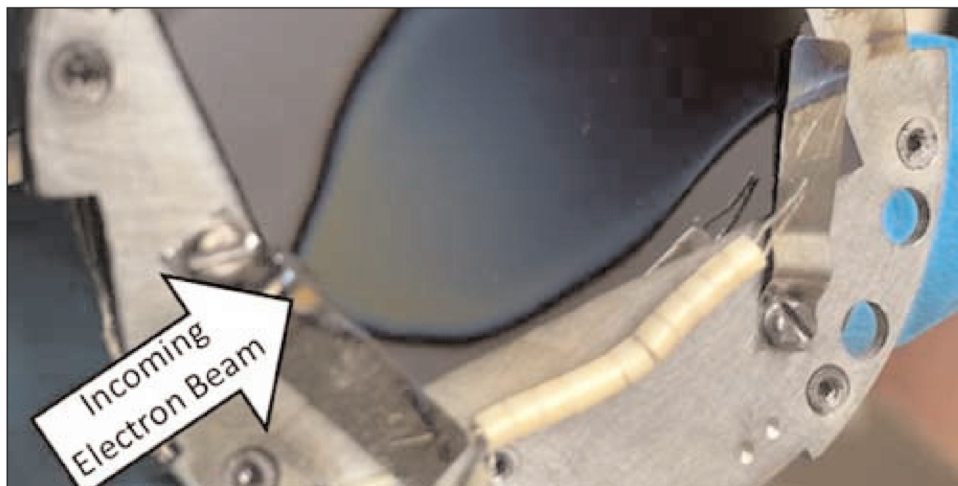
University of Colorado Boulder develops method for room-temperature atomic layer deposition

Electron-enhanced ALD demonstrated for GaN & silicon on 6" wafers

As part of the Local Control of Materials Synthesis (LoCo) program of the US Defense Advanced Research Projects Agency (DARPA), the University of Colorado, Boulder (CU) have developed the new electron-enhanced atomic layer deposition (EE-ALD) method for synthesizing ultrathin materials at room temperature (compared with existing approaches that require temperatures of 800°C or more). The advance is said to open a path to creating previously unattainable thin-film microelectronics whose production by conventional methods has been impossible because many components lose their critical functions when subjected to high temperatures.

The CU team demonstrated room-temperature deposition of silicon and gallium nitride (GaN) as well as the ability to controllably etch specific materials, leading to precise spatial control in three dimensions (critical as demand grows for ever-smaller device architectures).

After first demonstrating the process in early 2015, team members went on to perform detailed mechanistic studies to learn how best to exploit and control EE-ALD for film growth. By controlling the electron energy during the ALD cycles, they discovered that they could tune the process to favor either material deposition or removal. The ability to selectively remove (etch) deposited material with electrons under conditions as low as room temperature is said to be unprecedented and is expected to enhance film quality. The group is also exploring other methods to etch specific materials — such as aluminium nitride and hafnium oxide (key to specialized electronics applications) — showing that they can selectively etch these materials in composites, which provides an attractive alternative to traditional masking approaches.



A GaN film deposited on a silicon substrate at 27°C using electron-enhanced atomic layer deposition. Existing deposition methods require temperatures around 800°C, which is incompatible with microelectronics processing due to the damage that heat can wreak on underlying substrate materials. The new method could allow integration of previously incompatible microelectronics materials. (Image: University of Colorado Boulder).

CU has also built a custom deposition chamber to demonstrate industrial relevance and scalability of the EE-ALD process, which can deposit or etch films composed of multiple materials on industrial-scale 6-inch silicon wafers. In principle, the method could be scaled to larger substrates and parallelized to process many wafers at once. The researchers are now working to understand the vast parameter space of the EE-ALD process to better control film composition and properties in three dimensions.

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"Looking forward, the EE-ALD approach could serve not just as a tool for integrating incompatible materials but also more generally to build and etch device architectures at atomic scales, an increasingly important capability as circuit geometries shrink," says DARPA program manager Tyler McQuade.

CU's work, performed in collaboration with the US Naval Research Laboratory (NRL) and National Institute of Standards and Technology (NIST), was recognized as one of six 'Highlights of 2016', selected from over 400 accepted oral presentations and posters, at the 16th International Conference on Atomic Layer Deposition (ALD 2016) in Dublin, Ireland (24–27 July).

www.colorado.edu
www.darpa.mil/program/local-control-of-materials-synthesis
www.ald2016.com

IQE's revenue grows 18% year-on-year in first-half 2016

45% growth in photonics drives rise in profit and cash generation

For first-half 2016, epiwafer foundry and substrate maker IQE plc of Cardiff, Wales, UK has reported revenue of £63m, up 18% on £53.2m in first-half 2015 (above the "at least 15% growth" given in a trading update in late July), reflecting increasing revenues in all markets.

Wireless sales were £43.2m, up 7% on £40.5m in first-half 2015. However, Wireless has fallen from 76% of total revenue in first-half 2015 to 69% in first-half 2016 as, continuing the firm's diversification, non-wireless sales have risen from 24% of revenue in first-half 2015 to 31% in first-half 2016.

In particular, Photonics sales continued to see strong double-digit growth to £10.7m, up 45% on £7.4m in first-half 2015 (rising from 14% to 17% of total revenue in first-half 2016). Infrared sales were £4.7m (7.5% of revenue), up slightly on £4.6m in first-half 2015. CMOS++ sales were £0.87m, up from £0.82m in first-half 2015.

License income from joint ventures (a new revenue stream since 2015) amounted to £3.5m, as both joint ventures continued to perform in-line with expectations.

"IQE's continued strong financial performance reflects the significant progress made in diversifying revenues over the past few years, and its growing portfolio of intellectual property," says chief executive Dr Drew Nelson. "A healthy performance in Wireless and IR has been supplemented by accelerated growth in photonics," he adds. "The photonics market is being driven by a diverse range of applications, and is at an early stage in the growth cycle. We expect our photonics business to continue to grow strongly for the foreseeable future."

Aided by the favourable product mix, adjusted gross margin rose from 24% in first-half 2015 to 28%. Hence, despite adjusted sales, general & administrative (SG&A) expenses rising from £6.2m to £7.3m (as IQE invested in anticipation of continuing growth), the adjusted operating profit rose from £6.7m to £10.8m. This resulted in a 62% increase in adjusted fully diluted earnings per share (EPS) from 0.90p to 1.46p.

Net cash generated from operations more than tripled from £3.5m to £11m, due to the improvement in profitability and strong working capital management.

During first-half 2016, net debt rose by £10.4m to £33.6m, largely reflecting that in January IQE settled the final balance deferred consideration from the Kopin acquisition (£10.7m). Conversely, the deferred consideration balance reduced from £17.9m to £1.8m, and will be eliminated in full by the end of September.

"IQE has developed a broad portfolio of intellectual property for advance semiconductor materials," says Nelson. "In addition to the £3.5m of license income generated in the first half, this IP portfolio is increasingly enabling IQE to differentiate itself, and create a platform for continuing growth across its current and emerging markets," he adds. "IQE has a pipeline of new products and customer qualifications which underpin its growth ambitions, with programs expected to ramp through 2017 and 2018. This includes new photonic applications, wireless base stations, advanced solar, and power switching applications."

IQE says that in second-half 2016 trading has commenced well and, with the benefit of a strong pipeline and increasing revenue diversification, the board remains confident that the firm is on track to deliver full-year earnings in line with expectations.

www.iqep.com

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HBTs pHEMTs BiFET/BiHEMTs

Israel's Technion purchases Veeco's 25th GENxplor

Veeco Instruments Inc has received an order for its 25th GENxplor R&D molecular beam epitaxy (MBE) system. Introduced in August 2013, the GENxplor system is said to be the top-selling R&D MBE system to universities and research institutions.

To be delivered to Technion — Israel Institute of Technology in Haifa, Israel, the system will be used by the Oxide Electronics Group for epitaxial growth of high-quality oxide materials, for development into applications including next-generation logic, memory, sensing and optoelectronics devices. The Oxide Electronics Group is a member of the Micro-Nano Electronics Center at the Andrew and Erna Viterbi Faculty of Electrical Engineering at Technion.

"The flexibility and superior technology of the GENxplor system, combined with the unique design of its enhanced e-beam evaporation solution, will enable us to accurately grow materials with exotic physics, which has exciting potential in developing new devices," comments assistant professor Lior Kornblum, head of the Oxide Electronics Group.

The GENxplor system deposits epilayers on substrates up to 3" in diameter and is used for a wide variety of applications such as developing high-speed transistors, night-vision systems, and wireless technology. Veeco says that its efficient single-frame design combines all vacuum hardware with on-board electronics to make it up to 40% smaller than other MBE systems, saving lab space.

www.technion.ac.il/en
www.veeco.com/products/

HC SemiTek orders MOCVD systems for high-volume production

Solid-state lighting manufacturer HC SemiTek Corp of Wuhan, China (which supplies full-spectrum visible light LED chips) has ordered multiple Veeco TurboDisc EPIK 700 gallium nitride (GaN) metal-organic chemical vapor deposition (MOCVD) systems and the TurboDisc K475i As/P (arsenic phosphide) MOCVD system for high-volume LED production.

HC SemiTek says that it ordered the systems on the basis of the award-winning EPIK platform and its own experience with other Veeco MOCVD reactors, including the TurboDisc MaxBright, K465i and K475 MOCVD systems. The EPIK and K475i systems will be installed to meet market demand driven by the need for high performance LEDs in lighting and fine-pitch displays.

"The seamless process transfer between legacy and new Veeco platforms made this an easy decision," comments HC SemiTek's president Dr Rong Liu. "Adding the EPIK and K475i systems to our production fleet ensures we can achieve the most optimal device performance while lowering our cost of ownership to accelerate our company's growth objectives."

"HC SemiTek, a leader in the Chinese LED market, has long been a valuable and important customer to Veeco," comments Veeco's president William J. Miller Ph.D.

Introduced in 2014, the EPIK 700 MOCVD system is reckoned to be the LED industry's highest-productivity system for blue/green LEDs. Introduced earlier this year, the K475i system can be used to make red, orange and yellow LEDs, as well as multi-junction III-V solar cells, laser diodes and transistors. Based on Veeco's proven TurboDisc technology and the proprietary Uniform FlowFlange, Veeco says that its MOCVD systems enable users to achieve cost per wafer savings of up to 20% compared with previous MOCVD systems through improved wafer uniformity, reduced operating expenses and increased productivity.

http://en.hcsemitek.com
www.veeco.com

Epistar orders Veeco EPIK 700 MOCVD systems to meet demand for LED lighting applications

Epistar Corp of Hsinchu Science-based Industrial Park, Taiwan (the world's largest LED epiwafer and chip maker) has ordered multiple Veeco TurboDisc EPIK700 GaN MOCVD systems for the production of LEDs.

"The improved demand of solid-state lighting combined with the need to compete in a competitive market dictates we choose the most productive and most cost-efficient MOCVD platform in the industry," states Epistar's president Dr MJ Jou. "Veeco has been our supplier of choice dating back to their innovative K465i system," he notes. "After adopting their latest EPIK platform, we have achieved superior yield results and lowered manufacturing costs. The addition of these new EPIK MOCVD systems will help advance our production goals and improve our product competitiveness," he believes.

"A leader such as Epistar ramping production to meet demand of LEDs is a positive sign for the industry as a whole," believes James T. Jenson, senior VP, Veeco MOCVD operations, noting that the market seems to be turning upward again. We look forward to supporting Epistar's future MOCVD requirements as they continue their growth plans."

www.epistar.com.tw

Riber slashes losses in first-half 2016, driven by 29% growth in MBE system revenue

Order growth of 40% to strengthen turnaround in full-year 2016

For first-half 2016, Riber S.A. of Bezons, France, which manufactures molecular beam epitaxy (MBE) systems as well as evaporation sources and effusion cells, has confirmed revenue of €6.9m, up 21% on first-half 2015's €5.7m. Growth was driven by all product lines, with MBE systems sales up 29% from €2.8m to €3.6m, sales of services & accessories up 14% from €2.1m to €2.4m, and sales of cells & sources up 25% from €0.8m to €1m.

In addition, reflecting the increased sales and the stronger absorption of fixed production costs, Riber has now reported gross margin up from 9% in first-half 2015 to 37% in first-half 2016.

Following the roll-out of its savings plan, Riber has cut operating expenditure by 10% year-on-year. Hence, despite continuing to invest (ramping up R&D with a view to developing its range of products and services), net loss has been cut significantly from –€3.5m to –€1.2m.

During first-half 2016, cash (net of financial debt) has improved from €0.7m to €0.8m (factoring in the sale of non-strategic real-estate assets for €2.6m at the end of first-half 2016). Furthermore, a capital increase undertaken in August raised €1.4m. Also, the delivery schedule for the end of the year should further strengthen the cash position.

reflecting the increased sales and the stronger absorption of fixed production costs, Riber has now reported gross margin up from 9% in first-half 2015 to 37% in first-half 2016

As announced on 12 July, orders rose by 40% from €6.3m in first-half 2015 to €8.8m in first-half 2016, comprising five MBE systems (including one production machine) for delivery in 2016 supplemented by strong growth in sales of components and services.

Riber notes that the turnaround is expected to be further strengthened between now and the end of the year. Growth is being supported by sustained development of its range of services and accessories plus concrete progress made with upcoming major contracts.

Riber is hence confirming its full-year 2016 revenue target of growth of over 30%, paving the way for improved net income versus 2015.

www.riber.com

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SUSS MicroTec appoints former company veteran as new president & CEO

The supervisory board of SUSS MicroTec AG of Garching, Germany, which makes photomask aligners, laser processing systems and wafer bonders, has appointed Dr Franz Richter as a new member of the management board (with a contract running for three years, after assuming the role of president & CEO on 7 September.

Following his professional activities as a scientist at the Carl Zeiss Group and the Fraunhofer Institute for Laser Technology, Richter spent 14 years working for SUSS MicroTec, the last six of them as its CEO until 2004. During this time, the IPO took place and revenue grew beyond 200m Euro. After serving as president of the Semiconductor Equipment Division at Unaxis (now OC Oerlikon) in Pfäffikon, Switzerland, he set up Thin Materials AG and became its CEO in 2007. The firm is engaged in process development for 3D chip integration and was sold in 2013 to Nissan Chemical Industries Ltd of Tokyo, Japan. Richter currently serves as a member of the supervisory board of the stock-listed firm Siltronic AG of Munich, Germany, and of the administrative board of Meyer Burger Technology AG of Gwatt, Switzerland and the COMET Holding AG of Flamatt, Switzerland.

SUSS MicroTec says that, during his career, Richter has gained international expertise in technology management topics, especially in the semiconductor industry. In all these years, he remained closely linked to SUSS MicroTec. Richter stands for "continuity and, at the same time, for innovative solutions," comments supervisory board chairman Dr Stefan Reineck.

www.suss.com

Mitsubishi Heavy Industries Machine Tool collaborating with D-process on room-temperature wafer bonding services

Integrated polishing and room-temperature bonding system targets expansion of foundry business

Mitsubishi Heavy Industries Machine Tool Co Ltd of Ritto, Shiga, Japan (founded in October 2015), a group company of Tokyo-based machinery maker Mitsubishi Heavy Industries Ltd (MHI), has agreed with D-process Inc of Yamato, Kanagawa, Japan to collaborate on bonding services performed using MHI's room-temperature wafer bonding tools.

Room-temperature bonding activates wafer surfaces by irradiation with an ion or atom beam in a vacuum. Because — in contrast to conventional bonding — no heat is applied, room-temperature bonding is suited to materials with different coefficients of thermal expansion (CTE) as well as the manufacture of micro-electro-mechanical systems (MEMS), which require very precise finishing, and biodevices, which cannot be heated. Room-temperature bonding can also be performed on a wide range of materials, including silicones, oxide dielectrics, glass, compound semiconductors, metals and ceramics.

The collaboration aims to establish an integrated service structure for polishing and room-temperature bonding

The collaboration aims to establish an integrated service structure for polishing — including D-process' chemical mechanical polishing (CMP) — and room-temperature bonding as a way of advancing and expanding MHI's semiconductor foundry operations.

The agreement calls for Mitsubishi Heavy Industries Machine Tool to perform bonding, using its own room-temperature bonding machines, of wafers that have undergone CMP and/or other surface smoothing processes at D-process on consignment from customers. Mitsubishi Heavy Industries Machine Tool has offered room-temperature bonding services since 2014, including orders received from D-process. Future expansion is now anticipated in the bonding foundry business.

By providing services through D-process, Mitsubishi Heavy Industries Machine Tool looks to market the benefits of room-temperature bonding technology to the semiconductor manufacturing industry. The firm also aims to raise the level of bonding processes through close information exchange with D-process, as a way of expanding sales of its room-temperature bonding machines. Meanwhile D-process, which primarily deals in CMP services and is seeking to expand and improve its bonding services segment, aims to develop a customer base for room-temperature bonding.

Mitsubishi Heavy Industries Machine Tool reckons that, by teaming up with D-process, it will be positioned to accelerate the widespread adoption of room-temperature bonding both in Japan and abroad.

www.d-process.jp
www.mhi-machinetool.com/en

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DISCOVER PROGRESS

Leti orders EVG HERCULES nanoimprint lithography system to bolster process development and demo capabilities of joint EVG–Leti INSPIRE program

EV Group of St Florian, Austria — a supplier of wafer bonding and lithography equipment for semiconductor, micro-electro-mechanical systems (MEMS), compound semiconductors, power devices and nanotechnology applications — says that a HERCULES nanoimprint lithography (NIL) track system has been ordered by micro/nanotechnology R&D center CEA-Leti of Grenoble, France, where it will augment the process development and demonstration capabilities available to participants in the collaborative EVG-Leti INSPIRE program.

More than an industrial partnership to develop NIL process solutions, the INSPIRE program was launched by Leti and EVG in June 2015 to demonstrate the cost-of-ownership benefits of NIL for a wide range of applications, such as photonics, plasmonics, lighting, photovoltaics, wafer-level optics and biotechnology. Through INSPIRE, Leti and EVG are supporting the development of new applications from the feasibility-study stage to the first manufacturing steps on EVG platforms, as well as transferring integrated process solutions to industrial partners. The aim is to significantly lower the barriers for adopting NIL for use in manufacturing novel products.

"Nanoimprint lithography has shown significant potential as a low-cost, high-resolution patterning solution for emerging and growing applications outside the semiconductor industry," says Laurent Pain, patterning program manager, Leti. "The INSPIRE program launched by Leti and EVG is designed to accelerate the adoption of this promising technology in high-volume manufacturing. Installing this tool supports our goal of expanding and accelerating the scope of INSPIRE and demonstrating the benefits of this versatile, powerful nano-patterning technology," he adds.

"To date, this program is supporting the development of NIL solutions for several customers thanks to the combined expertise and capabilities provided by both organizations," says Markus Wimplinger, EVG's corporate technology development and IP director. "With the addition of EVG's HERCULES NIL track system — which has already been installed in multiple high-volume manufacturing sites — we expect INSPIRE's success to continue to grow."

HERCULES NIL is a fully integrated track system that combines cleaning, resist coating and baking pre-processing steps with EVG's proprietary SmartNIL large-area NIL process in a single platform. It can imprint structures in sizes ranging from tens of nanometers up to several microns while offering throughput of 40wph (wafers per hour) for 200mm wafers. The system is built on a highly configurable and modular platform that accommodates a variety of imprint materials and structure sizes — providing a high degree of flexibility in addressing manufacturing needs. The fully integrated approach also minimizes the risk of particle contamination.

www.evgroup.com/en/products/lithography/nanoimprint_systems
www.leti.fr

OIPT systems used in UV LED manufacturing

UK-based Oxford Instruments, which provides process technology equipment for the manufacturing of high-brightness light-emitting diodes (HBLEDs), says its systems are being used to facilitate the introduction of ultraviolet (UV) LEDs being utilized in water purification systems to bring safe drinking water to remote places.

The firm's PlasmaPro1000 Stratum plasma-enhanced chemical vapour deposition (PECVD) tool is used for depositing dielectric materials essential to the manufacture of UV LEDs, for which the film quality, batch size and throughput are suited. The systems can produce the thicker passivation layers that UV LEDs need to operate reliably at high powers while maintaining film quality and low cost of ownership. The batch size of up to 14 x 4" wafers is enabled by the chamber design, which ensures that each wafer within the batch achieves the same amount of high-specification film deposition, says the firm. Also, fast plasma clean of the chamber is automatically controlled through optical emission spectroscopy (OES), helping to realise maximum yield and uptime.

"UV LEDs have several advantages over traditional UV light sources," says Dr Mark Dineen, optoelectronics product manager at Oxford Instruments Plasma Technology (OIPT). "They operate at low DC power, meaning that they can be powered from a solar energy source. Combined with the fact that they are lighter and more robust than the traditional sources, this makes them ideally suited for use in remote, off-grid locations where clean water supplies are limited or non-existent," he adds.

"UV LEDs are also tuned to the optimum wavelength for the removal of bacteria, making them significantly more effective in purifying water than traditional light sources," Dineen says. "Lastly, UV LEDs do not contain mercury, an essential component part of traditional UV lamps. Consequently there is a significant reduction in the environmental impact risk, through both accidental contamination and the need for recycling when comparing UV LEDs and traditional UV lamps."

www.oxford-instruments.com/plasma

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Rubicon closing Malaysia plant by end-2016

Sapphire substrate maker refocusing from LEDs to optical and industrial market for foreseeable future

Rubicon Technology Inc of Bensenville, IL, USA (which makes monocrystalline sapphire substrates and products for the LED, semiconductor and optical industries) has announced plans to cease all production activities at its plant in Penang, Malaysia by the end of November and complete shutdown of the facility by the end of the year.

The Malaysia facility has been engaged primarily in producing polished sapphire substrates and patterned sapphire substrates (PSS) for the LED market, and the decision was made in order to focus on the optical and industrial sapphire market for the foreseeable future.

"The sapphire industry continues to be very challenging, with pricing for LED sapphire products continuing to decline throughout this year," says CEO Bill Weissman. "Given the market conditions, our strategy has been to build a business more focused on the optical and industrial sapphire market, where we have greater differentiation from our competitors and have interesting new technologies in development," he adds.

The sapphire industry continues to be very challenging, with pricing for LED sapphire products continuing to decline throughout this year... Our strategy has been to build a business more focused on the optical and industrial sapphire market,

"We had also been trying to stay in the LED substrate market by limiting our product offering to 6-inch diameter wafers, where there is less competition, and working hard to reduce cost to make that product profitable. While we made significant progress on that front, the continual decline of prices has made the prospects of becoming profitable in the LED substrate market unlikely for the foreseeable future."

Rubicon cites its high-quality crystal, strong and developing US customer base, and optical finishing capability as strong differentiators in the optical and industrial sapphire market and believes that there are emerging applications in that market that will drive revenue and margin growth in coming years.

www.rubicon-es2.com

BluGlass installs upgraded RPCVD chamber to improve uniformity of low-temperature process

Upgrade to be implemented next on larger chamber to demonstrate scaling of technology

BluGlass Ltd of Silverwater, Australia — which was spun off from the III-nitride department of Macquarie University in 2005 to develop a low-temperature process using remote plasma chemical vapor deposition (RPCVD) to grow material including gallium nitride (GaN) and indium gallium nitride (InGaN) on glass substrates — has completed installation of an RPCVD chamber upgrade that is now fully operational.

The new chamber installation is part of BluGlass' scaling plans for the commercialization of RPCVD and has been designed to improve the uniformity of the low-temperature manufacturing process. This upgrade has been implemented on BluGlass' smaller RPCVD chamber (the BLG-180). Upon optimizing the new chamber on the BLG-180, BluGlass expects to similarly upgrade its larger RPCVD chamber (BLG-300).

BluGlass is currently focused on demonstrating LED efficiency improvements with several major LED players. In addition to these industry collaborations, BluGlass is also required to demonstrate the scalability of RPCVD technology in order to align with current LED manufacturing capabilities within the industry. While BluGlass has to date retrofitted both Veeco and Aixtron deposition systems, these are relatively small by today's LED manufacturing standards. Following a successful demonstration of uniformity, a similar upgrade will be fitted onto BluGlass' larger RPCVD system. The firm also intends to work with manufacturing partners for further scaling of the systems to commercial production standards using the same scalable design approach currently being tested on-site at BluGlass.

The upgraded chamber has been designed to build on and improve current performance data, including both thickness and performance uniformity using an easily scalable chamber design that can be applied to larger deposition areas. BluGlass says that it chose to implement this design on the smaller of the two RPCVD systems to avoid any disruption to ongoing collaborations with its industry partners that continue to make positive progress using its larger RPCVD system.

www.bluglass.com.au

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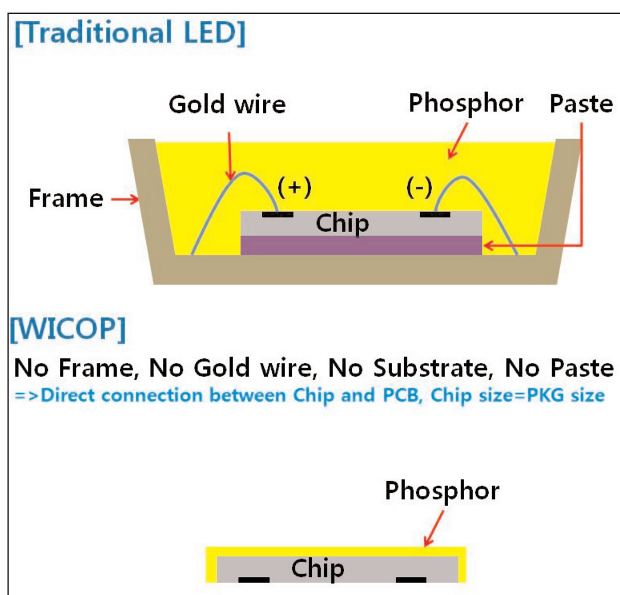
Seoul Semiconductor mass producing 210lm/W WICOP package-free LEDs

South Korean LED maker Seoul Semiconductor Co Ltd is now mass producing its new 'WICOP' products, with a luminous efficiency of 210lm/W (350mA).

Composed of just an LED chip and phosphor, it does not require chip packaging (e.g. frames and gold wires etc). This new concept of LED product hence does not require any investment in packaging equipment and parts that need to be packaged (previously essential for LED manufacturing).

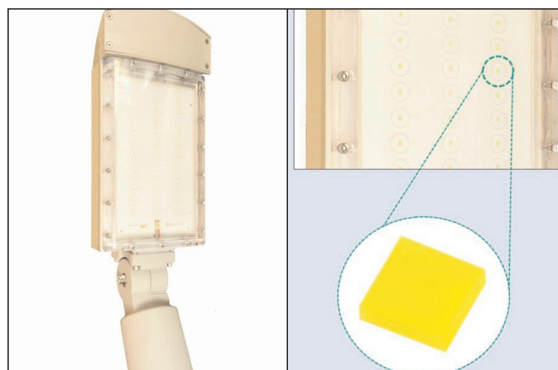
Seoul Semiconductor says that its new WICOP product (Y22) launched recently has broken the convention that if the product is structured simply (with only a chip and phosphor) then it would be hard to enhance luminous efficiency. The product has been realised based on Seoul Semiconductor's proprietary LED chip manufacturing technology and other related technologies. In particular, it has achieved higher luminous efficiency than conventional packaged high-power LED products. It is also reckoned to be over 17% more luminously efficient than CSP (chip-scale package), which is similar in appearance.

As the company that developed WICOP (claimed to be the world's first package-less LED), Seoul Semiconductor has supplied WICOP to both IT and automobile manufacturers since 2012. In 2015, it launched two models of WICOP lighting products. Now that it has started to mass produce WICOP with a 210lm/W luminous efficiency for the first time, it has positioned itself as a pioneer of package-less LED products.



Seoul Semiconductor says that the importance of high-power LEDs such as WICOP has recently risen rapidly in the global LED market. Market research firm Strategies Unlimited showed that in 2015 super-high-power LED products (with high luminous efficiency, such as WICOP) comprised 20% of the total LED market, and should exceed 30% by 2020.

"The WICOP products which have been independently developed by Seoul Semiconductor would render the currently increasing investment in the packaging industry unnecessary, and will become the standard for next-generation LEDs as it is an innovative product that reflects a new wind of change in the LED market," reckons chief technology officer Ki-bum Nam. "We will continue to develop various solutions related to WICOP for customers in addition to developing new WICOP products with a luminous efficiency of over 220lm/W by 2020," he adds.



WICOP module for lighting applications.

www.SeoulSemicon.com

Epistar files patent infringement lawsuit against Adamax

On 30 August, Epistar Corp of Hsinchu Science-based Industrial Park, Taiwan (the world's largest manufacturer of LED epiwafers and chips) has filed a patent infringement lawsuit against Adamax Inc (trading as Newhouse Lighting) in the US District Court for the Northern District of California. The complaint asserts that Newhouse Lighting products and technology infringe six Epistar patents and seeks injunctive relief to halt further sales.

Epistar's complaint alleges that the Newhouse Lighting filament bulbs such as the Dimmable Flame Tip 3.5W LED Vintage Edison Filament Bulb infringe one or more claims of Epistar's US patent numbers 6,346,771 ('High Power LED Lamp'), 7,489,068 ('Light Emitting Device'), 7,560,738 ('Light-Emitting Diode Array Having An Adhesive Layer'), 8,240,881 ('Light-Emitting Device Package'), 8,791,467 ('Light Emitting Diode And Method Of Making The Same'), and 9,065,022 ('Light-Emitting Apparatus').

Epistar notes that it has invested millions of dollars in R&D on LED technologies that have led to a patent portfolio consisting of over 4000 issued patents and pending patent applications, laying the foundation of its LED filament technologies.

www.epistar.com.tw

Seoul Semiconductor sues Kmart for patent infringement

South Korean LED maker Seoul Semiconductor Co Ltd (SSC), together with its affiliate company Seoul Viosys Co Ltd, has filed a patent infringement lawsuit in the US District Court for the Central District of California against global retail firm Kmart Corp (which has about 1000 stores in the USA and annual revenue of $25bn).

Seoul Semiconductor claims Kmart is selling LED products that infringe eight patents covering fundamental LED technologies, including high-CRI (color rendering index) enhancement with phosphor combinations, LED epitaxial growth, LED chip fabrication, multi-chip mounting technology, omni-directional LED lamp technology, and Acrich MJT (multi-junction technology). The accused product includes an LED filament bulb that is gaining widespread consumer attention in the USA as a replacement for traditional incandescent bulbs.

One of the patents was invented by professor Shuji Nakamura, recipient of the 2014 Nobel Prize in Physics for his contributions to blue LED development. Another co-inventor is Dr Steven DenBaars, a professor of Materials and Electrical and Computer Engineering at the University of California, Santa Barbara (UCSB).

Seoul Semiconductor says that it has continuously succeeded in patent enforcement actions since its case against Taiwan-based AOT Inc in 2003. Last year, the firm filed patent infringement actions against multiple North American TV makers, resulting in a judgment for infringement and/or payments for past damages. This year, Seoul Semiconductor won a unanimous jury verdict against Japanese LED lens maker Enplas, in which the jury held — and the US district court upheld — a finding that Enplas willfully infringed Seoul Semiconductor's patented technology and is liable for $4m. Seoul Viosys has also pursued active enforcement campaigns, resulting in a judgment for infringement as well as payments for past damages and a royalty-bearing license against a US-based UV LED curing device maker. Recently, Seoul Viosys filed another patent infringement lawsuit against a UV LED insect trap maker in the USA.

To protect its patented technology, Seoul Semiconductor has engaged the litigation and intellectual property firm Latham & Watkins, whose partner Larry Gotts was also lead counsel for Seoul Semiconductor's infringement lawsuit against Enplas (in which SSC succeeded in obtaining a willful infringement judgment).

"We have invested tremendous resources for environment-friendly technology innovation for 25 years, and as a result we have successfully commercialized various kinds of the first-developed technologies," says Ki-bum Nam, VP of the lighting business department at Seoul Semiconductor. "To create a fair market competition, we continuously take any and all actions necessary to deter such infringement and protect our intellectual property."

www.SeoulSemicon.com

Soraa launches Vivid GU24 base PAR20, PAR30 & PAR38 directional LED lamps for California regulations

Soraa Inc of Fremont, CA, USA, which develops solid-state lighting technology fabricated on 'GaN on GaN' (gallium nitride on gallium nitride) substrates, has added GU24 base PAR20, PAR30 (short and long neck) and PAR38 LED lamps to its LED product portfolio. Suitable for both commercial and residential California applications, Soraa's lamps provide a replacement for halogen lamps.

"California lighting designers and customers have been asking for high-quality large GU24 lamps," according to George Stringer, senior VP of global sales & marketing. "With low power consumption, unique narrow spot beams enabled by our Point Source Optics and our Violet-Emission 3-Phosphor technology; these lamps completely outshine the competition," he claims.

Soraa's Point Source Optics technology is said to produce high-intensity and uniform beams, enabling it to offer 8, 9 and 10° narrow-spot PAR versions with double the peak intensity of other LED makers, it is claimed.

Soraa's Violet-Emission 3-Phosphor (VP_3) LED technology allows the rendering of colors and whiteness. Utilizing every color in the rainbow, especially deep red emission, VP_3 Vivid Color renders warm tones accurately, and achieves a color-rendering index (CRI) of 95 and deep red (R9) rendering of 95. Also, unlike blue-based white LEDs without any violet emission, the VP_3 Natural White is achieved by engineering the violet emission to properly excite fluorescing brightening agents including natural objects like human eyes and teeth; as well as manufactured white materials such as clothing, paper and cosmetics.

Designed for seamless fixture integration, Soraa's GU24 PAR lamps are compatible with a wide variety of dimmers and are suitable for use in enclosed, non-ventilated indoor and outdoor fixtures. They are available in 8°, 9°, 10°, 25°, 36°, 50° and 60° beam angles as well as 2700K, 3000K, 4000K and 5000K color temperatures. Additionally, the 8°, 9°, and 10° lamps work the firm's its magnetic accessory SNAP System. With a simple magnetic accessory attachment, beam shapes can be altered and color temperature can be modified, increasing design and display possibilities.

www.soraa.com

Lumileds launches LUXEON SunPlus Series LEDs tailored to horticulture applications

LED maker Lumileds of San Jose, CA, USA has introduced the LUXEON SunPlus Series, its first line of purpose-built LEDs that provide the exact wavelengths of light needed for horticulture applications.

Based on the rapidly expanding world population and the increasing population in city centers, the horticulture industry is responding by growing more food indoors using LEDs, allowing a greater amount of food to be grown in smaller spaces (using up to 90% less water than growing outdoors).

The LUXEON SunPlus 20 Line targets the needs of greenhouses farmers who want to add supplemental high-bay lighting to enable 24 hour or year-round growth. Growers can develop single-channel solutions using key wavelengths for photosynthesis, blue (420–480nm) and red (620–670nm). Or they can develop multi-channel solutions with select LEDs to optimize light output for different stages of the plant's life cycle, including seedlings, germination, vegetative growth, flowering, etc. The SunPlus 20 Line consists of 2.0mm x 2.0mm high-power LEDs in Royal Blue (440–460nm), Deep Red (655–675nm), Far Red (720–750nm), Lime (broad spectra) and Cool White colors.

LUXEON SunPlus LEDs

"Only Lumileds bins its horticultural LEDs by PPF [photosynthetic photon flux in μmol/s] and wavelength, so lighting designers know exactly what they are getting and can design their fixtures for optimal plant productivity," claims Luis Aceña, senior manager of business development. "The SunPlus 20 Line features a high PPF per LED, which leads to more compact solutions. In addition, because all the LEDs have the same focal length, it is very effective."

Vertical farming, using multiple stacks of growth trays, requires lighting from short distances with high uniformity. The LUXEON SunPlus 35 Line addresses these needs with Blue (440–460nm), Lime, White and three shades of Purple mid-power LEDs in a 3.5mm x 3.5mm format. "Our Purple LED offerings are distinct in that they are long-lasting, high-efficiency blue LEDs under red phosphor, offering the highest uniformity for consistent growth," claims Aceña. "Other companies are combining blue and red LEDs to get purple hues, but this is problematic because red LEDs age faster than blue ones, so the red/blue ratio keeps changing over time, obtaining unreliable growth results," he adds. The Purple LEDs are offered with different blue PPF relative to PPF total across the photoactive region (400–700nm). The Purple (2.5% Blue) LED encourages stem growth and flowering, the Purple (12.5% Blue) LED encourages general-purpose growth, and the Purple (25% Blue) LED encourages vegetative growth for larger leaves.

www.lumileds.com/horticulture

Lumileds introduces LUXEON Stylist Series of LEDs optimized for fashion retail, fresh food and restaurant industries

Lumileds has launched the LUXEON Stylist Series, which is claimed to be the first series of LEDs engineered to provide the optimum lighting environment to sell products in fashion retail stores, fresh food markets and restaurants.

The Stylist Series is based on four proprietary technologies: CrispWhite Technology, CrispColor Technology, FreshFocus Technology and AtmoSphere Technology. "The right lighting has a profound impact on customer behavior, affecting the time spent in stores and net revenues," says Luis Aceña, senior manager, Stylist Series. "With the Stylist Series, lighting designers are now able to bring out the very best colors in the products and places it illuminates."

In fashion retail, CrispColor Technology highlights rich colors by achieving a higher color gamut. LUXEON LEDs with CrispColor have color points below the black-body line to target proposed ASSIST and ANSI requirements for Class A and TM30 specifications. CrispColor can enable a more continuous spectrum, offering a suitable replacement for halogen and incandescent lighting. CrispWhite activates fluorescent whitening agents in retail items, making white fabrics and paints appear vivid and bright white.

For fresh food, Lumileds has invested in spectra development that presents food in its most appealing light. FreshFocus offers five different lighting approaches for produce (fish, marbled meat, red meat, bread and pastries) to display food in its most natural way. "When food looks fresh, customers are more likely to purchase more and they will be more likely to return," says Aceña.

For restaurants and bars etc, AtmoSphere is designed to help to reinforce the image and brand by creating a warm ambiance.

The Stylist Series is available in a variety of product families, including CoB (chip-on-board), Mid Power and Matrix Platform.

www.lumileds.com/StylistSeries

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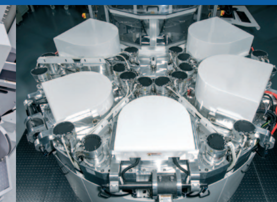

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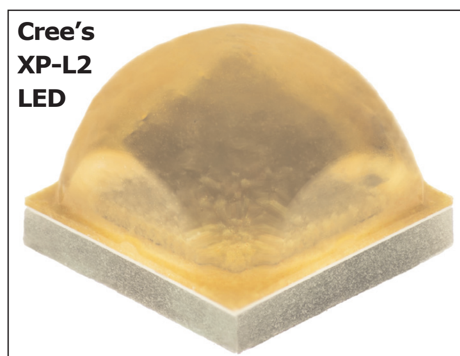
Cree launches next generation of high-power XP-L LEDs, boosting output by 7% and efficiency by 15%

LED chip, lamp and lighting maker Cree Inc of Durham, NC, USA has launched the XLamp XP-L2 LED, delivering up to 7% more lumens and 15% higher lumens-per-watt (LPW) than the XP-L LED.

Leveraging elements of Cree's SC5 Technology Platform, the high-power XP-L2 LED improves the lumen density, voltage characteristics and reliability of the XP-L LED in the proven XP package. The firm says that the new XP-L2 LED provides an easy drop-in upgrade to achieve higher system LPW for lighting manufacturers with existing XP-L designs, eliminating redesign costs. It also enables reduced size and cost for new designs.

"The new XP-L2 LED improves upon the XP-L LED in the same footprint, allowing us to quickly achieve higher system efficacy in our existing XP designs without the burden of increased development time and cost," comments Nathan Heiking, product manager at Kenall Lighting.


Cree's XP-L2 LED

The XP-L2 LED raises the luminous efficacy for warm-white color temperature (3000K) at a color rendering index (CRI) of 80 (at 85°C) to 171LPW. In addition, it is now available in EasyWhite 2-, 3- and 5-step color temperatures from 2700K to 6500K to enable luminaire color consistency. The XP-L2 LED has LM-80 data available immediately, enabling luminaires using XP-L2 to be qualified for ENERGY STAR and DesignLights Consortium.

"The new XP-L2 LED delivers twice the lumen output of other similar-size high-power LEDs, enabling lighting manufacturers to improve the performance of their lighting designs and reduce the size and cost of new designs for applications, such as industrial and stadium lighting," claims Dave Emerson, VP & general manager for Cree LEDs.

Product samples are available now and production quantities are available with standard lead times.

www.cree.com/xlamp/xpl2

Cree launches portfolio of 25 next generation LED bulbs

Cree has announced a completely new portfolio of next generation LED bulbs consisting of 25 new products, offering better light quality, better dimming, better lifetime, better warranty and better pricing.

Notable features in the new bulbs include superior lifetimes, with most projected to last 22+ years and some up to 32 years. Color rendition is improved, with smoother, quieter dimming to levels as low as 1%. Cree's 'Candlelight Dimming', available in the new candelabra bulb, mimic's a true candle flame with a warmer 1800K color when dimmed.

The new bulbs meet or surpass the requirements for ENERGY STAR product certification and are covered by a 10-year 100% satisfaction guarantee. The portfolio includes new A-lamps, BR lamps, PAR lamps and Candelabra lamps, as well as a new series of recessed downlight retrofit products.

The new LED bulbs are available both online and in-store at The Home Depot.

Cree offers 10-year warranty on intelligent lighting systems

Cree has introduced what it claims is the first 10-year warranty for intelligent lighting systems on all new SmartCast Technology luminaires with integrated sensors. Cree SmartCast Technology delivers up to 70% energy savings for half the cost of other solutions, it is claimed.

"After millions of cumulative hours of accelerated lifetime testing, Cree is confident that it has proven the long-term reliability of its intelligent lighting products," says David Elien, senior VP, lighting.

The new 10-year warranty covers all commercial-grade SmartCast Technology troffers and suspended luminaires. It is said to lower the total cost of ownership and overall install costs for SmartCast customers compared with control systems that require additional costs for extended warranties and are often limited to five-year terms.

Every luminaire in the SmartCast Technology portfolio uses OneButton Setup to commission up to an entire building with a single stroke, offering intelligence that is live within minutes. The result enables personalized, task-specific environments that adapt to users in each space for increased productivity. It also applies what it learns to drive energy costs lower for continual operational improvement, says Cree. The firm adds that SmartCast reduces design time, wires and setup time often associated with traditional controls systems. The system provides smart lighting that meets existing and emerging building codes and operates wirelessly or over Power over Ethernet.

www.cree.com/smartcast

Osram and BMW laser headlight development nominated for 2016 German Future Prize

A team from Osram and BMW is one of three nominees for the €250,000 2016 German Future Prize (to be presented by Germany's President Joachim Gauck on 30 November) awarded annually in recognition of outstanding innovations in technology, engineering or natural scientific. Working together on the project 'Laser light technology for the automobile — with safety and foresight into the future', the two companies have developed a light source and high-beam lamp technology that is already in use on the BMW i8 (since 2014) and BMW 7 series (since 2015).

In combination with other driver assistance functions, laser light technology (with ranges of up to 600m) significantly enhances the driver's field of vision at night, contributing to road safety. Additionally, Osram and BMW have implemented an integrated fail-safe system that prevents blue laser light from being emitted in the event of a malfunction, crash or manual manipulation (guaranteed by multiple redundant safety mechanisms).

BMW 7 Series headlight with laser light.

For laser technology to be a sustainable and successful option in road traffic, there needs to be a high level of usage. Current developments by Osram and BMW are therefore focused on reducing costs and simplifying module design. The two firms are working on the interplay between safety, comfort, energy efficiency and design. Osram has already developed further generations of laser technology for other models of vehicle, and BMW is planning to install laser light in several series of cars being revised over the next few years.

Additional applications in other forms of transportation are conceivable, such as in aircraft, ships and trains. Also, the healthcare and entertainment sectors could benefit from the technology in the future, the firms reckon.

www.deutscher-zukunftspreis.de

Osram adds bright, compact true green and hyper red LEDs for design flexibility in mobile fitness applications

Osram Opto Semiconductors GmbH of Regensburg, Germany is launching two LEDs in true green and one version in hyper red as additions to the PointLED and Firefly families for mobile applications such as fitness tracking and health monitoring. Osram can therefore offer a greater selection of products to supplement its integrated sensors.

Due to their greater brightness, the PointLEDs in true green offer better performance and provide better signals than comparable solutions on the market, it is claimed. The Firefly E 1608 in hyper red has a special narrow-band wavelength range around 660nm so it also offers optimized signal recognition. It is suitable for measuring oxygen levels in blood, while the true green version is suitable for use in pulse monitors. Both color versions of the Firefly have the advantage of compact dimensions, giving greater flexibility in designing products.

In true green the PointLED offers greater brightness of 1800–2800mcd at a drive current of 20mA. In fitness trackers it therefore provides an improved signal with a higher output compared with earlier versions. It hence needs less energy to produce the same signal as its predecessors, enabling the battery to last about 50% longer.

"Thanks to the compact dimensions, much less space is needed on the board in the tracker," says Russell Willner, product manager LED at Osram Opto. In addition, the hyper red version at 660nm has a special narrow-band wavelength range suitable for these applications. The true green version has a typical brightness of 1400mcd and a wavelength of 525nm. Both versions of the Firefly E 1608 have a small package of only 0.8mm x 1.6mm x 0.6mm.

Osram Opto says that, with the introduction of the new PointLED and Firefly E 1608, it is offering more options for developing mobile devices such as fitness tracking armbands. Customers can either produce their own designs or benefit from preconfigured integrated sensors such as the SFH 7050 from Osram's Biofy family. "Choice is a huge benefit for our customers because the wearables market is a fast-growing one and differentiated solutions are in demand," says Willner.

The Pointled is already fully available. The Firefly E1608 is available for first customer projects. Volume start-up is planned for the early 2017.

www.osram-os.com

EU's MIRPHAB project unveils mid-infrared chemical sensor six-times faster than alternatives

New chemical sensor capable of detecting drugs and explosives from a distance of 30m

The project MIRPHAB (MidInfraRed PHotonics devices fABrication for chemical sensing and spectroscopic applications) has unveiled a chemical sensor capable of detecting drugs and explosives from a distance of 30m.

Lasting from the beginning of 2016 to the end of 2019, the MIRPHAB project comprises an 18-strong consortium funded by €13m from the European Commission's Photonics Public Private Partnership (PPP) as well as €2m from the Swiss government. The aim is to create a reliable supply chain of mid-infrared (MIR) photonic components so that companies (particularly SMEs already active in analytical MIR sensing) can make ready-for-use sensing devices by 2020. MIRPHAB is also establishing a pilot line to serve the growing needs of European industry in the field of analytical micro-sensors.

"We are making the next generation of sensors that are compact, low cost, low on power consumption and capable of real-time detection where the speed and sensibility is unrivalled," says project coordinator Sergio Nicoletti. The new sensor, which reads the unique frequencies given off when liquids or gases interact with light, could soon be installed at the entrance of airports, in order to scan crowds and bags for suspicious materials before they enter the building. The latter is one of many potential applications contemplated. Among other things, the mid-IR sensor can detect diseases, scan for bacteria in fridges, detect the presence of alcohol or even monitor carbon emissions to help mitigate climate change.

The new development could lead to new business and commercial opportunities for SMEs and large industrial groups, reckons Jose Pozo, director of technology and innovation at the European Photonics Industry Consortium (EPIC). The planned pilot line will not only enable reduced cost, power consumption and size, but the exploitation of a mixed silicon/III-V technology is also foreseen to open the way to applications not addressable with current technologies and components.

The new sensor harnesses new photonics technology and uses the mid-IR wavelength band (3–12μm) for greater performance. In this so-called 'fingerprint region', chemicals exhibit intense absorption features that allow unmatched detection capabilities and unambiguous identification, it is claimed.

The device can detect chemicals at a rate of 1200 per hour — over six times more than standard portal scanners — and is also very small. "We want to shrink current technology down to the size of a mobile phone," says Nicoletti. To achieve this, the R&D process taps into project partners' expertise in the field of spectroscopy, mid-IR optoelectronics, sensing systems and applications.

MIRPHAB is one of three manufacturing pilot lines supported by Horizon 2020 (the European Union's framework program for Research and Innovation for 2014–2020) to boost Europe's competitiveness in the sector (along with PIX4LIFE, a photonics platform for health applications, and PI-SCALE, which is hoped to accelerate the commercial adoption of OLED technology).

www.mirphab.eu

II-VI presenting portfolio for laser material processing

Engineered materials and optoelectronic component maker II-VI Inc of Saxonburg, PA, USA will exhibit at EuroBLECH 2016 (24th International Sheet Metal Working Technology Exhibition) in Hanover, Germany (25–29 October) in Hall 11, Booth #F154, which will house the business divisions II-VI HIGHYAG, II-VI Infrared, II-VI Photop, II-VI Suwtech and II-VI Laser Enterprise in one location.

The firm will present its latest products for laser material processing including laser processing heads, laser light cables, laser optics and laser modules. The broad portfolio reinforces what II-VI claims is its leading global position in the laser material processing industry.

In particular, laser diode modules, visible and near-infrared (NIR) lasers, narrow-linewidth lasers and Q-switched lasers will be displayed.

This includes II-VI Suwtech's new 9xxnm fiber-coupled diode laser module (offering output powers from 140W up to 300W). The module is a single-emitter cascaded design that allows higher output powers with increased wall-plug efficiency and simplified thermal management.

Also, II-VI Laser Enterprise will highlight a higher-power 1060nm single-mode laser diode seed module and a new line of high-power multi-bar stack laser diode modules. The new 1060nm laser diode seed module delivers kink-free powers of up to 1.5W in nanosecond pulse operation, enabling fiber-laser systems with highly efficient pulse amplification and improved frequency conversions.

www.euroblech.com
www.ii-vi-photonics.com

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PhoeniX joins AIM Photonics manufacturing institute

Software provider to help lead PDK development and electronic-photonic design flows

PhoeniX Software B.V. of Enschede, The Netherlands — a vendor of photonic design automation (PDA) software used to synthesize integrated photonic circuits — has become a member of the consortium AIM Photonics (American Institute for Manufacturing Photonics).

PhoeniX is reckoned to be unique in the photonics industry as it enables photonic designers to work in a high-level technology-agnostic view and then synthesize the layout of their photonic integrated circuits (PICs) to different target fabrication processes. This capability is strategic to the AIM initiative as it enables photonic designers to quickly prototype their designs by targeting any one of AIM's photonic fabrication processes for layout and assembly in an AIM multi-project wafer (MPW) run.

"AIM Photonics is building a membership that includes some of the country's most innovative technology companies that each provide critical elements to the success of the institute," says Robert Duffy, chairman of the AIM Photonics leadership council. "Together, we are creating a world of new opportunities through this Rochester-based initiative," he adds.

"PhoeniX Software brings over 20 years of commercial photonic design automation experience, with extensive work in the creation and use of photonic process design kits (PDKs). We are excited to leverage their help in building the PDKs necessary to enable photonic designers to bring designs into our facilities," says Michael Liehr, CEO of AIM and executive VP of Innovation and Technology for SUNY Polytechnic Institute. "PhoeniX and other PDA companies are key to scaling photonic design into commercial applications and we look forward to working with PhoeniX Software to help us work on next-generation electronic–photonic design automation platforms (EPDA)."

PhoeniX pioneered the use of generic photonic building blocks and photonic synthesis with several European photonic foundries throughout the early 2000s. The firm also played a leadership role in designing interfaces with other PDA companies to create front-to-back photonic design flows and, more recently, to work with leading electronic design automation (EDA) firms like Mentor Graphics, Cadence Design Systems and Synopsys to create EPDA co-design environments.

"We have many customers in the United States who have been wanting a US-based fabrication site for their PICs," says PhoeniX's CEO Twan Korthorst. "PDKs and high-level photonic libraries will soon be available from AIM for the PhoeniX Software platform."

PhoeniX provides a photonics design automation platform that uses a hierarchical building block-based paradigm to enable photonic designers to capture and verify their photonic circuits at a higher level of abstraction that is agnostic to any given physical fabrication process. With a native curvilinear shape engine, efficient scripting capabilities and dedicated photonic waveguide and component implementation routines, the tool suite is reckoned to be unique in the market. It allows the high-level design description to be mapped to one or more different target fabrication processes and then synthesizes the correct layout of the circuit to meet the designers' intent while satisfying specific design rules of the targeted foundry process. PhoeniX Software's tools are also used to co-design the PIC within a package.

www.phoenixbv.com
www.aimphotonics.com/

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LESA ERC develops high-speed VLC link with integrated microchip receiver

The Center for Lighting Enabled Systems and Applications (LESA), an Engineering Research Center (ERC) funded by the US National Science Foundation (NSF) headquartered at Rensselaer Polytechnic Institute (RPI) in Troy, NY, recently achieved what is claimed to be the first high-speed, error-free, long-reach visible-light transmission link with a fully integrated microchip receiver.

These first-of-a-kind integrated results are said to advance the use of the unregulated visible spectrum in high-speed wireless systems. As demand for mobile wireless services continues to grow, and the deployment of Internet of Things (IoT) technologies expands, visible light communication (VLC) is emerging as a potential broadband transmission technology that will offer virtually unlimited spectrum for high-quality wireless services.

VLC is reckoned to have the potential to add significant value to existing lighting infrastructure, enabling cost-effective, high-bandwidth, wireless, lighting-enabled communications. As soon as LEDs replace conventional lighting, VLC can be employed in a wide variety of industrial, commercial and residential applications, says the LESA ERC (formerly the Smart Lighting Engineering Research Center).

The low-cost, compact, integrated microchip receiver developed at the LESA ERC will enable the development of more advanced technology that can be used for applications such as imaging, indoor GPS, occupancy tracking, self-alignment, and the hand-over required for mobile wireless scenarios.

LESA says that, in conjunction with RF wireless technologies, VLC is a promising candidate for inclusion in future 5G communications platforms. It also opens the path to new applications in outdoor applications, such as building-to-building, streetlight-to-streetlight, vehicle-to-vehicle and industrial communications where current WiFi networking can suffer from interference issues. In particular, higher-frequency RF platforms (60GHz and millimeter wave) have characteristics that are very similar to light-based communications (e.g. line of sight, limited ability to penetrate certain materials), making VLC-based platforms a contender for advanced high-bandwidth wireless communications.

www.lesa.rpi.edu

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GigPeak hits record shipments of 40G QSFP+ and 100G QSFP28 ICs for data centers

Driver & TIA IC chipsets sampled for 200G SR & LR PAM4 Ethernet

GigPeak Inc of San Jose, CA, USA (formerly GigOptix), which provides integrated circuits and software solutions for high-speed connectivity and high-quality video compression over the network and the cloud, has seen record quarterly orders for its 40Gbps QSFP+ and 100Gbps QSFP28 ICs for active optical cables (AOCs) and optical transceiver modules demanded by hyper-scale Web 2.0 data-center customers.

"This reflects our market-share domination as the sole merchant provider of ICs for the current generation of 40Gbps NRZ ICs, and our strong position in the initial shipments of our complete production chipsets for 100Gbps SFP+ and QSFP+ form factors, addressing active optical cables (AOCs) and transceivers for short-reach (SR) and long-reach (LR) Ethernet applications," says chief operating officer Dr Raluca Dinu. "While we are encouraged by the initial demand from data-center optical module customers for the 100Gbps NRZ complete chipset, we continue to see ever-growing demand for the current generation of 40Gbps NRZ, which will remain the workhorse for data-center connectivity for the next few years," he adds.

40Gbps, the first-generation networking technology to be deployed in data centers, has seen substantial growth over the last 3 years, and market analysts project continuous growth through 2018. Market research firms Ovum and LightCounting project that the 40Gbps SR and LR part shipment will remain the dominant speed, with volume growing from about 10 million units in 2015 to about 17 million units in 2018, before slowly transitioning to the 100Gbps NRZ generation of ICs. With GigPeak remaining the sole merchant provider of 40Gbps ICs for datacom optical modules, the firm has enjoyed an average compounded annual growth rate (CAGR) larger than 30% over the last 3 years, and expects to see the same growth for the next couple of years. For 100Gbps NRZ ICs, market analysts such as LightCounting project less than 1 million shipments of chipsets for data centers in 2015, growing to about 8 million chipsets in 2018.

In addition, to augment its data-center chipset solutions, GigPeak has announced sample availability of driver and transimpedance (TIA) ICs for 200Gbps short-reach (SR) and long-reach (LR) PAM4 Ethernet applications. This makes GigPeak the first firm to offer a complete chipset solution for all speeds applicable for data-center interconnectivity of 40Gbps currently and 100Gbps NRZ and 200Gbps PAM4 in future, says Dinu.

With a complete chipset solution offering what is claimed to be the lowest available power consumption per link, GigPeak believes that it will maintain significant market share in 100Gbps NRZ and benefit from the move into next-generation data-center connectivity at 200Gbps via its PAM4 ICs. Significant sales for PAM4 ICs are expected no later than 2020, if not earlier.

GigPeak samples low-power-consumption 32Gbps dual-channel linear coherent trans-impedance amplifier

GigPeak has announced availability for wider-base customer sampling of its GX32222, a 32Gbps dual-channel linear trans-impedance amplifier (TIA)/variable-gain amplifier (VGA) designed for use in 100-200Gbps DWDM optical receivers used for both long-haul and metro telecom applications. This fundamental TIA design enables its use in a number of currently deployed fiber-optic receiver modules of 100Gbps and 200Gbps coherent optical systems, as well as future 400Gbps-and-beyond applications. The GX32222 is now available for general sampling, after completion of initial sampling by selected customers.

GigPeak claims that the GX32222 TIA offers low power consumption and a cost advantage compared with competing solutions for the ever-growing 100G metro and long-haul WDM applications. Market research firm Ovum projects that those 100G port shipments will continue to increase with an accelerated compound annual growth rate (CAGR) of 25–30% to 2020, while being augmented with the next generations of higher-speed coherent single-wavelength solutions, for both line-cards and pluggable modules.

"The introduction of this product substantiates our already well accepted GPPO connectorized and SMT drivers for 100Gbps and 200Gbps applications, allowing us to provide our customers with ICs for transmit and receive applications," says Dr Koichi Murata, senior director of marketing for Telecom Products.

Key features of the GX32222 TIA include: an adjusted frequency range (supporting 28–32Gbps); low power consumption of 515mW at 3.3V; differential gain >7000 ohm; linear gain over 30dB of dynamic range; and features such as internal AGC (automatic gain control), output voltage control, peak detection, shutdown mode, and BW adjustment.

www.gigpeak.com

MACOM launches transmitter/receiver solution for SFP28 short-reach applications

MACOM Technology Solutions Inc of Lowell, MA, USA (which makes semiconductors, components and subassemblies for analog RF, microwave, millimeter-wave and photonic applications) has launched the MATA-37644, a multi-rate 28G CDR (clock & data recovery) device with trans-impedance amplifier (TIA) and limiting amplifier (LA), and the MALD-37645, a multi-rate 28G CDR with vertical-cavity surface-emitting laser (VCSEL) driver and input equalizer. The companion devices offer a complete transmit and receive solution for 25G Ethernet, 32G Fiber Channel and CPRI applications.

The MATA-37644 and MALD-37645 are both available in die form for low-cost wire-bonding assembly and feature high-performance, reference-free CDRs that can be bypassed to support legacy or non-standard data rates. The CDRs re-time at 25–28.1Gb/s and 21-25.3Gb/s as well as divide-by-two data rates. The devices can be individually controlled through the 2-wire serial interface and consume ultra-low power, making them the suitable for small-form-factor SFP28 applications.

The MATA-37644 includes a high-sensitivity TIA with selectable bandwidth control to support legacy data rates, and an output driver with programmable output swing and 2-tap de-emphasis. The MALD-37645 provides programmable bias and modulation current, enabling interoperability with a variety of VCSEL lasers as well as an adaptive input equalizer to support flexible VSR connections to host ASICs.

"MACOM is delighted to offer these one-channel companion devices as a complete solution for SFP28 chip-on-board applications, including optical modules, active optical cables (AOCs) and on-board optical engines," says director of marketing Marek Tlalka. "Our new chipset expands MACOM's existing family of CDRs, laser drives and TIA products to emerging 25G Ethernet and 32G Fiber Channel data center and enterprise applications as well as to 24G CPRI telecom applications."

"MACOM's latest chipset solution is enabling the development of low-cost and low-power SFP28 short-reach optical modules," comments Charlie Wang, VP of research & development at Innolight Technology Corp of Suzhou, China, which designs and makes optical transceivers for the cloud computing market.

The MATA-37644 and MALD-37645 were both exhibited in private demonstrations at the 18th China International Optoelectronic Expo (CIOE 2016) in Shenzhen (6–9 September).

www.macom.com/products/optoelectronics

MACOM launches chip-set for short-reach VCSEL-based 100Gbps onboard optics applications

MACOM has introduced the MALD-37345, a quad 28G vertical-cavity surface-emitting laser (VCSEL) driver with input equalizer, and the MATA-37344, a quad 28G transimpedance amplifier (TIA). The complete transmit/receive solution is targeted at short-reach VCSEL-based 100Gbps onboard optics, but is also suitable for optical modules and active optical cable (AOC) applications.

As an addition to MACOM's portfolio of short-reach VCSEL drivers and TIAs, the new chipset is a next-generation evolution of the existing MALD-37045 and MATA-37044 (currently shipping) that eliminates the need for clock & data recovery (CDR). The new chipset is backwards pin compatible with the MALD-37045 and MATA-37044, enabling customers with the ability to mix and match parts to include or not include a CDR for extreme flexibility.

"These devices, while optimized primarily for on-board optics, are still able to support active optical cables and optical modules," notes director of product marketing Marek Tlalka. "By eliminating the need for the clock and data recovery circuitry present in its predecessors, this chipset enables our customers to deliver ultra-low-power and low-cost transceivers that can be placed close to host ASICs for intra-system optical connectivity," he adds. "Additionally, with its compatibility to our existing MALD-37045 and MATA-37044 devices including CDR, the new chipset is a truly versatile solution."

The VCSEL driver of the MALD-37345 includes programmable eye-shaping features and an input equalizer. The high-sensitivity TIA of the MATA-37344 features selectable bandwidth to support up to 28.05Gbps and lower-speed legacy data rates, as well as an output driver with programmable output swing and 2-tap de-emphasis. Both devices are available in 2mm x 3mm die form, supplied in waffle packs, whole wafers or quartered wafers.

"Increasing data rates on the PCBs creates signal integrity and thermal constraints due to concentration on the optical IO at the front panel," comments Simon Stanley, founder & principal consultant at Earlswood Marketing Ltd and analyst-at-large with Heavy Reading. "By placing a transceiver close to the host ASIC, these constraints are alleviated," he adds. "MACOM's chip-set is enabling the deployment of 100Gbps onboard optical transceivers."

Mellanox launches 25Gb/s Ethernet SFP28 optical transceivers and AOCs for data-center networks

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) has announced the availability of 25Gb/s SR (short reach) Ethernet optical transceivers and active optical cables (AOCs) that enable next-generation servers and storage appliances to interface with 100Gb/s switches and routers.

The new products were featured at the 18th China International Optoelectronic Expo (CIOE 2016) in Shenzhen, China (6–9 September) in live demos using Mellanox 100Gb/s Spectrum Ethernet switches to aggregate traffic from four servers, each connected with 25G/s ConnectX-4 network adapters.

"The transition to 100Gb/s networks in data centers is linked to server upgrades to 25Gb/s and 50Gb/s," notes Westwood Liu, China general manager at Mellanox. "Our new optical transceivers and AOCs enable a new generation of server and storage connectivity," he adds.

"Mellanox is currently the market share leader in shipments of data-center Ethernet NICs [network interface controllers] with speeds of 25GbE and greater," comments Seamus Crehan, president & founder of Crehan Research. "High-speed optical interconnects allow data centers to break the traditional 3m copper link between servers and TOR [top-of-rack] switches," he adds. "With these optics, racks of 25Gb/s servers and storage can be placed anywhere in the data center."

At CIOE, Mellanox featured live demonstrations of the entire LinkX interconnect product portfolio linking Mellanox 100Gb/s switches and high-speed servers:

- SN2410: 48-port 25GbE + 8-port 100GbE open Ethernet top-of-rack switch;
- SN2100: half-width 16-port non-blocking 100GbE open Ethernet switch;
- ConnectX-4 single- and dual-port network adapters in 25/50/100G combinations;
- 25/50/100G direct attach cables (DAC) and active optical cables (AOCs);
- 25G SR and 100G SR4, multi-mode transceivers;
- 100G LR4 10km, 1310nm, single-mode transceiver;
- 100G PSM4 2km, 1550nm, silicon photonics single-mode transceiver; and
- 100G WDM4 2km, 1550nm, silicon photonics single-mode transceiver.

Also at CIOE, Mellanox technology experts presented in several key sessions:

- Didi Ivancovsky, director of LinkX product marketing, is presenting 'Silicon Photonics Enables the Use of Data' at the First Silicon Photonics Industry Summit on 7 September;
- Tong Liu, senior director of market development, is presenting 'Silicon Photonics Technology Innovation at Mellanox' at the Shenzhen Convention & Exhibition Center on 8 September.

www.mellanox.com
www.crehanresearch.com

Mouser to distribute Oplink's optical components, modules and subsystems globally

Semiconductor and electronic component distributor Mouser Electronics Inc has entered into a global distribution agreement and partnership with Molex company Oplink Communications Inc, a provider of optical communication components, intelligent modules, and subsystems. "These products align with our existing line card and customer base," notes Jeff Newell, senior VP of products for Mouser Electronics.

Oplink's product line adds advanced solutions covering fused couplers and splitters, optical isolators and hybrid components, Gigabit Ethernet and 10Gigabit Ethernet transceiver solutions.

Oplink offers fiber-optic network designers a broad array of single- and multi-mode fused couplers and splitters, including its supervisory channel wavelength division multiplexers (WDM) — an integrated component that separates the network supervisory channel from the signal channels for use in monitoring network performance.

The line of optical isolators and hybrid amplifier components is available in various fiber lengths and configurations. The product family features compact size, suitable for optical component solutions for erbium-doped fiber amplifier (EDFA) applications.

The small-form-factor SFP Gigabit Ethernet (GbE) transceivers and SFP+ 10 Gigabit Ethernet (10GbE) transceivers are hot-pluggable and designed for telecom, datacom and mobile backhaul applications, with link ranges of several hundred meters on multi-mode fiber and up to 80km on single-mode fiber.

"Having Mouser Electronics' expertise as a global distributor positions Oplink to better support our customers and grow our worldwide distribution network," comments Oplink's president Peter Lee. "With the combination of Mouser's excellent supply chain and logistics support, we can continue to drive new growth opportunities and expand our presence," he believes.

www.mouser.com/oplink

Mellanox and Oclaro team to connect 100Gb/s PSM4 silicon photonics to next-generation 25Gb/s long-reach transceivers for servers and storage

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) has teamed up to seamlessly connect its 1550nm PSM4 transceivers with the 1310nm LR (long reach) SFP28 transceiver line of Oclaro Inc of San Jose, CA, USA (which provides components, modules and subsystems for optical communications). The solution enables the linking of servers, storage and network appliances to network switches, and demonstrates the transparent interoperability between transceivers of differing wavelengths.

At the European Conference on Optical Communications (ECOC 2016) in Dusseldorf, Germany (18–22 September), Mellanox gave a live demonstration of the solution, connecting its 100Gb/s PSM4 1550nm transceivers to four of Oclaro's 1310nm LR SFP28 transceivers over 10m of single-mode fiber, connecting Mellanox 100Gb/s Spectrum Ethernet switches to 25G/s ConnectX-4 Lx network adapters.

"Customers select PSM4 transceivers because they provide the most cost-effective Ethernet links for reaches of 100m to 2km," says Amir Prescher, Mellanox's senior VP of business development. "We teamed up with industry leader Oclaro to demonstrate that PSM4 transceivers, with fiber breakout cables, can connect directly to four separate SFP28 LR transceivers. This enables next-generation servers and storage appliances to be located anywhere in the data center or even across campus," he adds.

We teamed up with industry leader Oclaro to demonstrate that PSM4 transceivers, with fiber breakout cables can connect directly to four separate SFP28 LR transceivers

"This illustrates the strength of our transceiver design as being capable of interoperating at multiple wavelengths," says Yves LeMaitre, president, Optical Connectivity business at Oclaro.

Mellanox's ECOC booth also featured live demonstrations of the entire LinkX interconnect product portfolio linking Mellanox 100Gb/s switches and high-speed servers, including:

- SN2410: 48-port 25GbE + 8-port 100GbE open Ethernet top-of-rack switch;
- SN2100: half-width 16-port non-blocking 100GbE open Ethernet switch;
- ConnectX-4 single and dual port network adapters in 25/50/100G combinations;
- 25/50/100G direct attach cables (DAC) and active optical cables (AOCs);
- 25G SR and 100G SR4, multi-mode transceivers;
- 100G LR4 10km, 1310nm, single-mode transceiver;
- 100G PSM4 2km, 1550nm, silicon photonics single-mode transceiver; and
- 100G WDM4 2km, 1550nm, silicon photonics single-mode transceiver.

Also at ECOC, Mellanox gave the following presentations:

- 'Silicon Photonics Optical Engines for 400G/800G Cobo on Board Optics and Next Generation Pluggables'; and
- 'Next Generation Ultra-Broadband Silicon Photonics-Based Integrated Circuits'; and
- 'Bringing Technology to Market'.

www.oclaro.com
www.mellanox.com/products/interconnect

Oclaro receives Cisco Excellence in Emerging Technology award

During Cisco's 25th Annual Supplier Appreciation Event (SAE) in Santa Clara on 8 September, Oclaro Inc of San Jose, CA, USA (which provides components, modules and subsystems for the core optical communications, enterprise and data-center markets) received the 2016 Excellence in Emerging Technology award for "contributing in the area of exceptional technology or value proposition, and continually bringing in emerging technology for the future success of Cisco".

"The theme for our Silver Anniversary SAE event, 'Celebrating the Journey', puts the spotlight on our continued journey towards digitization and the tremendous opportunities that come from connecting people, processes, data and things," notes John O'Connor, VP, global supplier management, at Cisco. "Cisco's supply chain has evolved into the recognized leader it is today with suppliers and partners playing an instrumental role in the company's growth, development and success," he adds.

Cisco presented awards to suppliers in recognition of their contributions to Cisco's success in fiscal 2016. Celebrating 25 years of partnering, Cisco recognized the dedication and successes of the best of its strategic suppliers and manufacturing partners, which it says is critical to a complex, global supply chain like Cisco's.

www.oclaro.com
www.cisco.com

Oclaro showcases innovations for enabling faster 100G, 200G and 400G networks at ECOC

At the European Conference on Optical Communications (ECOC 2016) in Düsseldorf, Germany (19–21 September), Oclaro Inc of San Jose, CA, USA (which provides components, modules and subsystems for optical communications) featured a live demonstration of a 400GBASE-LR8 CFP8 transceiver, the firm's CFP2-ACO (analog coherent optical) transceiver, and a full portfolio of 100G components and modules.

"The explosive growth in applications such as video services, smart-phones and cloud-based software solutions is driving the need for high network speeds to meet the growing bandwidth demands for data-intensive applications," notes chief commercial officer Adam Carter. "Our ECOC line-up demonstrates our advancement and leadership in speeds of 100G and beyond, integrated small form factors, photonic devices, and indium phosphide (InP) technology, which are delivering the speed, power consumption and size required for these services."

Featuring a small 40mm x 102mm x 9.5mm form factor, the new CFP8 transceiver module delivers four times more bandwidth than existing 100G solutions, enabling Oclaro to meet demand for higher data rates between router and transport 400G client-side interfaces in core networks. The CFP8 leverages Oclaro's proven technology from its earlier CFP, CFP2 and CFP4 designs. This includes its cooled 1310nm 28Gbps EA-DFB (electro-absorption distributed feedback) laser technology, and 28Gbps 4-channel integrated PIN-PD (photodiode) array.

Additional features of the CFP8 transceiver include the following:
- compliant with 400GBASE-LR8 optical and CDAIU-16 electrical interface specifications that are under final standardization process by the IEEE 802.3bs task force;
- fully integrated 8l x 53.125Gbit/s optical transceiver module modulated using 4-level pulse amplitude modulation (PAM4) format;
- consists of 1310nm wavelength EA-DFB laser diodes, driver ICs, PIN photodiodes, trans-impedance amplifier (TIA) ICs, optical multiplexer/demultiplexer and a PAM4 to NRZ encoder/decoder and SerDes integrated digital signal processing (DSP) IC with a 16-channel x 26.5625Gbit/s electrical interface;
- conforms to CFP8 hardware specifications for mechanical dimensions, connectors and footprint; and
- features power supply voltage of +3.3V and is hot pluggable in the Z-direction by a 124-pin connector.

CFP2-ACO technology enables users to achieve the higher density, lower cost and lower power dissipation needed for next-generation 100G & 200G coherent networks

Already shipping in thousands of units, Oclaro reckons that its CFP2-ACO represents a milestone in acceptance of the coherent CFP2-ACO form factor. Compared to conventional solutions, the coherent CFP2-ACO module features what is claimed to be an unprecedented small form factor to enable increased density at the faceplate, reduced power dissipation, and optimal optical performance.

In addition, the CFP2 pluggable form factor enables users to minimize first installation costs and maintain flexibility to scale networks over time by adding more capacity as needed. As a result, the CFP2-ACO technology enables users to achieve the higher density, lower cost and lower power dissipation needed for next-generation 100G and 200G coherent networks, the firm says.

Components and modules for 100G and beyond

Also on display was a portfolio of components and pluggable modules showcasing Oclaro's technology for enabling bandwidths at 100Gbs, 200Gbs and 400Gbs. Along with the CFP2-ACO, this includes lithium niobate modulators at 100Gb/s and 400Gb/s as well as a portfolio of µ-ITLAs (micro integrated tunable laser assemblies) supporting bandwidths up to 400Gb/s for long-haul, metropolitan and datacenter interconnect markets. For intra-datacenter and enterprise networks, Oclaro's portfolio of 100Gb/s single-mode pluggable modules (including the CFP, CFP2, CFP4 and QSFP28 form factors along with the 400G CFP8) is also on display.

www.ecocexhibition.com
www.oclaro.com

Presentations at European Conference on Optical Communications

At ECOC, Oclaro representatives gave the following presentations:
- 'Non-Linearity Compensation of High-Speed PAM4 Signals from Directly-Modulated Laser at High Extinction Ratio' by Takayoshi Fukui of Oclaro Japan;
- 'Two-Section RSOA with Enhanced Modulation-Cancelling Effect for Self-Seeded Colorless WDM Transmitter' by Masaru Mukaikubo and Yoshiaki Nakano of Oclaro Japan;
- 'Emission Beam Engineering of 1.3um High-power DFB Laser Using Monolithically-integrated Mirror and Lens for Silicon Photonics' by K. Adachi, T. Suzuki, K. Nakahara, A. Nakanishi, K. Naoe and S. Tanaka of Oclaro Japan;

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Oclaro demos 400GBASE-LR8 CFP8 transceiver over 10km single-mode fiber

At the European Conference on Optical Communications (ECOC 2016) in Düsseldorf, Germany (19–22 September), Oclaro Inc of San Jose, CA, USA (which provides components, modules and subsystems for optical communications) showcased a live demonstration of a 400GBASE-LR8 CFP8 optical transceiver operating over 10km of single-mode fiber. Featuring a small 40mm x 102mm x 9.5mm form factor, the new CFP8 module delivers four times more bandwidth than existing 100G solutions, enabling Oclaro to meet the explosive demand for higher data rates between router and transport 400G client-side interfaces in core networks.

"As the first optical company to demonstrate a CFP8 design, we have once again leveraged our proven leadership in delivering volume CFP modules, and our world-class expertise in photonics integration and cooled 1310nm 28Gbps EA-DFB [(electro-absorption distributed feedback)] laser technologies," claims Yves LeMaitre, president, Optical Connectivity Business at Oclaro. "As we continue stretching the limits of core optical technologies, this expertise will be critical for moving the industry forward and providing the higher bandwidths required in future networks."

The 400G CFP8 transceiver provides a dense-port and high-throughput solution with compact size and low power consumption. It leverages proven technology from Oclaro's earlier CFP, CFP2 and CFP4 designs, including cooled 1310nm 28Gbps EA-DFB laser technology, an integrated TOSA and ROSA, and a 28Gbps 4-channel integrated PIN-PD (photodiode) array. Additional features include the following:

- compliant with 400GBASE-LR8 optical and CDAIU-16 electrical interface specifications that are under final standardization process by the IEEE 802.3bs task force;
- fully integrated 8l x 53.125Gb/s optical transceiver module modulated using the 4-level pulse amplitude modulation (PAM4) format;
- consists of 1310nm-wavelength EA-DFB laser diodes, driver ICs, PIN photodiodes, transimpedance amplifier (TIA) ICs, optical multiplexer/demultiplexer and a PAM4 to NRZ encoder/decoder and SerDes integrated digital signal processing (DSP) IC with a 16-channel x 26.5625Gbit/s electrical interface;
- conforms to CFP8 hardware specifications for mechanical dimensions, connectors and footprint; and
- features a power supply voltage of +3.3V and is hot pluggable in the Z-direction by a 124-pin connector.

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Oclaro appoints global human resources veteran to board

Oclaro has appointed Denise Haylor to its board of directors and as chair of the board's Compensation Committee during an "important phase of our development and growth," comments Marissa Peterson, chair of the board. "Denise brings with her a wealth of global human resources experience with leading technology companies," she adds.

Haylor is a global executive with more than 25 years of professional experience, with competencies in executive compensation, talent acquisition and development and human resources. She currently serves as the chief human resources officer and a member of the executive committee of Royal Philips, based in The Netherlands.

Some of Haylor's previous professional positions include chief human resources officer of Flextronics and corporate VP & deputy head of human resources of Motorola Mobility.

Haylor replaces Lori Holland, whose resignation from the board became effective on 26 August. In connection with Haylor's appointment as chair of the board's Compensation Committee, Kendall Cowan was appointed as chair of the board's Audit Committee.

www.oclaro.com

Oclaro prices public offering of common stock

Oclaro Inc of San Jose, CA, USA (which provides components, modules and subsystems for optical communications) has priced its public offering of 15,000,000 shares of its common stock at $8.35 per share. In addition, Oclaro has granted the underwriters a 30-day option to purchase up to 2,250,000 additional shares. (The offering was proposed on 19 September as 13,000,000 shares plus 1,950,000 additional shares for underwriters.) Oclaro expected to close the offering on 27 September (subject to customary closing conditions).

Oclaro intends to use the net proceeds from the offering for general corporate purposes, including working capital, capital expenditures, other corporate expenses and acquisitions of complementary products, technologies or businesses. The company adds that it does not have agreements or commitments for any specific acquisition at this time.

www.oclaro.com

AppliedMicro, MACOM and BrPhotonics demo first 100Gb/s PAM-4 single-wavelength solution enabling 100Gb/s & 400Gb/s connectivity in QSFP transceivers

Single-wavelength solution increases faceplate and fiber bandwidth density by 4x over 25Gb/s NRZ solutions and 2x over emerging 28 Gigabaud interconnects

Applied Micro Circuits Corp of Santa Clara, CA, USA (which provides silicon-based computing and connectivity solutions for next-generation cloud infrastructure and data centers), BrPhotonics (BrP) of Campinas-SP, Brazil (a joint venture between GigOptix Inc of San Jose, CA, USA and independent Brazil-based research center CPqD that provides high-speed optoelectronic devices and digital microelectronics for high-density form-factor integrated transceivers and subsystems) and MACOM Technology Solutions Inc of Lowell, MA, USA (which makes semiconductors, components and subassemblies for analog RF, microwave, millimeter-wave and photonic applications) have announced the first demonstration of 100Gb/s PAM4 (4-level Pulse Amplitude Modulation) single-wavelength (lambda) technology over single-mode fiber.

The solution features AppliedMicro's 16nm FinFET 100Gb/s PAM4 digital signal processor (DSP), BrPhotonics' newest ultra-high-bandwidth Thin Film Polymer on Silicon (TFPS) modulator and MACOM's high-bandwidth, low-noise transimpedance amplifier (TIA). The demonstration illustrates that the complete eco-system for 100Gb/s over a single-wavelength technology is ready now, with deployments expected in 2017.

It is expected that single-wavelength 100Gb/s will transform the market for 100Gb/s and 400Gb/s intra-datacenter interconnects by enabling deployments of 100Gb/s QSFP, 400Gb/s double-density QSFP and 800Gb/s CFP8 modules. For 100Gb/s, this technology reduces the number of lasers to one and eliminates the need for optical multiplexing. For 400Gb/s implementations, only four lasers are needed, representing a major opportunity for data-center operators to reduce capital expenditure (CapEx) and operating expenses (OpEx) with an extremely compact module form factor.

"As data-center and access network developers demand lower costs and higher port density, we've seen huge market interest in our single-wavelength PAM-4 technology," says AppliedMicro associate VP Omar Hassen. "AppliedMicro's technology is fundamental in enabling 400Gb/s connectivity in a QSFP family of transceivers. This is a feat that has not been achieved previously," he adds.

"This 56 Gigabaud TIA, developed in silicon, demonstrates our leadership in physical media devices as we enable the next generation of data-center optical interconnects," says Gary Shah, MACOM's VP, High-Performance Analog.

"The industry requires significantly lower-cost optical 100Gb/s connections for data-center and access network applications and will be moving to 400G in data centers during 2018/19," comments Simon Stanley, founder & principal consultant at Earlswood Marketing Ltd and analyst-at-large with Heavy Reading. "Single-wavelength PAM4 100Gb/s promises a cost-effective solution for 100Gb/s and enables high-density 400G connections in the data center," he adds. "This demonstration shows that this technology is coming faster than many people think."

AppliedMicro, BrPhotonics and MACOM showcased live demonstrations of the new technology in AppliedMicro's booth at the European Conference on Optical Communications (ECOC 2016) in Düsseldorf, Germany (19–21 September).

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Luxtera ships millionth silicon photonic transceiver

Fabless silicon photonics firm Luxtera of Carlsbad, CA, USA says it has shipped more than 1 million silicon photonic PSM4 (parallel single-mode fiber 4-lane) transceiver products. The firm's patented technology combines the long-reach capabilities of single-mode fiber with low-cost transceivers, enabling the cost-effective scaling of cloud computing data centers.

A critical component of driving cost-effective optics inside the data center was the introduction of parallel single-mode (PSM) fiber-optic solutions, says Luxtera. Regarding standardization efforts to allow multi-vendor interoperability of PSM4, Luxtera was a founding member and drafter of the 100G-PSM4 multi-supplier agreement (MSA) in 2014, the first standard to enable silicon photonics interoperability with legacy DML (directly modulated laser) optical modules for PSM4 fiber without compromising the cost benefits of silicon photonics. Luxtera says that this MSA has the support of dozens of companies with PSM4 product offerings and is being deployed at scale by the major cloud computing operators. The firm adds that it has continued to drive further adoption of PSM4 for higher data rates, and has been standardized in IEEE 802.3bs, 200GBase-DR4 and 400GBase-DR4 specifications, creating a migration path to 400G.

Each Luxtera 100G PSM4 optical transceiver product includes four independently operating transmitter and receiver channels, integrating high-speed phase modulators, photodetectors, waveguides, grating couplers, high-speed electrical retimers, and integrated control circuitry, powered by a single integrated laser. These components combine into a fully integrated silicon photonics chipset or PSM4 optical engine with no additional external elements required. Luxtera says that it now has a broad customer base including major cloud datacenter operators, system OEMs, HPC (high-performance computing) operators, and many additional users.

VP of engineering Peter De Dobbelaere PhD presented on data-center photonics at the 4th Optical Interconnect in Data Centers EU-Symposium at the European Conference on Optical Communications (ECOC 2016) in Düsseldorf, Germany (19–21 September).

www.luxtera.com

II-VI Inc unveils 980nm uncooled pump laser module with in-package wavelength stabilizer

Engineered materials and optoelectronic component maker II-VI Inc of Saxonburg, PA, USA, which makes pump laser modules and micro-optics for transceiver-embedded optical amplifiers, has launched an uncooled 980nm pump laser module that features patent-pending in-package wavelength stabilization within an 8-pin mini-DIL package.

High-bit-rate transceivers operating at 100Gb/s and higher continue to be designed into smaller packages to meet the needs of telecom carriers and cloud service providers for equipment with greater bandwidth to form-factor density. Since II-VI's new 980nm uncooled pump laser module integrates a wavelength stabilizer into the small 8-pin mini-DIL package, it eliminates the need for an external fiber Bragg grating in the fiber pigtail assembly. Instead, the new pump laser features an 80μm low-bend loss, small-bend radius and polarization-maintaining fiber pigtail that enables optical amplification within small transceiver packages.

"With our existing portfolio of ultra-compact optical components, we are the leader in pump lasers and micro-optics for transceiver-embedded optical amplifiers for the fast-growing 100Gb/s CFP2-ACO market," claims Dr Sanjai Parthasarathi, VP, product marketing & strategy, Optical Communications Group. "Our 8-pin uncooled mini-DIL pump lasers continue to be the smallest commercially available," he adds. "With the integrated wavelength stabilizer technology, these pump lasers are now also the most versatile solutions for the growing market of optically amplified high-bit-rate coherent transceivers."

With the integrated wavelength stabilizer technology, these pump lasers are now also the most versatile solutions for the growing market of optically amplified high-bit-rate coherent transceivers

The new 980nm pump lasers are built on II-VI's field-proven OC-2 packaging platform (with over 2 million modules shipped to date). They also house II-VI's market-proven G08 lasers to ensure what is claimed to be superior wavelength locking performance, reliability and stability. The new 980nm pump lasers, together with II-VI's portfolio of ultra-compact hybrid passives based on the firm's micro-optics technology platform, enable low-noise and high-power optical amplification within transceiver form-factors previously unachievable.

www.ii-vi-photonics.com

Kaiam launching new WDM transceiver platform

Kaiam Corp of Newark, CA, USA — a private company founded in 2009 commercializing hybrid photonic integrated circuit (PIC) technology for pluggable optical transceivers in data-centers — has launched the new platform LightScale2.

The planar approach combines multiple transmit and receive blocks in a very dense architecture that is said to be simple to assemble and delivers higher performance than standard transmitter/receiver optical sub-assemblies (TOSA/ROSA) approaches. Kaiam is currently sampling CWDM4 100G QSFP28 transceivers based on this architecture. The firm also expects to deliver 200G, 400G and higher density on-board optics with this platform in the future, extending its capabilities in hybrid integration technology for single-mode WDM transceivers.

Kaiam has been shipping 40G and 100G transceivers for hyperscale datacentres in volume since 2014 using a MEMS-aligned hybrid optical integration approach. The firm's LightScale1 platform uses this proprietary MEMS technique for optical engines in a standard TOSA/ROSA architecture. LightScale2 flattens the internal architecture of the transceiver to further improve density, RF signal integrity, thermal management, power consumption, and manufacturing simplicity.

"Today most single-mode transceivers use legacy telecom-type approaches that result in bulky packaging of components," says CEO Bardia Pezeshki. "This not only increases cost and manufacturing complexity, but degrades performance, as electrical and optical signals and heat must traverse multiple interfaces," he adds. "Kaiam's MEMS-based packaging is intrinsically dense, combining best-of-breed components such as indium phosphide (InP) lasers, silicon photonics, and silica-waveguide integrated optics. By liberating our technology from outdated telecom architectures, we can manufacture very dense and high-performance multi-wavelength transceivers and modules."

Kaiam exhibited at the European Conference on Optical Communications (ECOC 2016) in Düsseldorf, Germany (19–21 September).

www.ecocexhibition.com
www.kaiam.com

ColorChip shipping 100G QSFP28 10km transceivers

Privately held integrated optical communications component and sub-system developer ColorChip Ltd of Yokneam, Israel has begun production of 100G QSFP28 10km transceivers.

The range is based on the emerging 4WDM multi-source agreement (MSA), supporting large data centers and mobile backhaul applications. The transceiver is interoperable with 100G CWDM4 and CLR4 2km transceivers, as it is identical in the hardware design, and likewise offers a cost-effective solution in a small QSFP28 form factor. The 100Gbps 4WDM 10km and CWDM4 2km transceivers were demonstrated at the European Conference on Optical Communications (ECOC 2016) in Düsseldorf, Germany (19–21 September).

The 100Gbps CWDM4/CLR4 QSFP28 2km transceiver is currently shipping in volumes of tens of thousands to tier-1 datacenters, system vendors and telecom operators. Similar to the 2km offerings, ColorChip's 100G 10km 4WDM transceiver is characterized by high density, low power consumption (~2.5W) and robust performance with an extended link margin that supports a 10km reach with a 6.3dB link budget when forward error correction (FEC) is enabled. The firm says that the 100G 10km transceiver leverages its core strengths of optical head to PCB integration, as well as the volume manufacturing efficiencies achieved by what is claimed to be a unique industrialized optics production approach.

ColorChip's optical head is based on the its SystemOnGlass integrated optical technology, which is a proprietary waveguide-in-glass photonic lightwave circuit (PLC)-based optical platform coupled with fully automated photonic integration of active and passive optical elements, creating a dense, multi-lane optical head. This approach eliminates the need for free-space optics and allows ColorChip to deliver an optical head characterized by nested multiplexing, low optical losses and high coupling efficiencies, resulting in what is said to be a reliable, low-cost solution. The SystemOnGlass photonic integration expertise is based on wafer-scale PLC manufacturing and automated optical head assembly, enabled by ColorChip's industrialized optical manufacturing approach at the heart of the firm's family of high-speed transceiver products.

SystemOnGlass photonic integration expertise is based on wafer-scale PLC manufacturing

"The latest $45m round of financing the company completed in the last 12 months is intended to fuel the company with sufficient means to quickly address the growing market demand for top-of-rack, hyper-scale applications," says CEO Yigal Ezra. "ColorChip has been making tens of millions of dollars investments to expand the company production capacity of the SystemOnGlass-based optical head manufacturing as well as building off-shore production lines that will facilitate high-volume, low-cost transceiver integration and testing."

http://color-chip.com

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Finisar quarterly revenue grows a more-than-expected 7%, driven by 22% growth in 100G datacom transceivers

QSFP28 transceiver sales more than doubling quarter-on-quarter

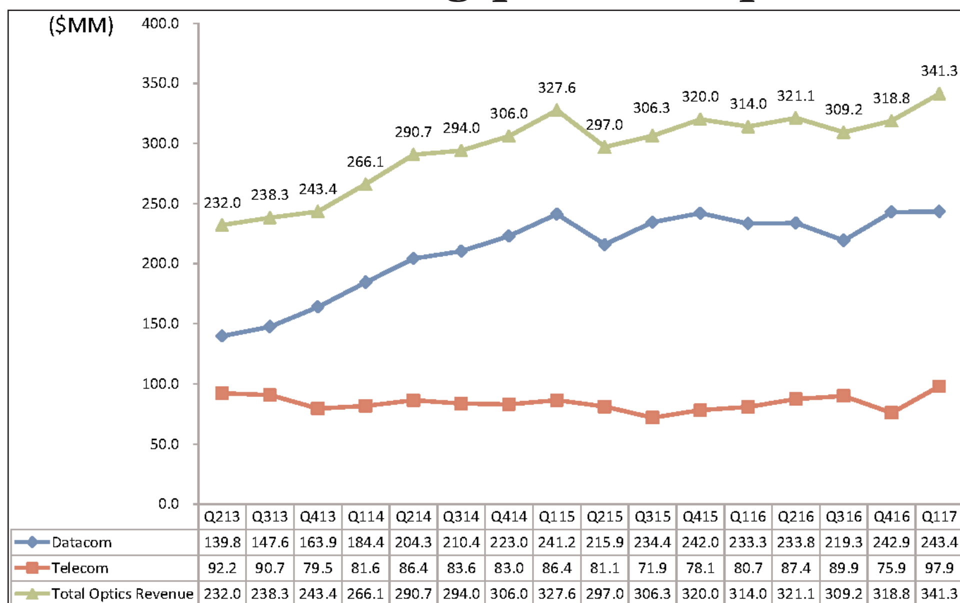
For its fiscal first-quarter 2017 (ended 31 July 2016), fiber-optic communications component and subsystem maker Finisar Corp of Sunnyvale, CA, USA has reported record revenue of $341.3m, up 7.1% on $318.8m last quarter and up 8.7% on $314m a year ago.

There were two 10%-or-greater customers. The top 10 customers represented 60.2% of total revenue, up from 56.4% last quarter.

Datacom product sales were $243.4m, up 4.3% on $233.3m a year ago and up 0.2% on $242.9m last quarter. Growth was driven primarily by strong demand for 100Gb/s transceivers (including CFP, CFP2, CFP4 and QSFP28 form factors) offset partially by a decline in sales of transceivers for wireless applications and in 40G transceivers (to about 20% of datacom revenue). Excluding transceivers for wireless applications, datacom revenue rose by 3.1% sequentially. In particular, sales of 100G transceivers for datacom applications were up 21.8% on last quarter and 115.8% on a year ago. QSFP28 sales especially more than doubled in fiscal Q1.

Telecom product sales were $97.9m, up 21% on $80.7m a year ago and up 29% on $75.9m last quarter. Growth was due to higher sales of wavelength-selective switches (WSS, growing more than the expected 10%) as well as coherent receivers and 100G transceivers. Growth was boosted by a broad rebound in demand for other telecom products (including amplifiers and both tunable and fixed-wavelength 10G transceivers) following an unexpected decline in a variety of products last quarter.

On a non-GAAP basis, gross margin improved significantly, from 30.2% a year ago and 30.6% last quarter to 33.1% (well above the expected 31%). This is attributed to a favorable product mix (selling more 100G transceivers than expected, aided by the decline in lower-margin wireless transceivers) and leveraging the firm's vertically integrated manufacturing infrastructure over the larger volumes.



	Q213	Q313	Q413	Q114	Q214	Q314	Q414	Q115	Q215	Q315	Q415	Q116	Q216	Q316	Q416	Q117
Datacom	139.8	147.6	163.9	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
Telecom	92.2	90.7	79.5	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
Total Optics Revenue	232.0	238.3	243.4	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

Finisar's quarterly revenue trends.

Operating expenses are up from $66.2m last quarter to $69.3m (above the expected $68.5m) due to higher payroll taxes from the annual vesting of employee stock grants, higher legal expenses from two patent trials completed during the quarter, and higher employee compensation levels. However, operating expenses as a percentage of revenue have fallen from 20.8% last quarter to 20.3%.

Operating income has risen from $26.5m (operating margin of 8.4% of revenue) a year ago and $31.2m (9.8% margin) last quarter to $43.5m (12.8% margin, well above the expected 9.9–10.9%).

"The combination of revenues being at the higher end of our guidance range [of $323–343m] and better-than-expected gross margins resulted in earnings per fully diluted share exceeding the upper end of our guidance range [of $0.27–0.33]," says executive chairman & CEO Jerry Rawls. Net income has risen from $24.5m ($0.23 per diluted share) a year ago and $31.8m ($0.29 per diluted share) last quarter to $41.8m ($0.38 per diluted share).

Capital expenditure (CapEx) was closer to $20m rather than the expected $30m, since some expenditures associated with the fit-out of additional space at Oclaro's Malaysia assembly & packaging facility has rolled from fiscal Q1 into fiscal Q2, and the timing of receiving some high-dollar-value equipment into one of the firm's fabs also got pushed out.

Overall, cash, cash equivalents and short-term investments rose by $31.3m during the quarter, from $562.5m to $593.8m.

"We continue to see strong worldwide demand for telecom optical components due to the new long-haul, metro and wireless deployments by many major carriers," says Rawls. "Demand from North America and China remain particularly strong from the metro build outs in North America and both long-haul and metro deployments in China," he adds.

For fiscal second-quarter 2017, Finisar expects revenue to rise by about 7% to $355–375m. Datacom

product revenue should grow primarily due to increased sales of 100 Gigabit Ethernet transceivers. In particular, QSFP28 sales could again more than double. "We are capacity constrained and we are adding capacity as fast as we can on those products," comments chief financial officer Adzema. Telecom revenue growth will be driven by strong demand for wavelength-selective switches and reconfigurable optical add-drop multiplexer (ROADM) line-cards. In addition, Finisar expects increased line-side revenue for 100Gb/s and 200Gb/s coherent CFP2-ACO transceivers.

Gross margin should rise further to 34%. Operating expenses are expected to increase further to $71m, due primarily to annual salary merit increases that occurred on 1 August plus higher sales & marketing expenses related to increased revenue, offset partially by lower legal expenses. Operating margin is expected to rise further to 14.3–15.3%. Earnings per fully diluted share should rise to $0.44–0.50. CapEx should return to the more usual $30m.

"We are still sold out for a number of products and continue to add capacity to meet the strong demand," notes Rawls. "Some of our capacity expansion investments include a 100G client-side transceivers, QSFP28, wavelength-selective switches, line-cards, 25G lasers and our 100G and 200G coherent CFP2-ACO transceivers," he adds.

"In fiscal 2017, we expect to benefit from the ramp of many new products," says Rawls. "Revenue growth will be driven by data-center construction, 100G upgrades and the increased deployment of ROADMs and 100Gb/s and 200Gb/s coherent transceivers in telecom long-haul and metro markets."

www.finisar.com

Lumentum and Finisar jointly demonstrate 100G SWDM4 transceiver interoperability

At the European Conference on Optical Communications (ECOC 2016) in Dusseldorf, Germany (19–21 September), optical and photonic product maker Lumentum Operation LLC of Milpitas, CA, USA and fiber-optic communications component and subsystem maker Finisar Corp of Sunnyvale, CA, USA showcased what is claimed to be the industry's first interoperability demonstration of 100G SWDM4 optical transceivers.

The demonstration took place on the exhibit floor at ECOC, with a live data link set up to run between the Lumentum and Finisar booths. The two module makers will be exchanging data generated by local sources through their respective SWDM4 optical transceivers. They will be linked via a traditional duplex multi-mode fiber (MMF) link, demonstrating the transceivers' ability to communicate with each other. The QSFP28 modules will be plugged into test systems provided by Anritsu and Viavi.

Using shortwave wavelength division multiplexing (SWDM, a novel technology in short-reach data communications), multiple data streams from lasers emitting different wavelengths in the 850nm band are optically multiplexed into a single fiber at the transmitter and de-multiplexed at the receiver into the original data streams. This provides a direct, low-cost solution for 100G data-rate upgrades for data-center customers who have an installed base of duplex MMF running at 10G currently. Before SWDM, the standard upgrade path was to switch to multi-mode ribbon fiber and use 100G SR4 over four parallel data streams.

"SWDM is expected to play an important part in the migration from a 10G-centric data center to an architecture based on 40, 100 or 200G," says James Wynia, director of product management at Dell EMC Networking. "We are pleased to see multiple vendors embrace a common interface because of the security of supply it provides to end customers."

Lumentum and Finisar use a common set of transceiver optical specifications in order to provide interoperability of their respective transceivers. This benefits users by presenting two well known optical module suppliers with this key technology for the most economical 100Gbps upgrade path.

"This demonstration marks an important step in the development of a low-cost 100G solution for a great many customers who have made the investment over the years in a duplex multi-mode fiber infrastructure for their data centers," says Lumentum product line manager Kevin Redner. "We knew the technology existed to use SWDM for 100G short-reach applications, and today we're pleased to show that customers can move confidently forward knowing that they have multiple sources for this product," he adds.

"SWDM technology enables data-center operators to extract ongoing value from their legacy duplex multi-mode fiber plant," says Finisar senior product line manager Tony Abdilla. "Duplex multi-mode fiber was widely deployed for 10G data transmission. With SWDM transceivers, the same fiber can be used to carry 100G data."

In 2015 the SWDM Alliance was created with the express purpose of promoting this technology in response to a need in the industry. With SWDM4, an optical transceiver with a standard QSFP28/CAUI-4 electrical interface can be plugged into an Ethernet switch or network interface controller (NIC) and drive 100Gbps over legacy duplex MMF.

www.swdm.org
www.lumentum.com
www.finisar.com/optical-components

Finisar demos first suite of extended-reach 100Gb/s QSFP28 modules for enterprise & hyperscale data centers

New portfolio includes eSR4, eCWDM4 and eLR4 transceivers

At the European Conference on Optical Communications (ECOC) in Dusseldorf, Germany (19–21 September), fiber-optic communications component and subsystem maker Finisar Corp of Sunnyvale, CA, USA demonstrated a new family of 100Gb/s optical modules extending communication reaches in modern enterprise and hyperscale data-center environments.

Based on the QSFP28 form factor, the comprehensive portfolio includes an eSR4 (extended short-reach) transceiver designed for 200m reaches, an eCWDM4 (extended coarse wavelength division multiplexing) transceiver for 10km reaches, and an eLR4 (extended long-reach) transceiver for 20km reaches, each operating using four 25Gb/s channels.

It was estimated in a recent report by the Dell'Oro Group that the cloud market for Ethernet switching is expected to reach $8bn globally by 2020. Hyperscale data centers are widely used by cloud service providers to house cloud-based resources and services. As the strong demand for Internet bandwidth drives the need to build data-center facilities that are both larger in footprint and encompass more buildings within a data-center campus, Finisar is offering what is claimed to be the first suite of extended-reach products tailored to meet this bandwidth requirement.

During the ECOC exhibition, Finisar demonstrated its new eSR4 QSFP28 transceiver transmitting 100Gb/s over 200m on OM3 multi-mode fiber (MMF), exceeding the 70m reach specified by the IEEE 802.3bm standard. It can also run over 300m on OM4 MMF. This transceiver will interoperate with four Finisar 25GE SFP28 eSR transceivers at its maximum specified reach, or with a standard QSFP28 SR4 transceiver at the IEEE specified 70m reach.

Finisar also demonstrated its new eCWDM4 QSFP28 transceiver transmitting 100Gb/s over a 10km reach on duplex single-mode fiber (SMF). It consumes less than 3.5W of power and will meet the requirements of the recently announced 4WDM MSA (4-wavelength Wavelength Division Multiplexing Multi-Source Agreement) 10km interface. This device will also interoperate with modules compliant to the CWDM4 MSA, up to 2km.

Thirdly, Finisar demonstrated its new eLR4 QSFP28 transceiver transmitting 100Gb/s over a 20km reach on duplex SMF. It also consumes less than 3.5W power and will meet the requirements of the 4WDM MSA 20km interface. The device will interoperate with modules compliant to 100GBASE-LR4 specifications, up to 10km.

The new 4WDM MSA (of which Finisar is a founding member) will drive the development of extended-reach low-cost 100G optical specifications. The industry consortium will also promote adoption of industry interoperability of 100G optical transceivers for 10km based on the CWDM4 wavelength grid, and 20–40km based on the LAN-WDM wavelength grid, over duplex SMF, which are important requirements for supporting hyperscale data center needs.

"Finisar has the broadest portfolio of 100Gb/s QSFP28 products on the market," claims Rafik Ward, VP of global marketing. "These products were designed with longer-reach capabilities in a low-power and low-cost package," he adds. "We are also able to provide these products in high volumes by leveraging our solid vertically integrated manufacturing infrastructure."

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

Finisar unveils 64 Gbaud Class 40 integrated coherent receiver

Finisar has introduced its CPRV422XA family of Class 40 high-bandwidth OIF Micro-ICR receivers.

The new family of 64 Gbaud capable receivers, in the micro-intradyne coherent receiver (μ-ICR) form factor, offers a reduced footprint while bringing the latest technology to market, enabling the next generation in coherent transmission systems targeting single-wavelength applications up to 600Gb/s data speeds, says Finisar.

The next generation of coherent optical systems will utilize high data rates up to 64 Gbaud and more complex modulation formats up to 64 QAM (quadrature amplitude modulation). The CPRV422XA is designed to support these data rates and modulation enhancements to enable next-generation systems for service provider and data-center interconnect applications.

"Finisar is continuing to invest in coherent communications technology. The CPRV422xA introduction is the latest in our discrete component product line to address high-bandwidth applications," says John DeMott, senior director of marketing. "In addition to receivers, we are also continuing to enhance the capabilities of our advanced coherent components, including integrated TOSA and ROSA, narrow-linewidth lasers, Mach–Zehnder modulators and related electronics."

The CPRV422XA Class 40 Micro-ICR is sampling now. The component is offered with an evaluation kit to support component and system integration testing.

www.finisar.com

4WDM MSA Group formed to drive development of 10, 20 and 40km low-cost 100G optical specifications targeting modern datacenters

Industry consortium defining and promoting cost-effective, extended-reach 100G specs addressing inter-datacenter and access applications

The 4WDM MSA (4-wavelength Wavelength Division Multiplexing Multi-Source Agreement) Group has announced its formation as an industry consortium dedicated to defining optical specifications and promoting the 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 datacenter interconnects and mobile backhaul applications. The 4WDM MSA participants say they are responding to previously unmet industry needs for longer reaches, lower costs and lower power consumption, compared with previously available standards, in small form factors.

"The CWDM4 MSA defined the first duplex low-cost 100G specification for 2km reaches based on a CWDM grid and using RS (528,514) FEC [Reed-Solomon forward error correction]," notes Dale Murray, principal analyst at LightCounting Market Research. "Now the 4WDM MSA is extending the value proposition of the CWDM4 MSA and RS-FEC to define an even more cost-effective set of specifications for reaches from 10 to 40km," he adds. "Customers, particularly hyperscale cloud service providers and carriers, are looking for optimized solutions for up to 40km."

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

www.4wdm-msa.org

NeoPhotonics introduces 64 Gbaud Class 40 micro-intradyne coherent receiver

At the European Conference on Optical Communications and Exposition (ECOC 2016) in Dusseldorf, Germany (19–21 September), 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) announced that it is sampling a Class 40 high-bandwidth micro-intradyne coherent receiver (HB Micro-ICR) capable of supporting 64 Gbaud symbol rates (double the bandwidth of standard 32 Gbaud ICRs). The HB Micro-ICR supports higher-order modulation up to 64 QAM (quadrature amplitude modulation) which, when coupled with NeoPhotonics ultra-narrow linewidth, external-cavity micro-ITLA (integrated tunable laser assembly), can achieve 600Gbps over data-center interconnect distance of 80km.

Similarly, using dual-polarization QPSK (quadrature phase-shift keying) modulation, the HB Micro-ICR extends the reach to 2000km at 200Gbps (double the data rate of standard coherent transmission). NeoPhotonics says that, by using its coherent components, system designers can increase the bandwidth by up to a factor of six and dynamically change the reach and modulation format while keeping the number of components unchanged, enabling software-defined networks (SDN) and greatly reducing the cost per bit.

NeoPhotonics' HB Micro-ICR is designed to support the Optical Internetworking Forum (OIF) Implementation Agreement for Micro-Intradyne Coherent Receivers (#OIF-DPC-MRX-01.0). The HB Micro-ICR form factor is designed to fit into both CFP2-ACO (analog coherent optics) and CFP-DCO (digital coherent optics) pluggable modules. Both the HB Micro-ICR and the ultra-narrow-linewidth laser also exhibit the low electrical power required for use in pluggable modules. NeoPhotonics also offers a 45 Gbaud (Class 30) micro-coherent receiver which, when used with the firm's ultra-narrow-linewidth tunable laser in a DP-32QAM configuration, achieves 400Gbps in data-center interconnect applications.

"Our new HB Micro-ICR enables coherent system designers to greatly reduce the cost per bit by getting much higher data rates out of the same number of optical components while at the same time flexibly changing the reach and data rate under software control in SDN," says chairman & CEO Tim Jenks. The new product is made possible by the firm's hybrid photonic integration technology and, along with its line of multi-cast switches, helps to enable users to achieve a completely flexible high-speed network that can dynamically adjust to changing needs, he adds.

www.neophotonics.com

MiaSolé launches next-generation 17%-efficient flexible, ultra-light CIGS PV modules

At Solar Power International in Las Vegas (12–15 September), copper indium gallium diselenide (CIGS) thin-film photovoltaic solar cell and panel maker MiaSolé of Santa Clara, CA, USA (founded in 2004 and bought by Beijing-based renewable energy firm Hanergy in December 2012) launched its next generation flexible ultra-light solar modules.

MiaSolé says that the new products deliver efficiency of up to 17% (twice that of previous flexible, thin-film, solar technology) in a thin form factor (four times lighter than traditional rigid solar panels).

The firm says the new product can be installed in any location, on and off the grid — in places where it previously was not possible to install solar — with an energy payback of less than half a year. MiaSolé is in high-volume production and began shipping volume orders in 2016.

In the past, solar installations were limited to rigid glass panels that could only be installed in certain conditions based on the type of structure or roofing of the building. MiaSolé reckons its new panel will open up new markets, create new applications and enable new product design possibilities for manufacturers to integrate solar into their products. MiaSolé's new products are part of a broader trend in the solar power industry toward more versatile integrations of solar panels into roofing and other products, e.g. Elon Musk has said that SolarCity intends to offer a 'solar roof' product with integrated solar technology. "Instead of just selling solar panels that can be placed on someone's existing roof, SolarCity can sell the entire roof itself with the solar power capabilities built into it," Musk said.

MiaSolé is already partnering to create building-integrated photovoltaic (BIPV) products, e.g. with roofing supplier McElroy Metal. "Their thin-film solar modules are aesthetically pleasing and attach very easily to our roofing systems, because they have a factory-applied adhesive that works well with our metal panel roofing," comments its VP of marketing Ken Gieseke. "MiaSolé's next-generation flexible solar panels have significantly improved in performance compared to previous flexible solar cells… performance is now on-par with rigid glass panels," he adds.

"Our new flexible ultra-light solar solution is bringing to light the next generation of flexible solar technology that overcome most obstacles to solar energy adoption," says Anil Vijayendran, MiaSolé's VP of product sales & marketing. "This technology is especially relevant as part of the larger conversation that Elon Musk and SolarCity are starting to promote, with the idea of an integrated 'solar roof' product instead of separate solar modules installed on a roof," he adds.

"Our thin-film solar technology has made a generational shift compared to previous limitations of rigid glass panels, and has reached a new level of efficiency and adaptability. This is especially important for installing solar on the roofs of buildings — our flexible solar technology is 4x lighter than standard glass panels, which helps solve one of the biggest challenge for integrating solar into roofing structures."

Vijayendran also said that MiaSolé's new panels are more cost-effective than previous generations of flexible solar technology. "Even as we have significantly expanded the efficiency of flexible solar technology, we have managed to keep costs under control — making flexible solar a more compelling and cost-effective proposition," says Vijayendran.

MiaSolé claims that its new flexible ultra-light solar product is the highest efficiency, thin-film solar technology on the market, with production efficiency of up to 17% (2x more efficient than previous generations) and more than 18% projected by 2017. It can be configured in various sizes and modified to fit an application by adhering directly to surfaces with peel-&-stick adhesive. Because they are so thin (2.5mm), the new panels are shatterproof and resistant to wind and seismic activity.

www.solarpowerinternational.com
http://miasole.com/products

MiaSolé forms sales channel partnership with Inovateus Solar

At Solar Power International, MiaSolé announced a new sales channel partnership with solar development, engineering, procurement & construction (EPC) and supply company Inovateus Solar of South Bend, IN, USA to distribute MiaSolé's new line of next-generation, ultra-lightweight flexible solar panel products. The strategic sales partnership is intended to help MiaSolé expand the penetration of flexible solar into new markets, new applications and new locations on and off the grid, making it increasingly possible to overcome obstacles to solar adoption.

"Since our company's inception, we have been strong supporters of flexible thin-film photovoltaic technology," says Inovateus' president TJ Kanczuzewski.

"Inovateus Solar has an exceptional track record of successfully developing and installing hundreds of megawatts of solar power systems in the US and around the world, as well as supplying solar components to hundreds of distribution customers," comments MiaSolé's VP of product sales & marketing Anil Vijayendran.

www.inovateus.com

Solar Frontier signs MoU for feasibility study on producing CIS thin-film solar panels in Saudi Arabia

Tokyo-based Showa Shell Sekiyu, along with its subsidiary Solar Frontier — the largest manufacturer of CIS (copper indium selenium) thin-film photovoltaic (PV) solar modules — have signed a memorandum of understanding (MoU) with Saudi Aramco and the Saudi Arabian National Industrial Cluster Development Program (NICDP).

The MoU stipulates that all three companies, along with the Saudi Arabian government, will conduct a joint feasibility study into the possibility of CIS solar panel production in Saudi Arabia. The country is currently promoting its Vision 2030 economic reform initiative and, as part of that, it intends to conduct the joint feasibility study to research the technological and economic aspects of CIS thin-film solar panel production in the Kingdom.

Showa Shell Sekiyu Group says that it has various interests and ties with the Kingdom of Saudi Arabia as well as Saudi Aramco. Further developments will be announced depending on the results of the joint feasibility study.

www.solar-frontier.com

Solar Frontier's 1.4MW CIGS PV installation powering Italy's biggest shopping center

Munich-based Solar Frontier Europe, a subsidiary of Tokyo-based Solar Frontier — the largest manufacturer of CIS (copper indium selenium) thin-film photovoltaic (PV) solar modules — says that its CIS modules have been selected for use in a solar installation on the roof of 'Il Centro' in Arese near Milan, which is the largest shopping center in Italy and among the largest in Europe (housing about 200 shops over an area of 100,000m^2).

The installation features 1.4MW of nominal power and completely covers the roof of the Il Centro shopping center. While P.M. Service of Pontassieve near Florence acted as the distributor, ING srl of Treviolo, Italy was responsible for the installation of both the thermal power plant and the PV system.

'Il Centro', in Arese near Milan, which is the largest shopping center in Italy and among the largest in Europe .

"We decided to propose Solar Frontier's modules as an alternative solution, given the higher performance and quality compared to crystalline silicon technology," says ING's owner Gabriele Ghilardi.

The energy generated is used to light the building and run the air conditioning system. Excess energy is sold to the grid. Altogether, the installation covers 50% of the daily energy needs of the shopping center, which opened in April. Comprising 8295 of Solar Frontier's 170Wp modules, the installation was mounted on the roof between October 2015 and January 2016.

"Solar Frontier is part of such a trendsetting project that can serve as a model for major consumers in Europe," says Solar Frontier Europe's managing director Wolfgang Lange. "With about 1400kW-hrs of solar radiation per square meter annually, the region around Milan is ideal for capitalizing on solar energy," he adds. "The installation saves more than 800 tons of CO_2 each year and ensures that the shopping center is not dependent on rising electricity prices."

"Solar Frontier has been a reliable partner for over five years," comment Massimo Innocenti and Andrea Parrini, owners of P.M. Service. "We selected the CIS modules for this project because of their excellent temperature stability, as well as the high yield at lower irradiation."

www.solar-frontier.com/eng
www.pmservicespa.com

Avancis and Sunpartner team on solar glass for BIPV

A strategic partnership has been announced for the copper indium gallium diselenide (CIGS) thin-film photovoltaic cell technology of Avancis GmbH of Torgau, Germany to be used in the semi-transparent WYSIPS Design Glass energy-producing solar glass of Sunpartner Technologies of Rousset, Aix-en-Provence, France for construction and use in smart city markets.

The partners' first semi-transparent solar glazing panel was shown at the glasstec trade fair in Düsseldorf, Germany (20–23 September). Six PV modules with different designs were showcased as first samples of WYSIPS Design Glass technology.

"It is essential to be able to count on strong partners who are globally recognized," says Sunpartner's president Ludovic Deblois. "Avancis develops and produces leading-edge thin-film CIGS PV modules that have some of the best performances on the market. In fact, they have been certified by TÜV, Fraunhofer ISE and other recognized certification bodies… Avancis has been smart in adapting developments in the solar market by positioning themselves very early in BIPV, which is growing strongly in Europe and around the world. We have already planned several new R&D ideas to explore at their R&D centers in Germany," he adds.

"Sunpartner Technologies has extensive experience in energy-generating glass," comments Avancis' CEO Dr Franz Karg. "After more than two years of intensive collaboration, we are pleased to cooperate with an innovative partner with whom we complete decisively our product portfolio for solar facades," he adds. "In addition to our existing colored architects' panels, we will be able to provide basic products for semi-transparent surfaces such as insulating facades, double facades and skylights."

Sunpartner provides architects with a range of semi-transparent photovoltaic glazings with customizable designs (gradients, shapes or colors available on request) and varying transparency (10–70%) whose power/yield can reach 110Wp/m^2.

Design Glass integrates into a building's structural design, making facades, canopies, skylights, balcony balustrades and sunshades into distinctive architectural elements.

Sunpartner plans to manufacture the Design Glass modules, with pre-series products available by the end of 2016. Serving the construction industry, this facility should increase its capacity from 30,000m^2/year in 2017 to 200,000m^2/year by 2022 to meet the needs of the European market. Expansion to other global markets will be achieved through manufacturing joint ventures.

The firm has also developed WYSIPS Vision Glass: transparent solar technology that integrates into glazing to turn windows into solar panels while preserving aesthetics. Vision Glass can power features such as darkening the windows, lighting, automated opening, or alarms. Compatible with laminated and tempered glass, it generates 18–50Wp/m^2 with a transparency of 20–70%.

With Design Glass and Vision Glass, Sunpartner aims to position itself as a key player in building-integrated photovoltaics (BIPV), with strong growth projected in the coming years. In new construction, energy regulations are pushing towards energy-positive buildings. There are also opportunities for integrated solar glazing in energy renovation. By 2020, the market for integrated solar glazing should reach $3.5bn, forecasts n-tech research.

www.sunpartnertechnologies.com

AVANCIS launches architectural CIS PV module for building sector

At the glasstec trade fair for glass production and processing (20–23 September), Avancis launched its PowerMax SKALA architectural PV module.

The construction of photovoltaic façades was previously an architectural challenge and subject to clear restrictions, but architects and planners now have a new freedom, says AVANCIS. SKALA is not only available in different colors and sizes, the panel can also be installed both in portrait and landscape format, according to regional requirements. Building engineers, architects and façade planners hence have the greatest possible freedom for design, planning and design of the building envelope.

"Solar façades based on thin-film technology are unique solutions which enable high-quality, aesthetic cladding solutions," says CEO Dr Franz Karg. "They are a real design alternative to traditional façades, and further they generate a significant portion of the energy needs of the building," he adds. "Our CIS thin-film technology already allows innately high color homogeneity. Thus, with SKALA we have developed an architectural module for the building sector which not only meets the high standards of performance and design in solar façades, this will set new standards."

SKALA is available in different colors and sizes and is especially suitable for ventilated facades. Due to the singular mounting system of the module (with solid back-rails on the back and no visible clamping on the front), the frameless architecture module can be inserted to fit any façade construction.

Another key feature is the power class of the façade module: Each standard-sized SKALA panel has 135Wp output. Also, the new architectural panel has earnt German General Building Approval (abZ), so time- and cost-consuming single-project audit procedures can be omitted from the start.

www.Avancis.de

Stacked perovskite/CIGS tandem solar module hits record 17.8% efficiency

Module exceeds efficiencies of separate perovskite and CIGS modules

Researchers at nanoelectronics research center imec of Leuven, Belgium (a partner in Solliance and EnergyVille), Germany's Karlsruhe Institute of Technology (KIT), and ZSW (Zentrum für Sonnenenergie- und Wasserstoff-Forschung — or Center for Solar Energy and Hydrogen Research — Baden-Württemberg) in Stuttgart, Germany, have fabricated a tandem multi-junction thin-film solar module stack consisting of perovskite and copper indium gallium selenide (CIGS) with a solar energy conversion efficiency of 17.8%, surpassing for the first time the highest efficiencies of separate perovskite and CIGS modules.

The 3.76cm^2 stacked module implements a fully scalable device concept: both the perovskite top module and the CIGS bottom module feature a monolithic interconnection scheme (using seven and four module cell stripes, respectively. The result is a reduction in area loss of less than 8% for both technologies.

The higher energy part of the spectrum is harvested in the semi-transparent perovskite module on top, while the light with lower energy passes and is harvested in the bottom CIGS cell. As a result, the prototype shows an unprecedented power conversion of 17.8%, outperforming the record 15.3%-efficient upscaled perovskite module reported by imec as well as the highly efficient stand-alone upscaled CIGS module of ZSW (with efficiencies nearing 15.7%).

"This result was achieved through close and intricate collaboration leveraging the expertise of the three partners," says imec's head of thin-film PV research Dr Tom Aernouts. "Imec's expertise in perovskite technology was underscored by the use of a perovskite top module in these stacked solar modules."

According to Dr Ulrich Paetzold, head of the research group at KIT, the result is just a starting point, with more results to come in the next few years such as perovskite/CIGS multi-junction solar modules surpassing efficiencies of 25%. Paetzold's Helmholtz Young Investigator group (in KIT's Institute of Microstructure Technology and the Institute of Light Technology) is focusing on the optics in multi-junction perovskite solar modules and will develop further specialized nanophotonic materials for these devices.

Finally, ZSW contributed its expertise in CIGS solar modules. ZSW holds the record for CIGS solar cell efficiency of 22.7%. "This success is an elegant way of combining the advantages of two highly advanced thin-film technologies," comments professor Michael Powalla, member of the board and head of the Photovoltaics Division at ZSW.

The module and technical details were presented by imec's Dr Tom Aernouts, KIT's Dr Ulrich Paetzold and ZSW's Dr Erik Ahlswede on 26 September at the 2nd International Conference on Perovskite Solar Cells and Optoelectronics (PSCO-2016) in Genova, Italy.

www.imec.be
www.kit.edu

Stion's CIGS module passes Thresher test

Stion Corp of San Jose, CA, USA says that its CIGS (copper indium gallium selenium) photovoltaic module has passed the 'Thresher' test performed at the Renewable Energy Test Center (RETC) in Fremont, CA.

The Thresher test is intended to simulate at least 25 years of real-world exposure to evaluate long-term durability and performance. Harsh conditions induced over a six-month period expose the modules to damp heat, humidity, freezing and dynamic mechanic load. To date, less than five of the world's top 30 photovoltaic module makers have passed the thresher test.

The Thresher test consists of four individual tests during which modules undergo rapid temperature changes from as much as 194°F (90°C) under 85% RH (relative humidity) down to –40°F (40°C):

- The Humidity Freeze test consists of five different sub-tests including a UV soak, 50 hours of thermal cycling and 30 humidity freeze cycles;
- The Thermal Cycling test consists of three different sub-tests including a total of 600 cycles, during which STC peak power current is simultaneously applied.
- The Damp heat test consists of two different sub-tests for a total of over 2000 hours of continuous damp heat (at 85°C and 85% RH).
- The Dynamic mechanical test consists of three different sub-tests that test Stion frameless clamps by applying 1000 Pa of downward and upward pressure over 1000 cycles that last 30 seconds each.

Post-testing degradation levels were well below the threshold limit needed to pass the thresher test, notes Stion.

"The thresher test is the most demanding test in the industry and has been difficult for even the largest solar manufacturer's to pass," says chief technology officer Bob Wieting PhD.

www.stion.com

MIT and Masdar develop photovoltaic 'step cell'

Stepped GaAsP/Si tandem cell yields 35% conversion efficiency, while reusable SiGe template promises low-cost manufacturing.

A team of researchers at the USA's Massachusetts Institute of Technology (MIT) and the Masdar Institute of Science and Technology in Abu Dhabi, United Arab Emirates has developed a new solar photovoltaic 'step cell' that combines two different layers of absorbing material arranged in a stepwise fashion — with the lower layer jutting out beneath the upper layer, exposing both layers to incoming sunlight — in order to harvest a broader range of the sun's energy. Such layered (multi-junction) solar cells are typically expensive to manufacture, but the researchers also used a novel, low-cost manufacturing process.

The step-cell concept can reach theoretical efficiencies above 40% and estimated practical efficiencies of 35%, prompting the principal investigators — Masdar Institute's Ammar Nayfeh, associate professor of electrical engineering and computer science, and MIT's Eugene Fitzgerald, the Merton C. Flemings-SMA Professor of Materials Science and Engineering — to plan a startup company to commercialize the solar cell.

Fitzgerald, who has launched several startups (including AmberWave Systems Corp, Paradigm Research LLC, and 4Power LLC) thinks that the step cells might be ready for the PV market within the next year or two.

The team presented its initial proof-of-concept step cell in June at the 43rd IEEE Photovoltaic Specialists Conference in Portland, OR, USA. The researchers have also reported their findings at the 40th and 42nd annual conferences, and in the Journal of Applied Physics and IEEE Journal of Photovoltaics.

Beyond silicon

Traditional silicon crystalline solar cells are relatively cheap to manufacture but are not very efficient at converting sunlight into electricity. On average, solar panels made from silicon-based solar cells convert 15–20% of the sun's energy into usable electricity.

Silicon's low efficiency is partly due to its bandgap energy, which prevents it from efficiently converting higher-energy photons (e.g. blue, green, and yellow light) into electrical energy. Instead, only the lower-energy photons (e.g. longer-wavelength red light) are efficiently converted into electricity.

In contrast, gallium arsenide and gallium phosphide can harness more of the sun's higher-energy photons. While these semiconductors have reached higher efficiencies than silicon, the highest-efficiency solar cells have been made by layering different materials on top of each other and fine-tuning them so that each can absorb a different part of the electromagnetic spectrum.

Layered solar cells can reach theoretical efficiencies above 50%, but their very high manufacturing costs have relegated their use to niche applications such as on satellites, where high costs are less important than low weight and high efficiency.

The Masdar Institute–MIT step cell, in contrast, can be manufactured at a fraction of the cost because a key component is fabricated on a substrate that can be reused. The device could thus help to boost commercial applications of high-efficiency, multi-junction solar cells at the industrial level, it is reckoned.

Steps to success

The step cell is made by layering a gallium arsenide phosphide (GaAsP)-based solar cell on a low-cost silicon solar cell. The silicon layer is exposed, appearing like a bottom step. This intentional step design allows the top GaAsP layer to absorb the high-energy photons (from blue, green, and yellow light), leaving the bottom silicon layer free to absorb lower-energy photons (from red light) not only transmitted through top layers but also from the entire visible light spectrum.

"We realized that when the top GaAsP layer completely covered the bottom silicon layer, the lower-energy photons were absorbed by the silicon germanium (SiGe) — the substrate on which the GaAsP is grown — and thus the solar cell had a much lower efficiency," says Sabina Abdul Hadi, a PhD student at Masdar Institute whose doctoral dissertation provided the foundational research for the step-cell. "By etching away the top layer and exposing some of the silicon layer, we were able to increase the efficiency considerably."

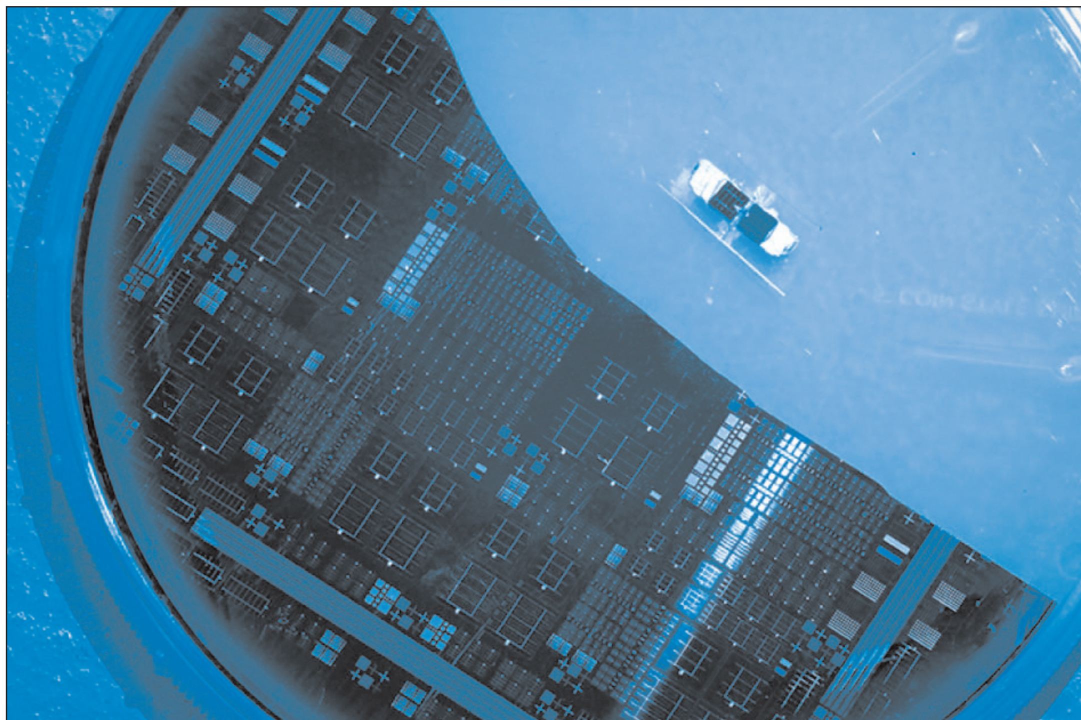
Working under Nayfeh's supervision, Abdul Hadi conducted simulations based on experimental results to determine the optimal levels and geometrical configuration of the GaAsP layer on silicon to yield the highest efficiencies. Her findings resulted in the initial proof-of-concept solar cell. Abdul Hadi will continue supporting the step cell's technological development as a post-doctoral researcher at Masdar Institute.

At MIT, the team developed the GaAsP by growing the semiconductor alloy on a substrate made of SiGe.

"GaAsP cannot be grown directly on silicon, because its crystal lattices differ considerably from silicon's, so the silicon crystals become degraded," notes Nayfeh. "That's why we grew the GaAsP on the SiGe — it provides a more stable base."

The problem with the SiGe under the GaAsP layer is that SiGe absorbs the lower-energy light waves before it reaches the bottom silicon layer, and SiGe does not convert these low-energy light waves into current. "To get around the optical problem posed by the SiGe, we developed the idea of the step cell, which allows us to leverage the different energy absorption bands of GaAsP and silicon," says Nayfeh.

The step cell concept led to an improved cell in which the SiGe template is removed and re-used, creating a solar cell in which GaAsP cell tiles are directly on top of a silicon cell. The step-cell allows for SiGe reuse, since the GaAsP cell tiles can be under-cut during the transfer process. "We grew the GaAsP on top of the SiGe, patterned it in the optimized geometric configuration, and bonded it to a silicon cell," says Fitzgerald. "Then we etched through the patterned channels and lifted off the SiGe alloys on silicon," he adds. "What remains then is a high-efficiency tandem solar cell and a SiGe template, ready to be reused."



A silicon solar cell with SiGe filter using a step-cell design (large) and a GaAsP layer on silicon step-cell proof-of-concept solar cell (small). (Photo: Tahra Al Hammadi/Masdar Institute News.)

Because the tandem cell is bonded together, rather than created as a monolithic solar cell (where all layers are grown onto a single substrate), the SiGe can be removed and reused repeatedly, which significantly reduces the manufacturing costs.

The step cell fits well in the existing gap of the solar PV market, between the super-high-efficiency and low-efficiency industrial applications.

Because the tandem cell is bonded together, rather than created as a monolithic solar cell (where all layers are grown onto a single substrate), the SiGe can be removed and reused repeatedly, which significantly reduces the manufacturing costs.

"Adding that one layer of the GaAsP can really boost efficiency of the solar cell but, because of the unique ability to etch away the SiGe and reuse it, the cost is kept low because you can amortize that SiGe cost over the course of manufacturing many cells," Fitzgerald says.

Filling a market gap

Fitzgerald believes that the step cell fits well in the existing gap of the solar PV market, between the super-high-efficiency and low-efficiency industrial applications. Also, as volume increases in this market gap, the manufacturing costs should be driven down even further over time.

This project began as one of nine Masdar Institute–MIT Flagship Research Projects, which are high-potential projects involving faculty and students from both universities. The MIT and Masdar Institute Cooperative Program helped to launch the Masdar Institute in 2007. Research collaborations between the two institutes address global energy and sustainability issues, and seek to develop R&D capabilities in Abu Dhabi.

"This research project highlights the valuable role that research and international collaboration plays in developing a commercially relevant technology-based innovation," says Nayfeh. ■

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GaAsP solar cells on silicon with record 12% efficiency

Dislocation engineering combined with silicon photovoltaics could lead to lower-cost ~30%-efficient double-junction devices.

Yale University and University of Illinois Urbana in the USA have improved the efficiency of gallium arsenide phosphide (GaAsP) solar cells on silicon (Si) by reducing threading dislocation densities (TDDs) [Kevin Nay Yaung et al, Appl. Phys. Lett., vol109, p032107, 2016]. The efficiency under simulated AM1.5G solar illumination of up to 12% is claimed to be among the best reported for uncoated GaAsP solar cells on GaP/Si templates. The researchers quote 9.8% as the previous record.

It is hoped that such cells can be used in tandem with low-cost silicon-based solar cells to compete with much more expensive ~45% high-efficiency multi-junction devices based on compound semiconductor substrates.

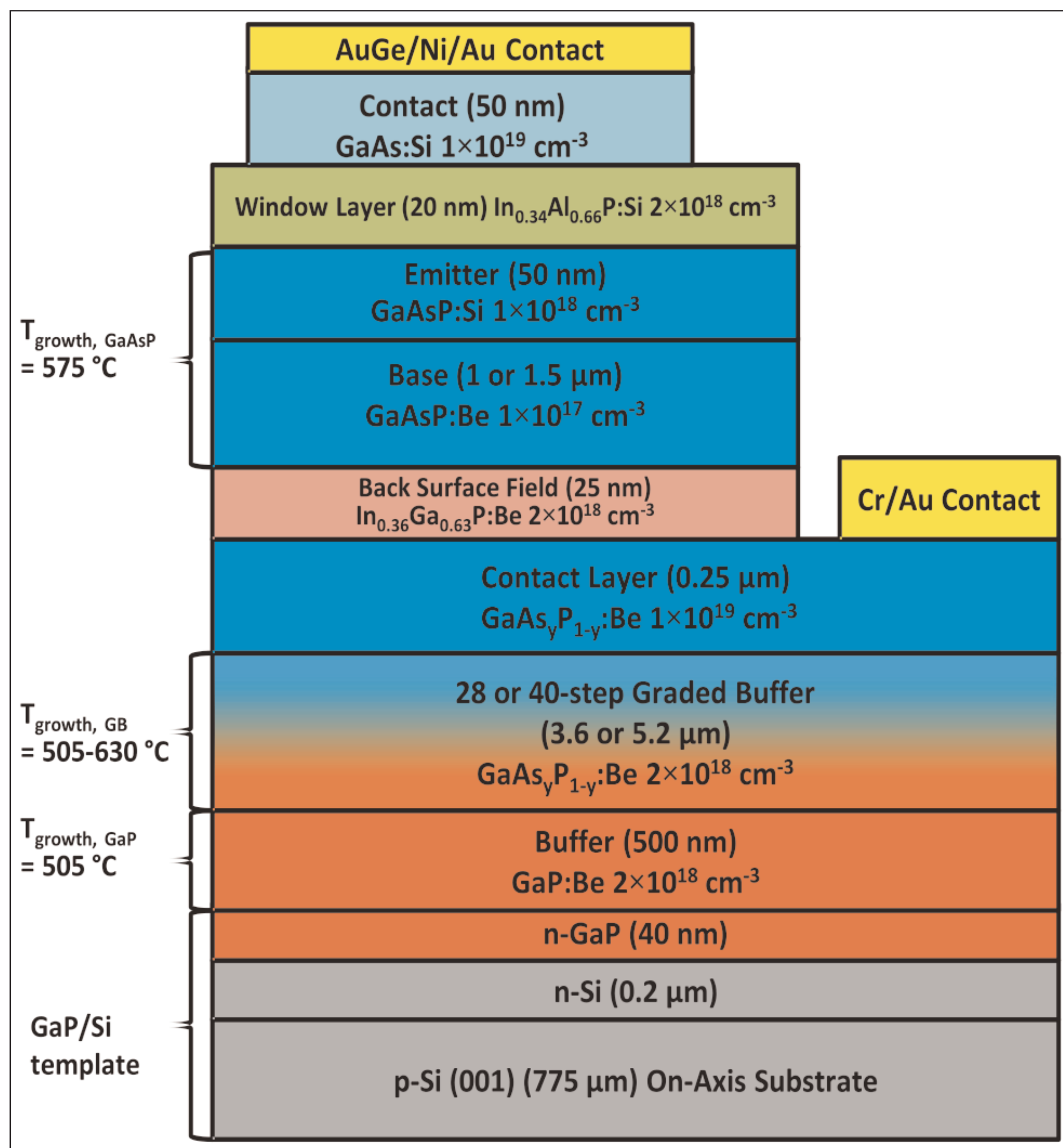

Figure 1. Schematic of GaAsP/GaP/Si solar cell layer structure.

The energy bandgap (E_g) of GaAsP can be tuned to the 1.6–1.8eV range, with 68-85% arsenic content, that would be useful as a top cell over silicon (~1.1eV). The GaAsP layers would more efficiently filter out and convert high-energy photons to energy, leaving silicon to handle the longer wavelengths that it is more suitable for.

Previously, TDD levels around $10^8/cm^2$ have hampered development of GaAsP solar cell layers on silicon. The Yale/Illinois-Urbana work has reduced this to as low as $4.0x10^6/cm^2$. High TDD results in non-radiative recombination and reduced open-circuit voltage (V_{OC})

The team comments: "We estimate that a well-designed anti-reflection coating with low grid coverage could boost our [short-circuit current density] J_{SC} to ~18mA/cm^2, resulting in a top-cell efficiency of ~16%. If the top-cell efficiency can be increased to 20% while achieving a bottom silicon cell efficiency of ~10%, then a dual-junction efficiency value approaching 30% is attainable."

Even higher efficiencies could result from adding another top junction solar cell based on indium gallium phosphide (InGaP). Such solar cells have already been produced with low TDD and bandgap offset ($W_{OC} = E_g/q - V_{OC}$, with q electron charge).

The team also suggests that its dislocation engineering could be used to integrate lasers and photoelectrochemical cells on silicon.

The GaAsP solar cell samples were grown on bulk GaP substrates and GaP/Si templates using molecular beam epitaxy (MBE). GaP has a lattice mismatch with silicon of ~0.4% at 300K. The GaP substrate was supplied by ITME of Poland. The GaP/Si was grown by NAsPIII/V GmbH of Germany using metal-organic chemical vapor deposition (MOCVD) on (001) p-Si (Figure 1).

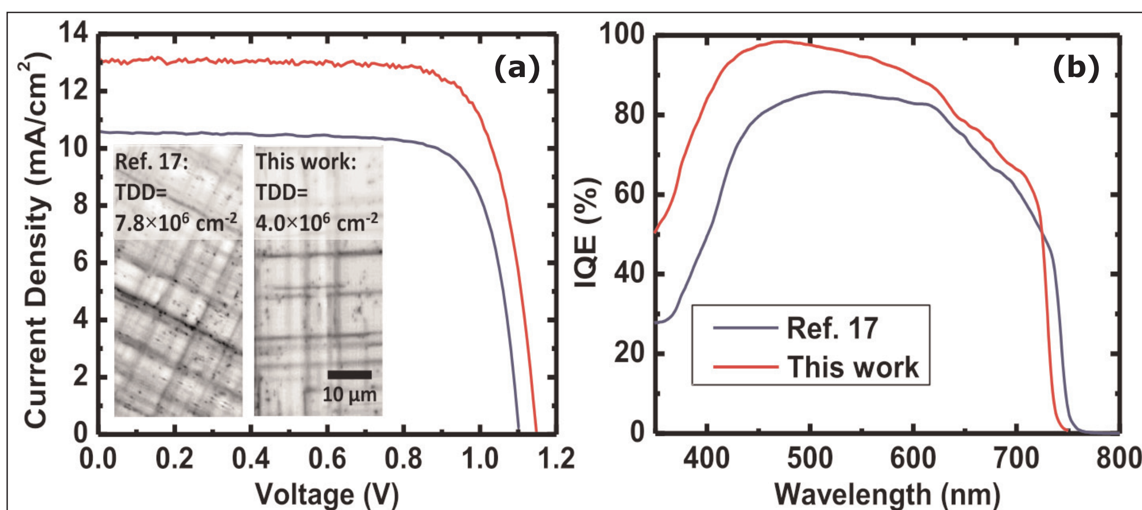

Figure 2. Comparison of GaAsP/GaP/Si solar cell (a) current density versus voltage curves with electron beam-induced current (EBIC) images inset and (b) IQE characteristics with group's latest (red, top line) and previous work (blue, bottom line).

Beryllium (Be) provided p-type doping for the MBE GaAsP buffer/contact/base and indium gallium phosphide (InGaP) back surface field layers. The n-type doping was provided by silicon for the MBE GaAsP emitter/contact and indium aluminium phosphide (InAlP) window layers.

The solar cell structures were fabricated with wet mesa etching and metal top contacts. There was no anti-reflective coating.

Before growing the solar cell, the researchers optimized the growth temperature by depositing thick GaP buffers on a GaP/Si template and studying the effect on threading dislocation density. The optimum temperature was found to be 505°C. Low-TDD buffer layers tend to result in better quality subsequent epitaxial layers.

The TDD increased below and above the 505°C value. The researchers believe the low-temperature increase (2x at 410°C) was due to reduction in the amount of dislocation glide. Dislocation glide is thought to relax strain, sweeping away the dislocations and thus reducing TDD. The high-temperature TDD increase (3x at 695°C) was attributed to nucleation of new dislocations.

Further reduction in TDD was achieved by lowering the growth rate at 505°C to allow more time for dislocation glide to act. However, increased growth time could also enhance dislocation nucleation at higher temperature.

The graded buffer (GB) layers with lower TDD were grown at temperatures in the range 575–600°C. Also, the grading rate was again important with lower TDD achieved at 575°C and 600°C when the rate was reduced from 0.8%/micron to 0.56%/μm (Table 1).

A smaller reduction in TDD was gained by reduction of the grading to 0.38%/μm at 575°C. Of course, reducing the grading rate increases production time and cost.

Comparing one of the better devices produced with the group's previous work (Figure 2), the researchers comment: "While the improvement in short-wavelength [internal quantum efficiency] IQE shown in [Figure 2(b)] results from a thinner emitter and higher-E_g window, we believe that the improvement in IQE near the band-edge largely results from lower TDD and higher electron lifetime in the base. Taken together, these performance boosts have enabled us to achieve GaAsP on GaP/Si solar cell efficiencies (without anti-reflection coatings) above 11.5%, surpassing the previously published record of 9.8%." ■

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Author: Mike Cooke

Table 1. Summary of device parameters of GaAsP solar cells grown on GaP/Si templates. GaP growth was fixed at 505°C. Highest efficiency and lowest TDD were for graded barriers grown in the range 555–600°C (TGB).

TGB [°C]	Grading rate [%/μm]	E_g [eV]	V_{OC} [V]	W_{OC} [V]	J_{SC} [mA/cm^2]	FF	TDD [x10^6/cm^2]	Efficiency [%]
505	0.80	1.69	1.05	0.64	12.7	0.76	27.5	10.2
555	0.80	1.71	1.13	0.58	12.4	0.80	5.1	11.2
575	0.80	1.69	1.12	0.58	12.7	0.77	6.0	10.9
575	0.56	1.69	1.15	0.54	13.1	0.76	4.6	11.5
575	0.38	1.70	1.15	0.55	13.3	0.79	4.2	12.0
600	0.80	1.70	1.15	0.55	13.2	0.78	5.3	11.8
600	0.56	1.69	1.13	0.56	12.0	0.80	4.0	10.9
630	0.80	1.69	1.11	0.58	11.9	0.78	7.8	10.3

Wafer reclaim for InGaAlP light emission

Researchers develop epitaxial lift-off process without expensive and time-consuming grinding and polishing.

Researchers in Germany have been developing an epitaxial lift-off (ELO) process that would allow gallium arsenide (GaAs) substrates to be reused for indium gallium aluminium phosphide (InGaAlP) thin-film light-emitting diode (LED) production without expensive and time-consuming grinding and polishing [M. Englhard et al, J. Appl. Phys., vol120, p045301, 2016].

Osram Opto Semiconductors GmbH was the main contributor to the research, with other researchers

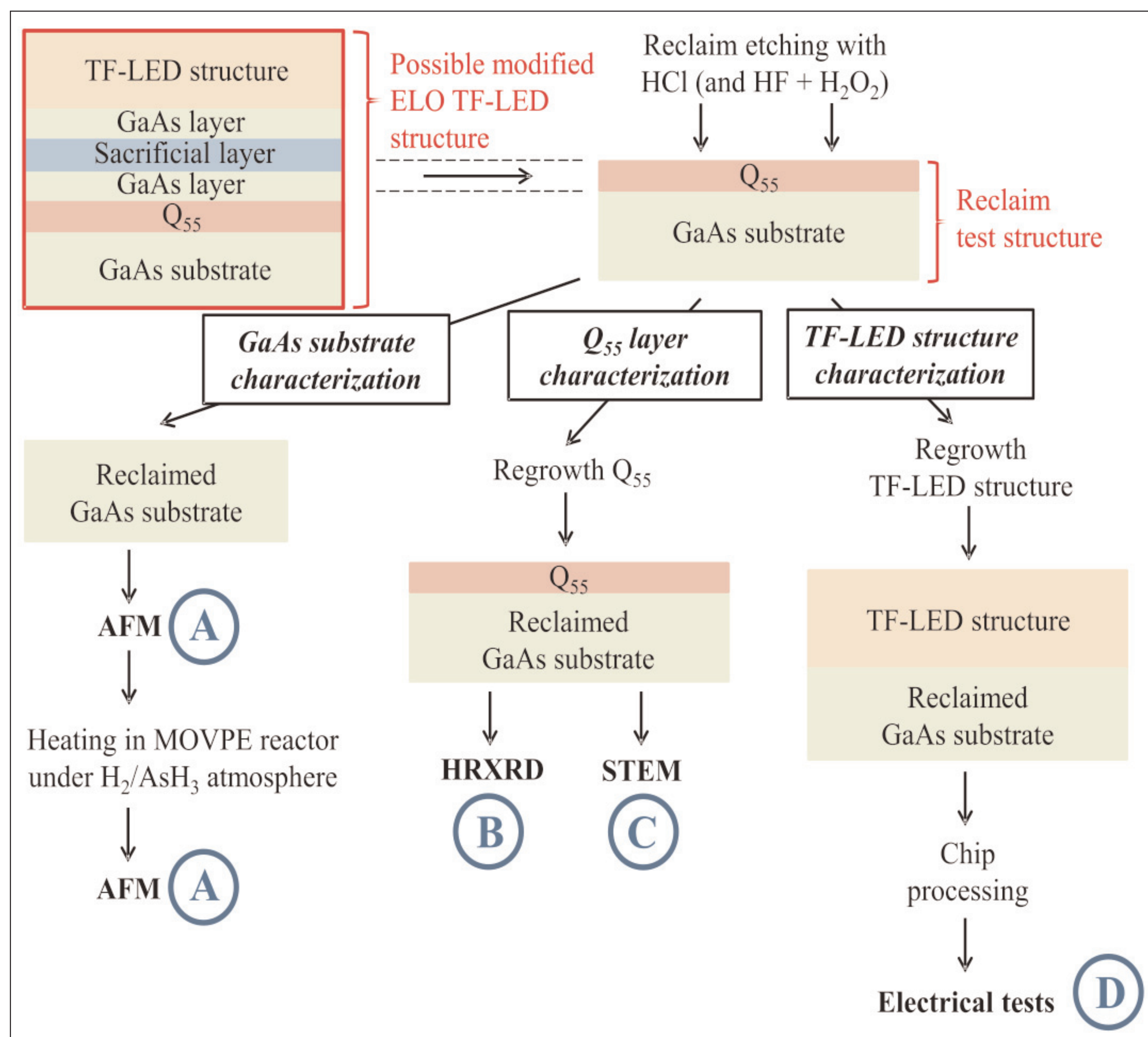

Figure 1. Schematic overview of different process steps to characterize quality of GaAs substrate after reclaim etching.

associated with Leibniz-Institut für innovative Mikroelektronik (Innovations for High Performance Microelectronics, IHP), Brandenburg University of Technology (BTU) Cottbus-Senftenberg.

The team writes: "These investigations can help by improving the ELO technique to reduce costs for GaAs substrates and reduce toxic arsenic waste. Expensive grinding or polishing processes are not necessary after ELO."

The proposed ELO process would use a sequence of layers that consisted of $In_{0.5}(Ga_{0.45}Al_{0.55})_{0.5}P$ (labeled as 'Q55') on the GaAs substrate, and GaAs layers sandwiching a selective-etch sacrificial layer such as AlAs (Figure 1). "This process would result in reducing costs for LEDs and reducing much arsenic waste for the benefit of a green semiconductor production," the team writes.

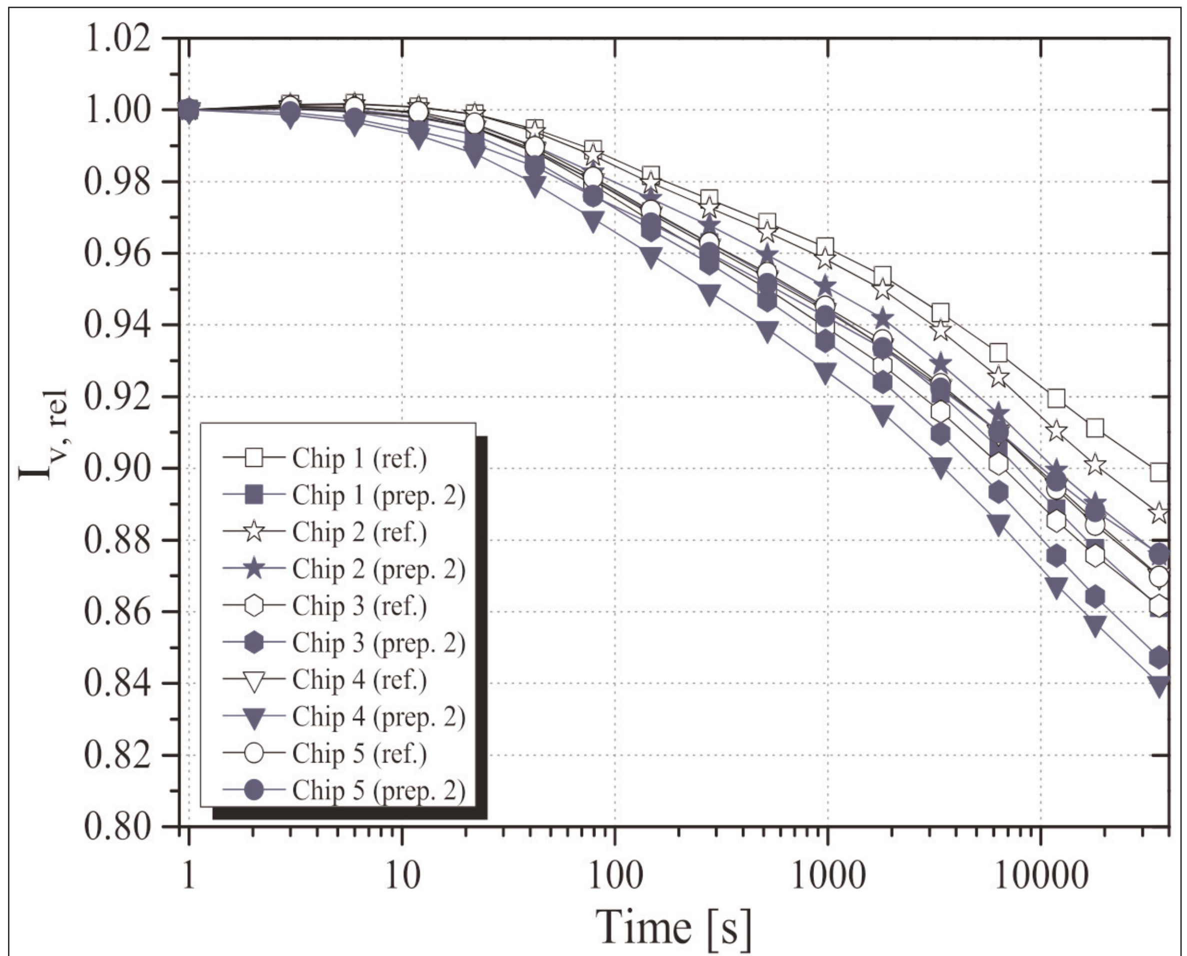

Figure 2. Typical relative luminous intensity ($I_{v,rel}$) degradation with time of chips on Ge-carrier in overstress testing of devices grown on reclaimed and reference wafers.

The Q55 layer is used to protect the GaAs substrate for reuse. The GaAs layers of the sandwich prevent damage to the Q55 and thin-film LED layers during sacrificial layer selective etch.

Normal thin-film InGaAlP LED production consists of growth on GaAs, bonding to a hard carrier wafer, and destructive removal of the GaAs growth substrate by grinding, polishing or etch. The toxic waste, including arsenic, is expensive to recycle. Even reclaiming the GaAs substrate with present ELO techniques involves grinding and polishing to achieve a suitable reconditioned surface for growth of further thin-film LEDs.

These investigations can help by improving the epitaxial lift-off technique to reduce costs for GaAs substrates and reduce toxic arsenic waste. Expensive grinding or polishing processes are not necessary after ELO.

The researchers focused on confirming that the Q55 layer removal resulted in a suitable GaAs surface for re-growth of thin-film LEDs on the reclaimed GaAs substrate. The Q55 layer was pseudomorphically grown by metal-organic vapor phase epitaxy (MOVPE) on 4" 6°-offcut GaAs at 660°C. The GaAs and Q55 layer are lattice matched at 784°C, so the growth is under slightly mismatched conditions. The reclaim etch resulted in a flat surface with ~0.2nm root-mean-square roughness.

The thin-film LEDs grown on various reclaimed wafers had similar performance to devices grown on reference substrates. The median forward voltage for all devices produced on reference or reclaimed wafers was 2.17V. The median center wavelength and optical intensity were 626nm (orange) and 1794mCd, respectively.

The researchers also performed high-temperature/current stress testing. The team claims good performance for the thin-film LEDs under stress. There was a "small inhomogeneity of the chips" attributed to process-related fluctuations. To my view, however, the presented graph (Figure 2) suggests that the chips grown on the reused substrates tend to be slightly less robust than the reference. ■

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Author: Mike Cooke

Chemical lift-off of full-wafer gallium nitride with zinc oxide interlayer

Technique could result in better quality material for lower cost with recycling of expensive growth substrates.

Researchers based in UK, France, Australia and the USA have developed a chemical epitaxial lift-off (ELO) technique for full 2-inch-diameter gallium nitride (GaN) grown on sapphire and free-standing substrates [Akhil Rajan et al, J. Phys. D: Appl. Phys., vol49, p315105, 2016]. The method used a sacrificial zinc oxide (ZnO) interlayer. The researchers hope that the ELO technique could result in better quality material, and hence higher efficiency, for light-emitting diodes and other GaN applications.

"The high optical quality of the lifted GaN suggests that ELO might offer the possibility, in the future, of transferring full wafers of GaN devices from the expensive GaN substrate to alternative substrates and then reclaiming/recycling the expensive GaN substrate for future use," comments the team from Heriot-Watt University in the UK, Nanovation in France, University of Technology Sydney in Australia, Georgiatech-CNRS in France, Georgia Institute of Technology/GT-Lorraine in France, Northwestern University in the USA, University of Nottingham in the UK, Génie électrique et électronique de Paris (GeePs) in France, and Université Versailles Saint Quentin in France

The researchers add: "Furthermore, our experience with laser lift-off of thicker GaN layers suggests that they would be self-supporting. As a next step it is thus envisaged to do ELO with thicker layers in order to test if it is possible to avoid using the host-bonding step."

The 140nm GaN epitaxial lift-off (ELO) layers were grown on 2-inch-diameter ZnO on free-standing GaN and on c-Al_2O_3 sapphire substrates. The ZnO layer thicknesses were 260nm on GaN and 160nm on c-Al_2O_3. The GaN substrate was bought from Lumilog, which uses hydride vapor phase epitaxy (HVPE) to produce free-standing wafers. The threading dislocation density of the Lumilog wafer was specified at less than 5x106/cm^2. Typical heteroepitaxy of GaN on sapphire results in threading dislocation densities of at least $10^7/cm^2$ and more usually in the range $10^8/cm^2$–$10^9/cm^2$.

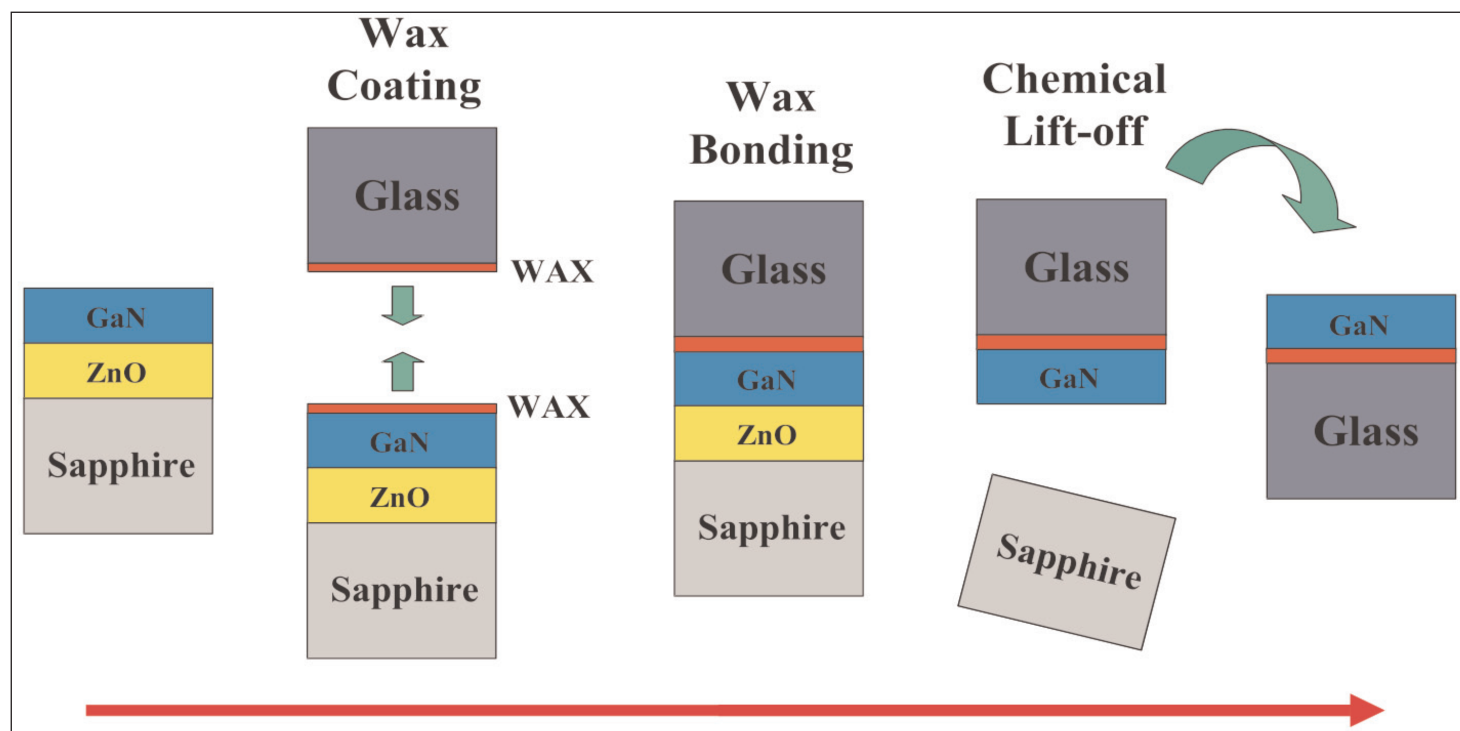

Figure 1. Wide-area chemical lift-off process flow.

The ZnO layers were grown by pulsed laser deposition of zinc in an oxygen atmosphere. The GaN epilayer was deposited using low-pressure, low-temperature metal-organic vapor phase epitaxy (MOVPE). The low pressure and temperature were designed to combat the ZnO dissociation that normally occurs in MOVPE of GaN on such material. The GaN nitrogen precursors were ammonia with added dimethylhydrazine ($C_2H_8N_2$) in nitrogen carrier. The dimethylhydrazine was used to enhance nitrogen concentrations.

The ELO used an Apiezon W wax host with a glass superstrate providing rigidity to avoid cracking, curling and break-up from strain release (Figure 1). The lift-off separation occurred using hydrochloric acid to dissolve the ZnO sacrificial layer. Near the edge, the ZnO etch rate was more than 1mm per hour, but this slowed to 0.5mm per hour towards the center.

X-ray analysis suggested that the GaN grown on free-standing GaN had "a significant reduction in crystallographic dispersion relative to typical GaN layers grown on ZnO/sapphire," according to the researchers.

The researchers report: "After lift-off, the substrates and the GaN layers all showed mirror-like surfaces although there was some cracking in the lifted GaN layers in regions where the wax did not bond the GaN layers to the glass host."

X-ray analysis of the ELO GaN gave broader peaks for material grown on free-standing GaN, compared with that grown on c-Al_2O_3. "This is not as would be expected from the increased grain size in the layer grown on GaN and film thickness effects should be negligible because the layers are approximately the same thickness," the researchers comment. The reason for the broadening after lift-off was unclear. One possibility raised is curling of the GaN from imperfect bonding of the wax to the glass.

However, cathodoluminescence (electron-beam excitation) studies at 8.5K on the ELO GaN from the free-standing GaN substrate showed near-band-edge peaks attributed to donor bound excitons (DX), and both zero phonon and single phonon donor-acceptor pair (DAP and DAP-LO) transitions at 3.33eV, 3.25eV and 3.16eV, respectively (Figure 2). The researchers add: "The presence of both excitonic emission and a phonon replica peak in this sample indicates that the growth on a GaN substrate led to a higher-quality GaN film than the growth on a sapphire substrate."

The response from the material grown on c-Al_2O_3 was broad blue (~2.9eV) and yellow (~2.15eV) lines and no near band-edge emission. It is suggested that the blue line was from zinc substitution in the GaN lattice at a level below the 1000 parts-per-million detection limit of energy-dispersive x-ray spectroscopy, which had found no detectable zinc. The yellow lines were probably due to carbon impurities. The zinc level was higher near the surface — the position where the ZnO/GaN interface was in the original growth before ELO. ■

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Author: Mike Cooke

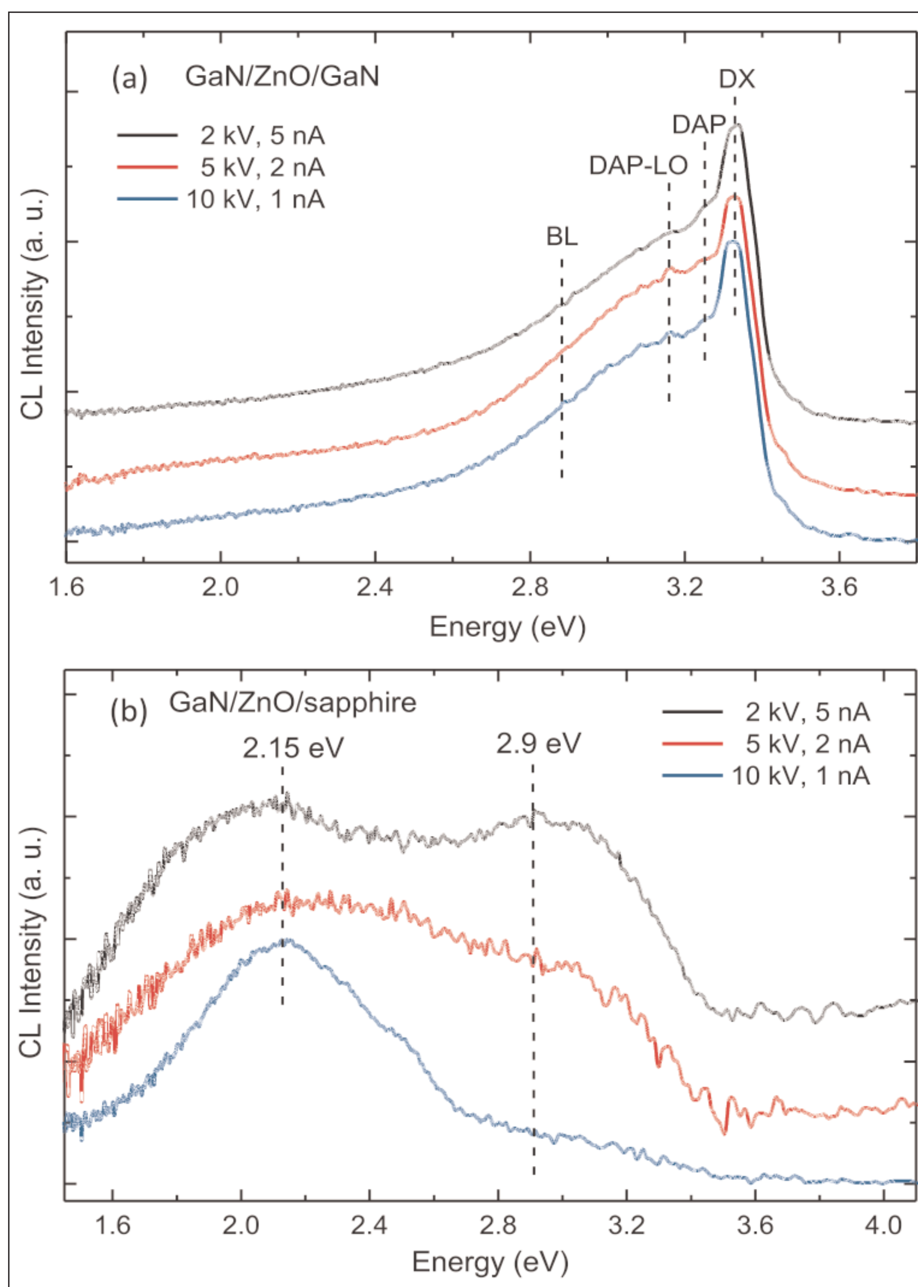

Figure 2. Depth-resolved cathodoluminescence spectra of GaN at 85K after lift-off from (a) GaN and (b) c-Al_2O_3 sapphire substrates and subsequent bonding to glass. Spectra are shifted vertically for clarity.

Reducing misfit dislocations in green semi-polar LEDs

Limited-area epitaxy eliminates non-basal-plane slip that most affects electrically generated light.

University of California Santa Barbara (UCSB) in the USA has used limited-area epitaxy (LAE) on semi-polar gallium nitride (GaN) substrates to reduce misfit dislocation (MD) densities in multiple quantum well (MQW) green light-emitting diode (LED) structures [C. D. Pynn et al, Appl. Phys. Lett., vol109, p041107, 2016].

The effect of greater limiting the area of growth mesas was to improve external quantum efficiency (EQE). At $35A/cm^2$ injection, the EQE for the most limited-area device with 5μm-wide mesas was 73% higher than for 20μm-wide LAE LEDs.

The researchers point out, however: "Still, the peak EQE of the best devices in this study was approximately an order of magnitude lower than that of previous reported green semi-polar InGaN-based LEDs. We attribute this to a reduction in radiative efficiency due to non-uniform carrier injection across the MQW active region, which likely caused an uneven distribution of electrons and holes near the bottom-most and top-most QWs, respectively. Further optimization of this MQW active region design is needed to mitigate these effects and improve device efficiency."

The MDs that reduce efficiency are caused by lattice mismatch between the underlying GaN substrate and high-indium-content indium gallium nitride (InGaN) needed for green light emission. The strain from mismatch is released by lattice plane slippages that generate MDs, which increase the probability of non-radiative electron-hole recombination and thus reduce efficiency.

To avoid MDs, the strained layers are usually limited below a critical thickness, reducing the active volume of the devices that can emit light.

The LED material was grown by metal-organic chemical vapor deposition (MOCVD) on $(20\bar{2}1)$ GaN substrates from Mitsubishi Chemical Company. The threading dislocation density was $\sim 5x10^6/cm^2$.

Substrate patterning for the limited-area epitaxy was achieved by chlorine plasma etch, giving 1μm-high mesas. The mesas were 300μm-long stripes of widths varying between 5μm and 20μm. A series of mesas 300μm wide was created with 2μm separation. The single LEDs consisted of these 300μmx300μm arrays.

The orientation of the mesas was in the c-direction projected in-plane, previous work having determined this as the most effective for preventing the generation of misfit dislocations.

The LED layer structure consisted of a 1μm n-GaN contact, five-period MQW, 8nm p-type aluminium gallium nitride (p-$Al_{0.15}Ga_{0.85}N$) electron-blocking layer, and 40nm p-GaN contact. The MQW contained 4nm $In_{0.25}Ga_{0.75}N$ wells separated by 4nm GaN barriers.

Silicon dioxide was deposited on the sidewalls of the mesas and 1μm into the top surface to confine current injection. The LED chip was defined by a further 1μm-high mesa etch of the 300μmx300μm array. The p-contact layer was coated with 100nm indium tin oxide (ITO) transparent conducting oxide (TCO) before metal deposition of the titanium/aluminium/nickel/gold n-contact, and titanium/gold n- and p-contact pads.

Light extraction was improved by thinning, polishing and roughening the back-side of the device. The roughening consisted of forming truncated pyramids. The wafer was diced and the single chips mounted on silver headers before encapsulation in silicone.

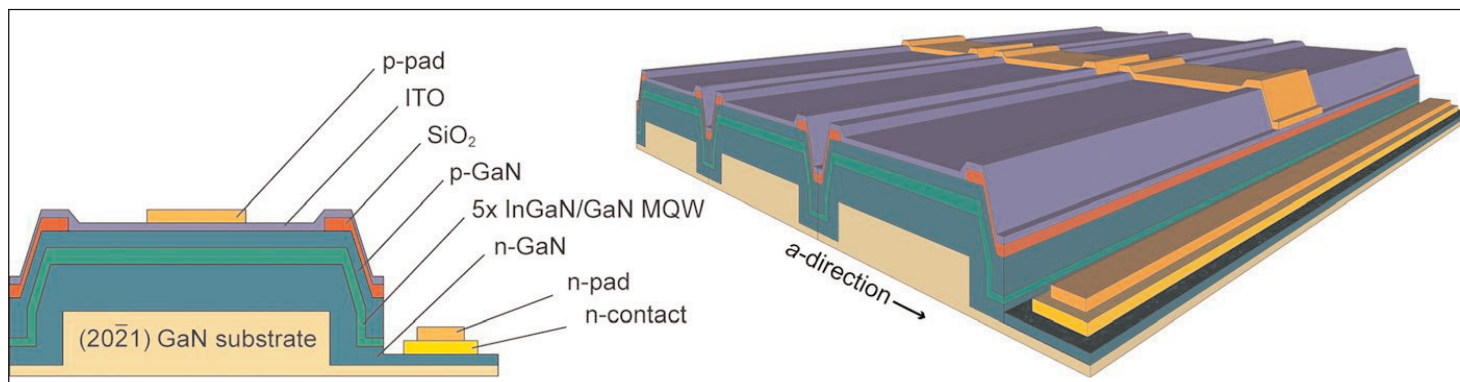

Figure 1. Cross-section and perspective schematics of LAE LED grown and fabricated on patterned substrate.

Fluorescent micrography found that the effect of increasing the mesa strip width was an increase in the number of dark-line defects, indicating stress relaxation via MD formation. There were three types of dark-line defects, suggesting different routes to MDs: one came through basal plane slip and the remainder through non-basal plane slip.

With 5μm mesa width, the basal-plane MD density was reduced, and the non-basal-plane MDs were "completely eliminated", according to the researchers. Non-basal-plane MDs were found to affect light emission from electrical injection more than basal-plane MDs.

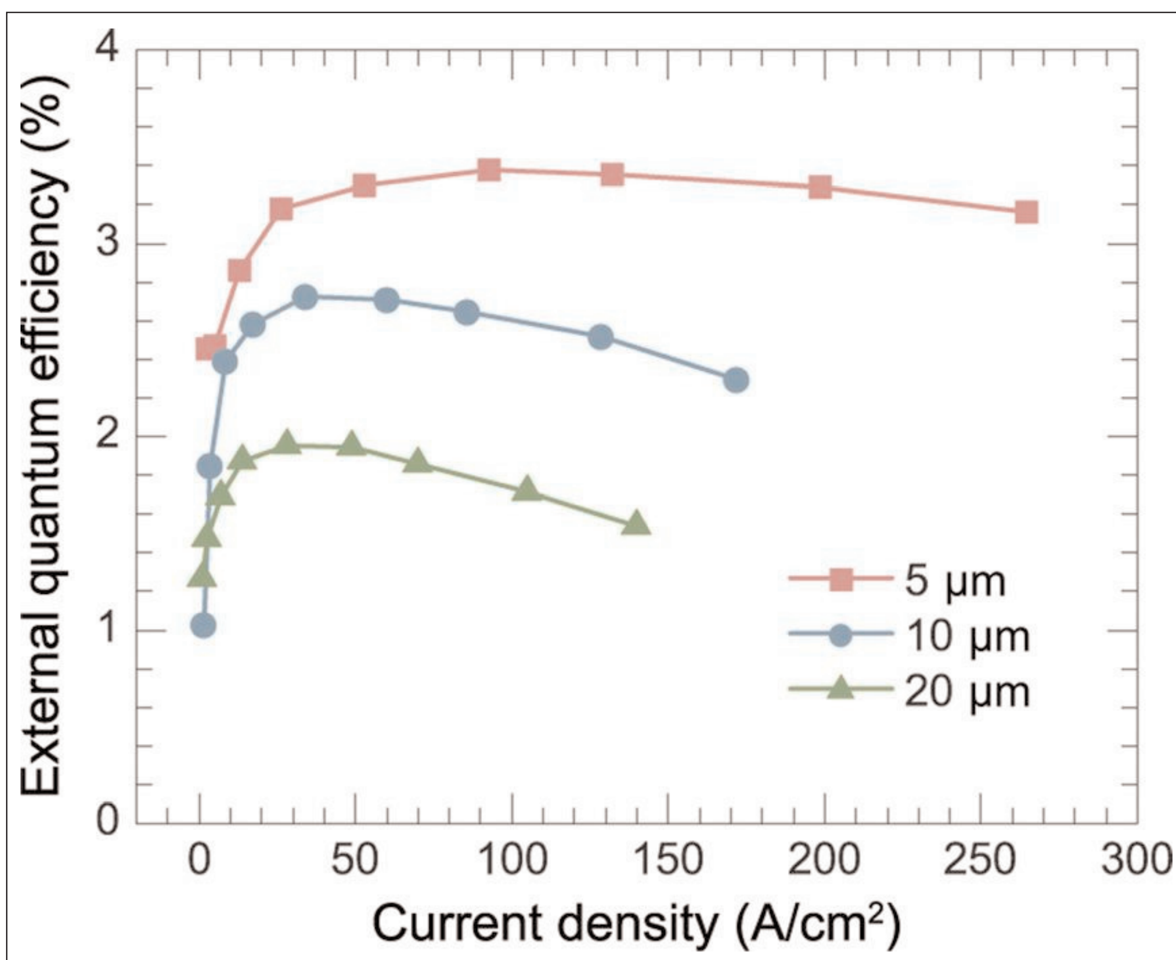

Figure 2. Dependence of EQE on current density for LAE LEDs with 5μm, 10μm and 20μm wide substrate mesas.

The team comments: "The MD density on the 5μm LAE mesas was too low to cause a measurable degree of relaxation, resulting in the nearly coherent growth of an active region with an average composition of $In_{0.12}Ga_{0.88}N$ and a thickness of 40nm that is at least twice the theoretically predicted limit."

The peak electroluminescence wavelength at $35A/cm^2$ injection was in the range 532–536nm.

The reduced mesa width of 5μm gave the highest external quantum efficiency (Figure 2).

In addition to reduced dislocation densities, the researchers suggest that the improved performance of the 5μm LAE LED could be partly due to enhanced light extraction caused by an increased number of mesa sidewalls. ■

http://dx.doi.org/10.1063/1.4960001

Author: Mike Cooke

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Monolithic band-engineered semi-polar white LED

Doping profile used to red-shift optically pumped long-wavelength quantum well.

Researchers at the University of California Santa Barbara (UCSB) in the USA have developed a monolithic white light-emitting diode (LED) with blue light produced by electrical pumping, and green/'red' by optical pumping from the blue source [S. J. Kowsz et al, J. Appl. Phys., vol120, p033102, 2016]. Also, the polarization properties of the device could be useful for more efficient liquid-crystal display (LCD) back lighting.

Normally, white LEDs consist of electrically pumped blue or ultraviolet light that pumps a broad-band yellow phosphor. The UCSB semi-polar device added green and 'red' indium gallium nitride (InGaN) quantum wells to those for the blue LED. The 'red' section of the device used doping-profile band engineering to shift to longer wavelengths with a relatively small increase in indium content to narrow the bandgap.

By using optical pumping for the long-wavelength emissions, the devices avoid the problems of electrical transport through high-indium-content InGaN caused by lower material quality. Also, the carrier densities in optically pumped quantum wells (QWs) are lower, which reduces non-radiative efficiency-sapping Auger-like recombination. Also, lower carrier density means lower screening of the red-shift effects of the band engineering, which would reduce the wavelength in the blue direction.

The blue LED component was grown first by metal-organic chemical vapor deposition (MOCVD) on the $(20\bar{2}\bar{1})$ face of a 7.5mmx7.5mm bulk GaN substrate from Mitsubishi Chemical (Figure 1). The researchers comment: "Previous work has demonstrated that blue LEDs with high power, low electrical droop, and small wavelength shift can be grown on this plane."

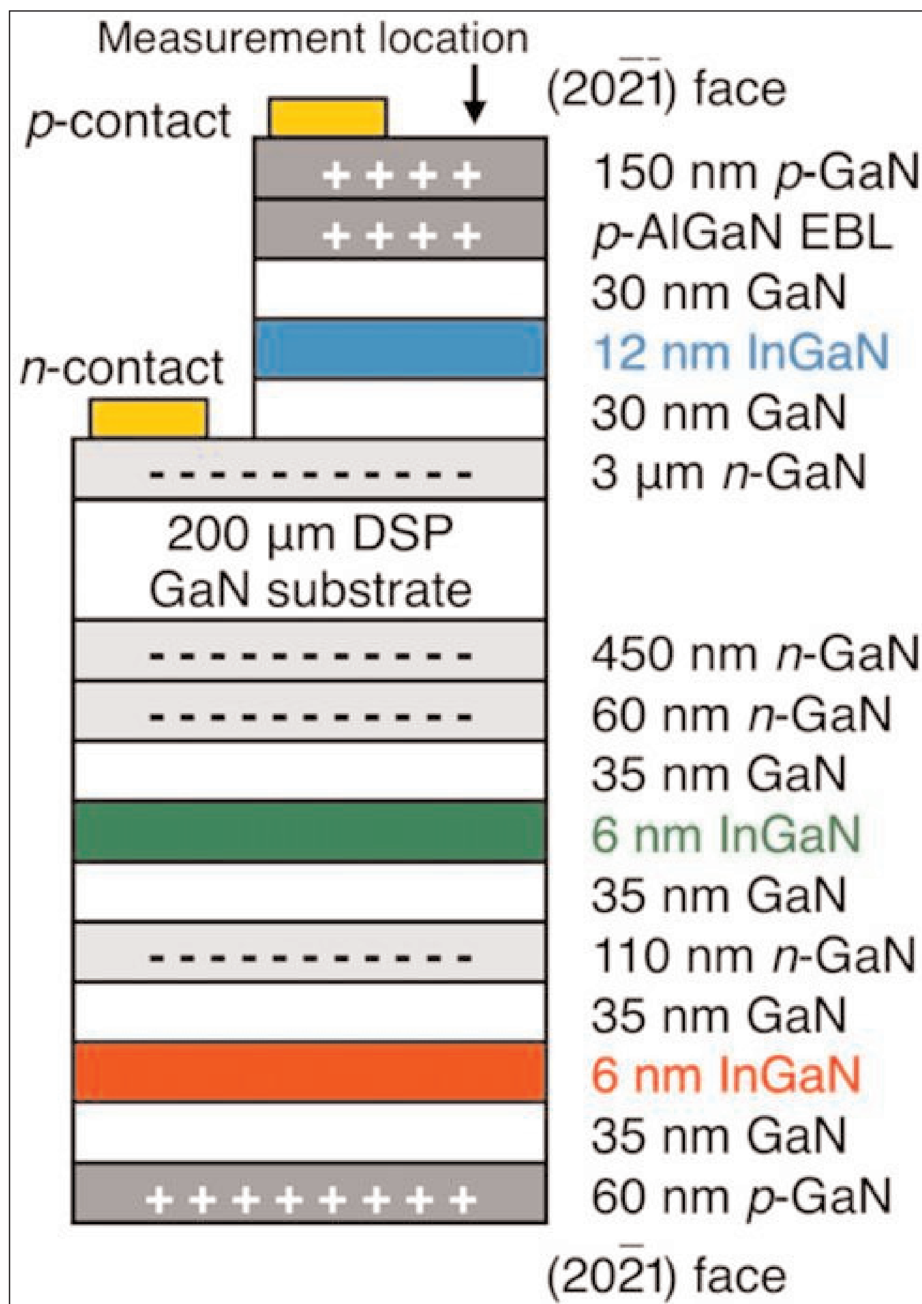

Figure 1. Cross-sectional schematic of epitaxial structure of UCSB white light-emitting semi-polar device.

The optically pumped material was grown on the $(20\bar{2}1)$ side of the substrate. By growing this material after the high-temperature blue LED process, the researchers avoided degradation of the higher-indium-content InGaN needed for longer-wavelength emission. Also, high-indium-content InGaN grown on $(20\bar{2}1)$ planes suffers less from stacking faults, compared with

$(20\bar{2}\bar{1})$ deposition. The $(20\bar{2}\bar{1})$/$(20\bar{2}1)$ planes also allow devices that produce polarized light.

Another advantage of $(20\bar{2}1)$ growth for the optically pumped high-In-content InGaN is that a doping profile can be used to create a built-in electric field that augments polarization-induced electric fields, red-shifting the photoluminescence. In particular, the p-GaN must be grown last to allow acceptor activation by thermally driving out hydrogen from magnesium–hydrogen complexes that form with the magnesium doping.

The red shift means that the indium content does not need to be as high for a given wavelength. The higher-indium-content final p-i-n quantum well was grown at 10° lower temperature, compared with the shorter-wavelength n-i-n optically pumped quantum well.

The electrical contacts for the LED were fabricated with a circular palladium/silver/nickel/gold p-contact of 180μm radius, and scribing down to the n-GaN layer for a soldered indium n-contact.

The researchers simulated the optically pumped wells as $In_{0.27}Ga_{0.73}N$ and $In_{0.29}Ga_{0.71}N$ for the short and long wavelengths, respectively. "The change in the indium content for the different QWs corresponds to the different growth temperatures used in growing the optically pumped QWs in the experimental sample," the team comments.

The simulation suggests the red-shift for the long-wavelength QW from aligning the built-in and polarization-induced fields would be 76nm, compared with the short-wavelength QW. The band-engineering/doping component accounted for 57nm of the shift in simulation, and the higher indium content the remaining 19nm.

The spectral properties of the emission from the device varied according to the data collection position. At a distance of 680μm from the center of the p-contact, the emission consisted of a blue ~450nm peak from the LED with $10A/cm^2$ injection, a green ~520nm peak from the short-wavelength optically pumped QW, and a ~590nm 'red' peak from the long-wavelength QW (a 70nm red-shift). Although the device is billed as a RGB (red-green-blue) device by the researchers, 590nm is more strictly in the 590–620nm orange range. The balance of the components changed with position, with the longer wavelengths becoming more significant with distance from the p-contact.

The researchers compared the color rendering to that of more common blue-yellow (BY) devices often used to create 'white' light. "By producing light that is more widely distributed across the visible spectrum, the RGB device is able to render colors more faithfully than the BY device, which is important for general illumination. The RGB device would also be more energy efficient than the BY device for backlighting displays. Creating red, green and blue emission peaks would align the white light spectrum with the transmission spectra of display filters that are typically designed to transmit red, green and blue light, resulting in less light being lost to absorption in the filters."

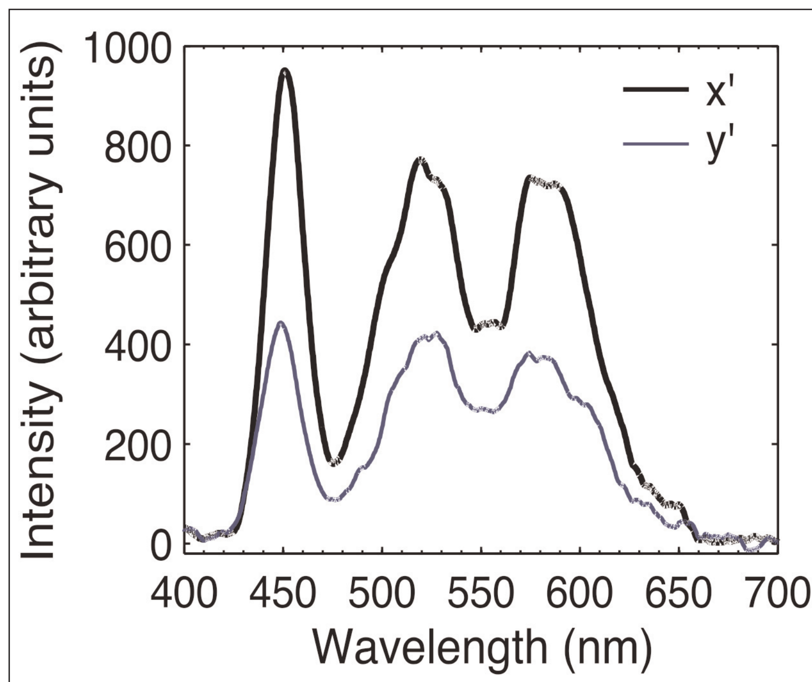

Figure 2. Electroluminescence spectra with polarizer aligned along x' and y' directions.

The emission had 1931 Commission Internationale de l'Eclairage (CIE) x, y coordinates of (0.33, 0.35), a correlated color temperature (CCT) of 5604K, and a color rendering index (CRI) of 70. The optical polarization ratio for integrated intensities was 0.3 for polarization vectors aligned along $[1\bar{2}10]$ (x') and $[10\bar{1}\bar{4}]$ (y') directions (Figure 2).

The polarization ratio was found to depend on measurement position, like the spectral properties. The researchers expect that the polarization ratio could be increased by improved color uniformity and extraction efficiency. In particular, the relative intensity of the longer wavelengths must be a focus of such work.

The team sees the need for developing growth conditions to increase the number, radiative efficiency and absorbance of optically pumped wells. The researchers comment: "Improved material quality and larger overlap of the electron and hole wavefunctions will result in better performance of the optically pumped QWs. In particular, because band engineering can enable the use of lower-indium-content InGaN or thinner QWs in achieving a desired emission wavelength, ongoing work is investigating the larger design space that is enabled by band engineering." ■

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Author: Mike Cooke

InGaN laser diode directly integrated with silicon

Researchers believe improvements in technique could hold great promise for commercializing devices on large-diameter cost-effective substrates.

Researchers in China have achieved continuous wave (cw) lasing at room temperature for indium gallium nitride (InGaN) laser diodes (LDs) grown directly on silicon (Si) [Yi Sun et al, Nature Photonics, published online 15 August 2016].

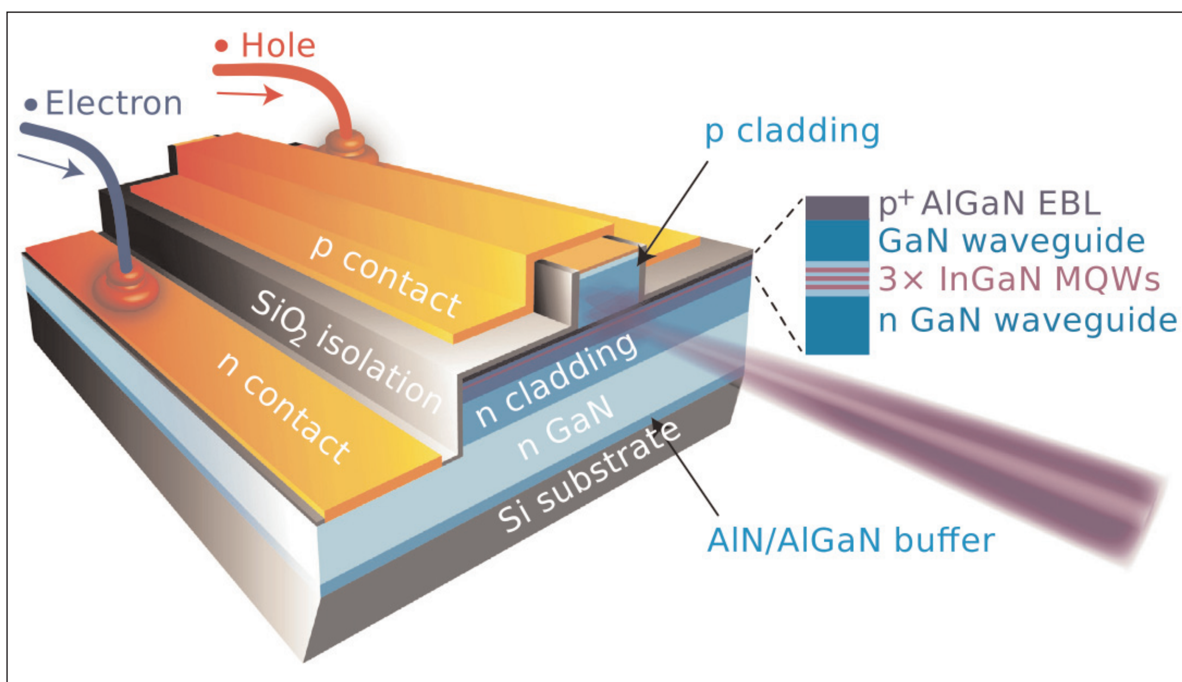

Figure 1. Schematic architecture of InGaN-based LD directly grown on silicon.

The team from Suzhou Institute of Nano-Tech and Nano-Bionics (SINANO), Huazhong University of Science and Technology, and Wuhan University, comments: "With further improvements in the material quality, device performance and life-time, GaN-on-Si technology holds great promise for commercializing III-nitride LDs on large-diameter and cost-effective substrates. Moreover, by growing GaN upon Si(111)-on-insulator-Si(100), InGaN-based LDs could be a useful alternative on-chip light source for monolithic-integrated silicon photonics."

Presently, integrating silicon with LDs involves difficult bonding of separate chips on the silicon platform, which is not generally compatible with large-scale wafer-level manufacturing as required by foundries.

The epitaxial material was grown by metal-organic chemical vapor deposition (MOCVD). The researchers used a sequence of aluminium gallium nitride (AlGaN) and aluminium nitride buffer interlayers to manage the differences in lattice parameter (~17%) and coefficient of thermal expansion (CTE ~ 54%) between Si and GaN that lead to threading dislocations (TDs) and cracking. TDs act as non-radiative recombination centers, reducing efficiency and increasing heat dissipation leading to device degradation.

The team comments: "It is found that the compressive strain that accumulates via the

Table 1. Epitaxial structure.

Contact	p-GaN	30nm
Superlattice/cladding	100x(p-$Al_{0.11}Ga_{0.89}N$/GaN)	100x(2.5nm/2.5nm)
Electron blocking	p-$Al_{0.2}Ga_{0.8}N$	20nm
Waveguide	GaN	60nm
Quantum wells	3x($In_{0.1}Ga_{0.9}N/In_{0.02}Ga_{0.98}N$)	3x(2.5nm/7.5nm)
Waveguide	n-GaN	80nm
Cladding	n-$Al_{0.05}Ga_{0.95}N$	1.2µm
Contact/template	n-GaN	3µm
Composition step-grading	$Al_{0.17}Ga_{0.83}N$	310nm
Composition step-grading	$Al_{0.35}Ga_{0.65}N$	180nm
Nucleation	AlN	280nm
Substrate	Si(111)	

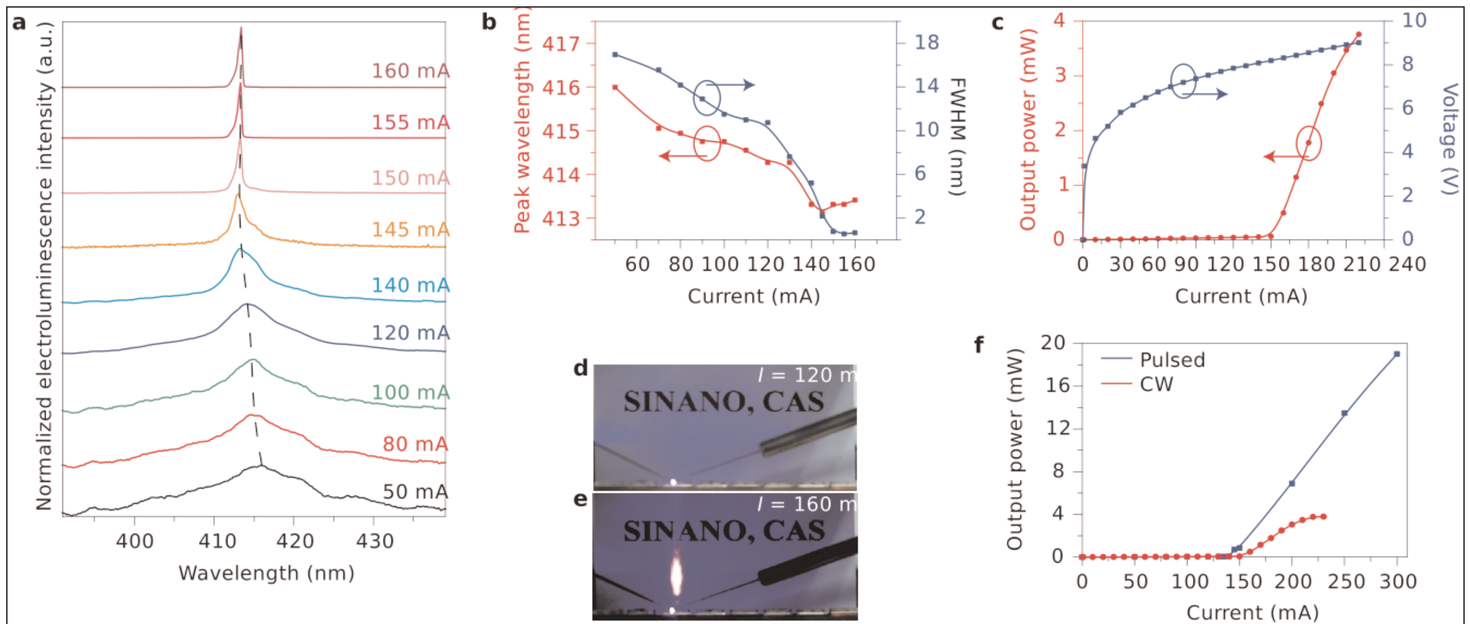

Figure 2. Characteristics: a, Electroluminescence spectra under various 1μs 10kHz pulsed currents at room temperature. b, Peak wavelength and full-width at half-maximum (FWHM) as a function of pulsed current at room temperature. c, Output power, current, voltage characteristics under cw injection at room temperature. d,e, Far-field patterns below threshold (120mA) (d) and above threshold (160mA) (e) by setting sheet of white paper in front of front facet of LD under cw injection at room temperature. f, Output power–current curves of LD in simple package with indium soldering operating under pulsed and cw conditions at room temperature.

$AlN/Al_{0.35}Ga_{0.65}N/Al_{0.17}Ga_{0.83}N$ multi-layer buffer can not only compensate for the tensile stress due to the CTE mismatch during cool down, but also induce the inclination and annihilation of TDs at the interfaces, according to cross-sectional transmission electron microscopy (TEM) observations."

The researchers estimate that the TD density in the subsequent GaN layer was $5.8x10^8/cm^2$, a value comparable to GaN grown on sapphire. After the addition of the laser diode layers to the GaN-on-Si template, the epitaxial film was 5.8μm thick and crack-free with wafer bow less than 10μm.

The epitaxial material (Table 1) was formed into lateral laser diodes (Figure 1) with 4μmx800μm ridges. The facets were cleaved and coated with reflective titanium dioxide and silicon dioxide quarter-wave layer pairs — 3 pairs on the front and 7 pairs on the back. The yield of laser-capable devices was 94%.

With further improvements in the material quality, device performance and life-time, GaN-on-Si technology holds great promise for commercializing III-nitride LDs on large-diameter and cost-effective substrates. Moreover, by growing GaN upon Si(111)-on-insulator-Si(100), InGaN-based LDs could be a useful alternative on-chip light source for monolithic-integrated silicon photonics

The LD was tested under pulsed and CW current injection at room temperature. In pulsed operation there was a blue shift from 415.9nm to 413.4nm with increasing current (50mA to 160mA). This is attributed to screening of the quantum-confined Stark effect. The full-width at half maximum (FWHM) was 0.64nm for stimulated emission.

For cw operation, stimulated emission began around 150mA ($4.7kA/cm^2$ density). The cw operation lifetime at 180mA was about a minute before a dramatic decay of output power. The researchers attribute the short life to an imperfect p–n junction doping profile and to the high TD density, relative to devices produced 'homoepitaxially' on bulk or free-standing GaN substrates (TD density ~ $10^6/cm^2$).

The poor doping profile leads to a high forward voltage of 8.5V, giving joule heating. The researchers comment: "Previous reports showed that the lifetime of InGaN-based LD grown on a sapphire substrate was improved from a few seconds to 300h when the operation voltage was reduced from 8 to 4V."

Also, at elevated temperature, the TDs become a route for migration of point defects and impurities into the active region, decimating internal quantum efficiency (IQE) and piling on threshold current. "It has been reported that the InGaN-based LD lifetime can be elongated to over 10,000h when the TD density in the GaN film is reduced from $10^8/cm^2$ down to $10^6/cm^2$ through epitaxial lateral overgrowth," the team writes. ■

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Author: Mike Cooke

InGaAs laser diode on exact germanium-on-silicon substrate

Continuous-wave operation has been achieved under cryogenic conditions and in pulsed mode at room temperature.

Researchers in Russia have developed an indium gallium arsenide (InGaAs) quantum well laser diode on (001) germanium-on-silicon 'virtual substrate' without offcut angle [V. Ya. Aleshkin et al, Appl. Phys. Lett., vol109, p061111, 2016]. Continuous-wave lasing with an emission wavelength of 941nm was possible at cryogenic temperatures of 77K. Room-temperature lasing at 992nm wavelength was restricted to pulsed mode.

The researchers hope that in future they will be able to extend the wavelength into the greater than 1.1μm (>1100nm) transparency range needed for use in conjunction with silicon waveguides. "It is assumed that the increase of the indium content in the InGaAs QW with an appropriate correction of the QW width could be a possible solution," the team writes.

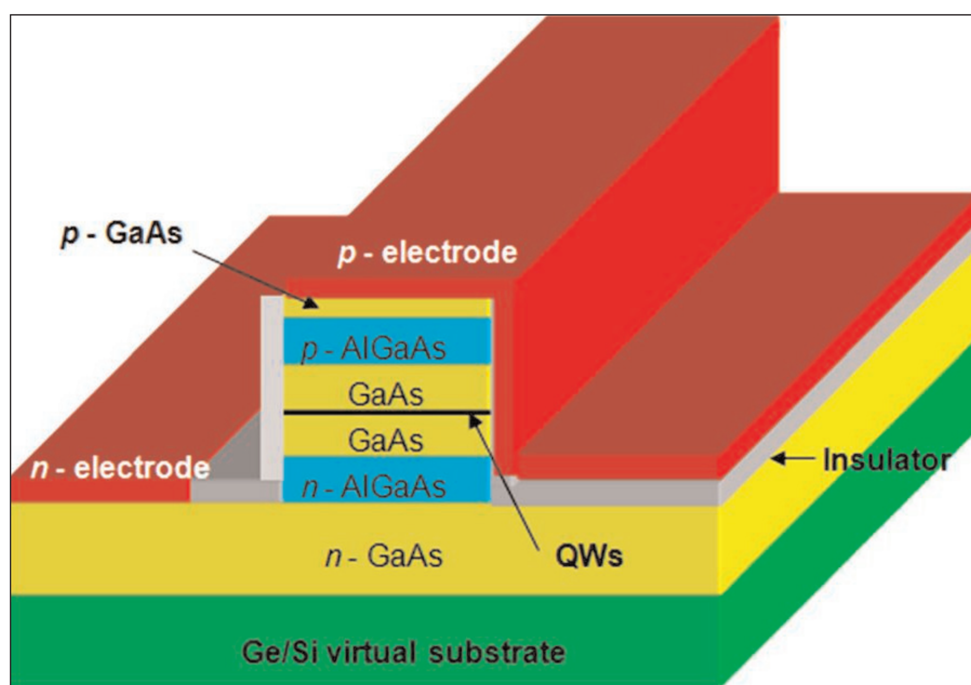

Figure 1. Schematic view of laser diode with planar ohmic contacts.

Normally III-V materials such as InGaAs on (001)-oriented silicon (Si) are grown with a significant offcut angle of 4–6° to avoid the formation of anti-phase boundaries (APBs), which is a problem for polar materials deposited on non-polar substrates.

However, offcut angles complicate integration with silicon electronics and photonics. In addition, germanium (Ge) buffers are often used to accommodate lattice mismatching of III-V heterostructures with Si, but Ge on offcut Si is generally of low quality. Finally, offcut substrates lead to difficulty when cleaving the final devices into laser bars to give high-quality mirror facets.

The team from Institute for Physics of Microstructures of the Russian Academy of Sciences, Lobachevsky State University of Nizhny Novgorod, and FGUE 'Salut' produced their Ge/Si 'virtual substrate' by solid-source molecular beam epitaxy (SS-MBE). The n-Si substrate had a (001) crystal orientation with offcut angle less than 0.5°. A two-step process was used, involving deposition of 50nm Ge at 275°C and then the remainder at 600°C. The thin-layer growth allows strain relaxation through misfit dislocations. The higher-temperature growth gives better crystal quality material in the thicker layer. Further improvement was achieved with short-time cycle annealing. The annealing was found to reduce threading dislocation densities from 3–4x10^8/cm^2 to ~10^7/cm^2.

The III-V (A_3B_5) epitaxy involved metal-organic chemical vapor deposition (MOCVD) — see Table 1. In the initial planarizing buffer, two aluminium arsenide (AlAs) inserts were used to reduce GaAs-Ge inter-diffusion and to filter out defects. The AlAs layer also reduced surface roughness by a factor of two.

There were some anti-phase boundaries (APBs) present due to the use of a substrate with near-zero offcut angle. The APB density in the buffer layer was around 0.6/μm. After the whole structure was grown the density was 0.3/μm. The researchers comment:

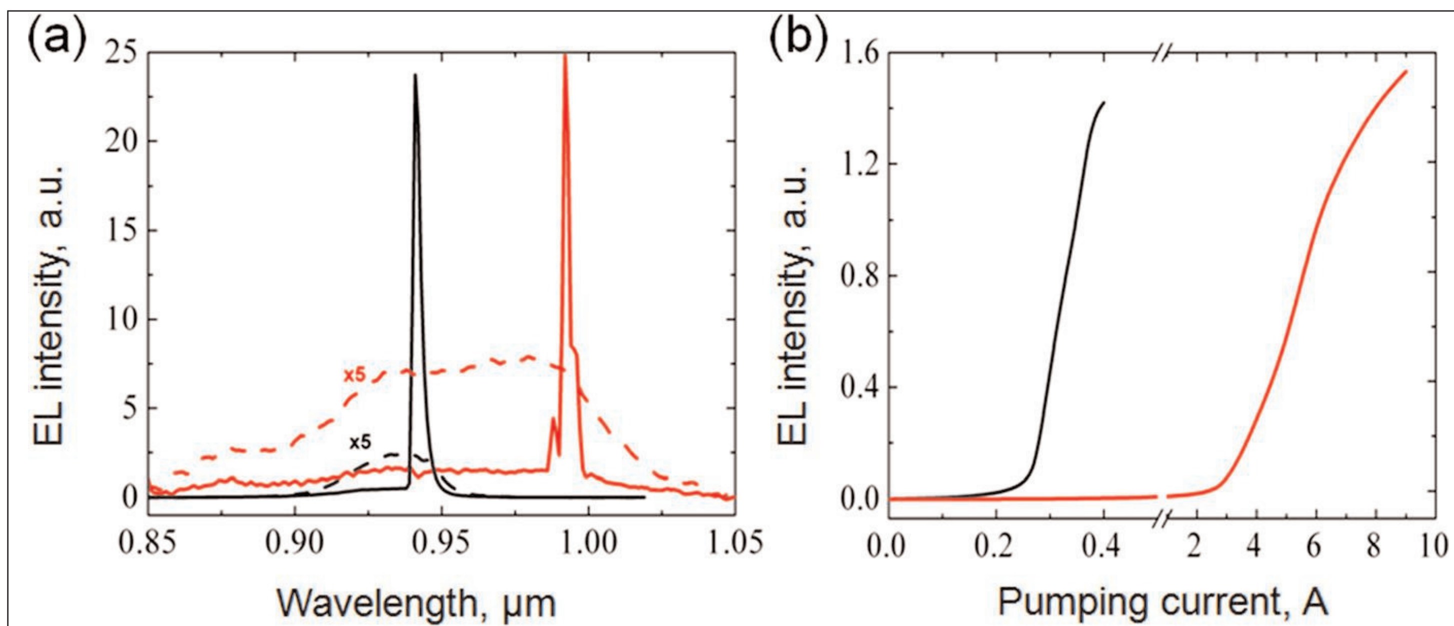

Figure 2. (a) Electroluminescence spectra at sub-threshold (dashed lines) and above threshold (solid lines). Black lines correspond to 77K, red ones to room temperature. For 77K (300K), pumping current density for subthreshold spectra was approximately 370A/cm^2 (3.7kA/cm^2); and for above threshold spectra 550A/cm^2 (5.6kA/cm^2). (b) Power-current characteristics of same laser diode.

"These values of the APB density are significantly smaller than the typical ones obtained during growth of polar materials on the exactly oriented non-polar Si(001) substrates. We believe that the influence of the APBs is not the main critical factor affecting the optical properties of the grown A_3B_5/Ge/Si(001) structure."

Table 1. Parameters of A_3B_5/Ge/Si(001) laser structure.

	Thickness (nm)	Doping (/cm^3)	Remark
Si(001) substrate (upper part)	. . .		Virtual substrate
Ge	~1000	. . .	
AlAs/GaAs/AlAs	10/50/10	. . .	Planarizing buffer
GaAs:Si	2500	2x10^{18}	Main buffer and n-contact
$Al_{0.3}Ga_{0.7}As$:Si	1000	5x10^{17}	Bottom waveguide layer
GaAs	340	. . .	Active region with multiple InGaAs QWs
$In_{0.17}Ga_{0.83}As$ QW	10	. . .	
GaAs	50	. . .	
$In_{0.17}Ga_{0.83}As$ QW	10	. . .	
GaAs	50	. . .	
$In_{0.17}Ga_{0.83}As$ QW	10	. . .	
GaAs	170	. . .	
GaAs:C	170	3x10^{16}	
$Al_{0.3}Ga_{0.7}As$:C	1000	5x10^{17}	Top waveguide layer
GaAs:C	500	2x10^{19}	p-contact

Laser diodes (Figure 1) were fabricated with the active region 20μm wide and 200μm wide planar ohmic contacts of gold-germanium-nickel-gold (n-type) and chromium gold (p-type). The substrate was thinned to 80μm. The material was cleaved into 2.7mm-long bars with mirror facets.

Under electric current injection at 77K (Figure 2), the 941nm-wavelength emission peak narrowed from 30nm below threshold to less than 1nm above. Room-temperature (300K) 992nm emission was 95nm wide below threshold and narrowed to less than 1nm above. The threshold for lasing at 77K was 463A/cm^2, low enough for continuous-wave operation. At 300K, only pulsed operation was possible with ~5.5kA/cm^2 threshold. ■

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Author: Mike Cooke

Silicon photonics and III-V integration

Mike Cooke reports on recent commercial activity driven by cloud and 'big data' developments, and efforts to integrate III-V light-emitting material with silicon photonic technology.

The rise of cloud and other 'big data' services has increased the need to transfer information over larger distances to link up otherwise 'stranded' computing capacity — an application for which light is a far better carrier than charge.

In free space, light has carried information from almost the time of the big bang, the beginning of time itself. On planet Earth, data carried by photons through fibers and other materials does require some refreshment, but far less often than would be needed by electronic-based carriage.

The key challenge is to integrate optical data transfer with data processing electronics. In particular, emitters and detectors are the vital interface between silicon electronics and optical systems.

Silicon photonics offers prospects for such integration and a number of companies already have products sampling and in 'mass production'. However, the integration is somewhat incomplete in the area of providing laser or some other light power into the system. This is usually piped in from outside using fibers, although there are increased possibilities for integrating laser chips more closely into the silicon photonics using wafer- or chip-bonding. However, these techniques suffer from problems such as implementing precise alignment, which adds complexity and expense.

The problem is that the III-V compound semiconductor materials favored for light emission (and detection) don't mix well with silicon. Challenges include mismatching of the lattice structure and poisoning of silicon electronics since the III and V groups of the periodic table are the ones used for doping silicon for p- and n-type conduction, respectively.

Direct integration of III-V materials on silicon should reduce process complexity and cost, but lattice mismatching reduces material quality and reduces the possibilities for efficient light emission, particularly for lasers. Although there have been few explicit reports of cross-fertilization up to now, there could in the future be transfer of expertise between those working on photonics and III-V high-mobility transistors, where similar integration problems have been raised.

While direct growth of III-V materials on silicon would be desirable, wafer bonding is often more practical at the present stage of technical development.

The light used by silicon photonics is generally in the infrared region, being restricted by the silicon transparency window and energy bandgap to wavelengths above 1.1μm. This window covers the common optical communications wavelengths around 1.55μm.

The substrates for such work are commonly silicon on insulator. The high refractive index of 3.5 optically confines light by total internal reflection, allowing microscopic waveguides to be created.

Waveguide paths for infrared light need less extreme pattern definition of the order of a micron rather than the (tens of) nanometers of bleeding-edge electronics. This could give new life to processing facilities that would otherwise be due for running down and eventual closure.

Intel says that it has been developing silicon photonics for 16 years — in other words the inception came at the crescendo of the dotcom boom–bust and the subsequent cold dark years for optical networking development.

Prospects for silicon photonic optoelectronic integration has been improving for a while and Intel now sees opportunities in the rise of cloud computing and related developments. The company is presently promoting its small-form-factor 100G PSM4 (parallel single-mode fiber 4-lane) QSFP28 optical transceiver (Figure 1). The stated aim is applications in large-scale

Figure 1. Intel Silicon Photonics 100G PSM4 QSFP28 optical transceiver.

cloud and enterprise data centers, along with Ethernet switch, router, and client-side telecom interfaces. The specification is for 100 Gigabit [per second] Ethernet (100GbE) optical links over single-mode fiber.

Originally due in 2015, but delayed due to unspecified difficulties, Intel now says that the product is "shipping in volume". The transceiver incorporates Intel's hybrid laser technology that allows greater than 90% coupling efficiency. Combined with high-density optical interconnects and Intel's "unmatched manufacturing capabilities", the technology should deliver scaling and cost benefits.

The reach of the device is up to 2km, beyond that required by the PSM4 multi-source agreement optical interface specification (www.psm4.org). The operating temperature range is 0ºC to 70ºC. Power consumption is rated at 3.5W maximum.

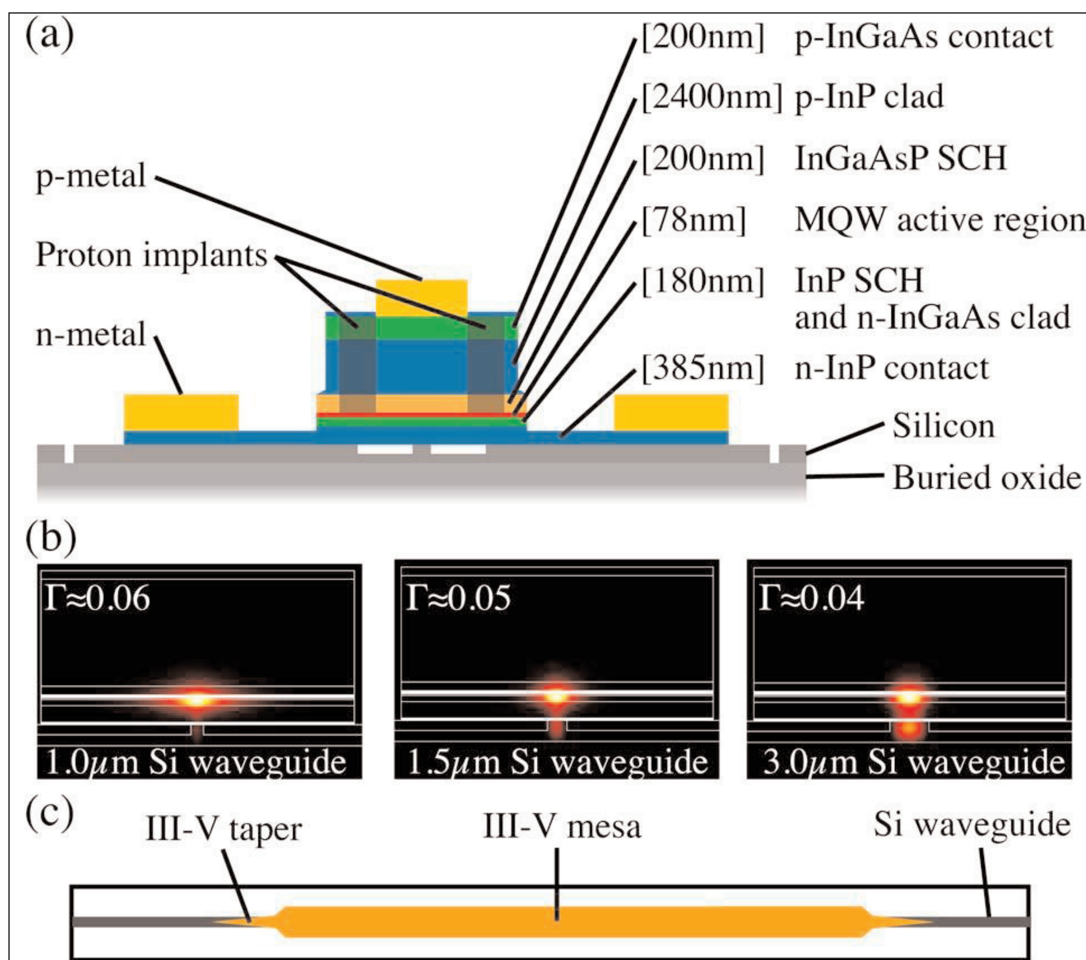

Figure 2. (a) Cross-sectional schematic of UCSB hybrid silicon active region with approximate layer thicknesses. (b) Simulated optical mode profiles and estimated MQW optical confinement factor of hybrid silicon active region for various silicon waveguide widths. (c) Top-view schematic of hybrid laser design. From [Alexander Spott et al, Optics Letters, vol40, p1480, 2015].

Beyond this specific device, Intel plans to move from pluggable to near-future embedded products at 400G, and towards integrating optical interconnects directly into switch and server electronics. Intel's roadmap also includes integrated optical application specific circuits (ASICs).

Intel has developed its hybrid silicon laser technology in partnership with University of California Santa Barbara (UCSB) [e.g. Alexander W. Fang et al, Optics Express, vol14, p9203, 2006]. The 2006 device consisted of aluminium gallium indium arsenide (AlGaInAs) quantum well epitaxial material bonded to a low-loss silicon strip waveguide (Figure 2). The cavity and contact formation was performed after bonding. The laser optical mode coupled evanescently into the silicon waveguide beneath.

UCSB continues to work on silicon photonics (http://optoelectronics.ece.ucsb.edu/publications/3), with recent work including further research on room-temperature hybrid silicon lasers, along with integrating quantum cascade lasers on silicon and more purely photonics engineering.

IBM has also been working towards integrating III-V laser and silicon photonics technology, likewise seeing cloud and 'big data' applications. In 2015, company researchers presented fully integrated wavelength-multiplexed silicon photonics chips that the company said would enable manufacturing of 100Gb/s optical transceivers. The technology links sub-100nm CMOS electronics with various optical components. Light signals are transmitted at four infrared wavelengths used for optical communications.

While the laser power for these devices seems to be fed in from outside, the company has also developed a self-aligned flip-chip assembly to couple III-V lasers into silicon photonic circuits. The solder pads of the silicon photonics and laser chips are purposely offset so that, during annealing, surface tension pulls the chip into alignment with precisely designed mechanical stops (Figure 3). The optical connections are butt-coupled and the electronic connection is through the solder pads. However, presented work seems to be at the level of demonstrations using silicon 'mock-up InP dies' in place of actual laser chips.

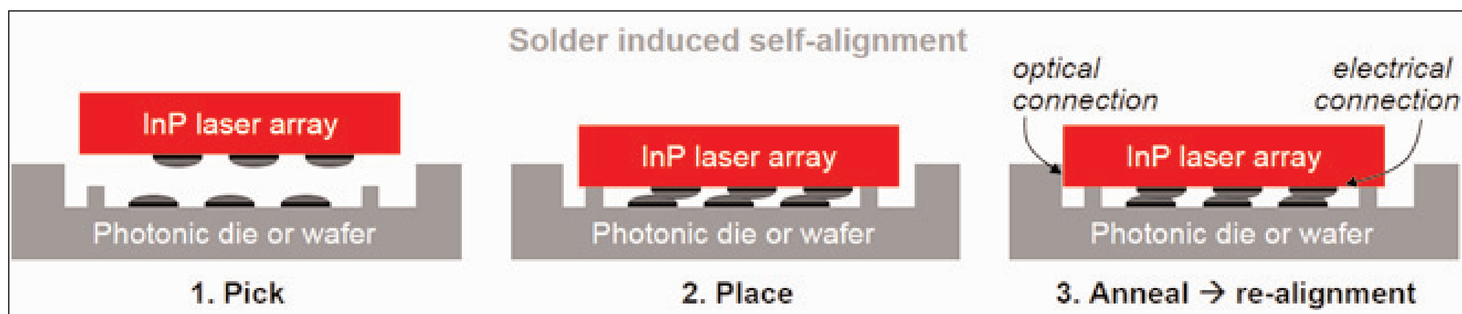

Figure 3. IBM's solder-induced self-alignment.

IBM says that it has been leading silicon photonics research for more than a decade with a series milestones starting in 2006.

In March 2016, Kaiam Corporation demonstrated what it claimed as the world's first 100Gb/s CWDM4 silicon photonics transceiver at the OFC optical networking and communication conference/exhibition. Also, the company announced sampling of devices in September 2015. Production is based at the company's facility in Livingstone, Scotland, UK.

According to Kaiam, the module is able to transmit signals through 10km of single-mode fiber. The silicon photonics component combines electronics (modulator driver, transimpedance amplifier, and clock & data recovery circuits) and silicon optical modulators and detectors in a single 3D chip stack. Wavelength multiplexing and demultiplexing is realized by glass-based planar lightwave circuits (PLCs). The continuous wave optical input is generated by indium phosphide lasers with micro-electro-mechanical coupling alignment into the PLCs. Grating couplers connect the glass PLCs to the silicon photonics IC.

InGaAs well ridges on 300mm silicon

A recent example of direct integration of III-V materials on silicon comes from Imec and Ghent University in Belgium. This team used aspect ratio trapping (ART) techniques to produce indium gallium arsenide (InGaAs) multiple quantum wells (MQWs) on 300mm-diameter silicon in a ridge format that could be used in future laser diodes [B. Kunert et al, Appl. Phys. Lett., vol109, p091101, 2016].

ART techniques have been developed to reduce defect density in III-V structures on silicon and Imec has used ART in its work on high-mobility transistors with a view to future high-speed/low-power electronics.

The Imec/Ghent team now reports: "Despite the narrow trench dimension, the grown out III/V ridge has reached a volume suitable for wave guidance,". The researchers add that they are investigating "optimized nano ridge structures with an increased GaAs volume and a confining InGaP cap layer to reduce carrier losses due to surface recombination". They expect realization of first nano ridge laser diodes using such techniques in the near future.

The III-V ridges were grown by metal-organic vapor phase epitaxy on 300mm-diameter silicon with exact (001) crystal orientation. The trenches were provided by a shallow trench isolation (STI) process used in mainstream silicon electronics, and were 10μm long with varying widths. Trenches of the same width were arranged in 600μm x 600μm fields. The trench areas were about 10% of the field. V-facets with (111) surfaces were formed by wet etching the silicon in the trench with tetramethyl-ammonium hydroxide.

The GaAs deposition started with nucleation at 360ºC using a triethyl-gallium precursor. The main growth inside and outside the trench was carried out at 580ºC with trimethyl-gallium precursor. InGaAs layers for the quantum wells were also grown at 580ºC.

The low-temperature nucleation/seeding was used to encourage two-dimensional growth, avoiding planar defects (stacking fault, twins...). The high-temperature growth gives a higher-quality GaAs crystal with misfit defect nucleation and threading dislocation gliding for full strain relaxation. Defects are trapped by the silicon dioxide trench walls. The researchers comment: "No indication of any misfit and threading dislocations was found above the STI level or close to the MQW region. Only three planar defects such as micro twins are visible in a 5.5μm-long transverse section."

The researchers add: "It is of key importance to avoid the formation of stacking faults and twins from the beginning by an optimized seed layer and sufficient pre-cleaning of the Si surface, whereas the nucleation of misfit- and threading dislocations should be initiated as deep as possible in the trench, close to the silicon surface, to benefit from a high aspect ratio."

The GaAs above the trench grew in a box-shape cross-section. The boxes were rectangular for both narrow and wide trenches. The researchers report that "the ridge courses are very straight and uniform with flat surfaces in all directions, which is essential for realizing a waveguide with low light scattering losses."

Reciprocal-space mapping using x-rays indicated that the GaAs ridges were fully relaxed. The InGaAs quantum wells were grown pseudomorphically on the GaAs buffer with ~19% indium content (Figure 4).

From bottom to top, the well thicknesses were 9.9nm, 8.9nm and 7.7nm. The periods of time for growth of the three wells was the same, as also for the three GaAs barrier layers. Although the growth is mainly on the top surface, there is some side-wall deposition.

The researchers comment: "Side-wall deposition leads to a very good lateral carrier confinement, reducing non-radiative recombination channels at the QW side surfaces and is therefore desirable. Especially, the evolving decrease in InGaAs thickness at the lateral ends of the QWs will lead to higher quantized electronic states, which induces an injection and repulsing of electrons and holes in the InGaAs layer at the box edges towards the centered QW region with constant layer thickness and lower energetic states. The InGaAs layer of less than 2nm thickness on the {110} side walls is too thin to hold bonded states with an efficient radiative recombination rate."

In photoluminescence (PL, Figure 5), a peak was seen between 1000nm and 1050nm, except for the very widest trench of 500nm. The photo-emission from the QWs was orders of magnitude higher than from the silicon substrate, which was centered around 1140nm. Some of the spectra show a shoulder around 980nm, which could be due to higher quantized states of the wells. The brightest peak was for 60nm-wide trenches. However, comparisons are complicated by factors such as ridge volume, carrier density, surface states, and so on.

The team comments: "Although it is difficult to judge about the overall impact of these uncertainties, it is very likely that the decrease in PL intensity towards wide trenches is linked to an increase in TD density. The aspect ratio of trenches wider than 100nm is quite low, leading to an insufficient defect trapping. Hence, the remaining defect density in the ridge material of wider trenches could cause high carrier losses. The intensity decline towards narrow trenches could be related to a disproportional rise in ridge surface area or less pump light absorption."

The differences in peak position are likely due to changes in indium content and/or QW width. The photoluminescence linewidth was 38meV for material grown from 100nm-wide trenches.

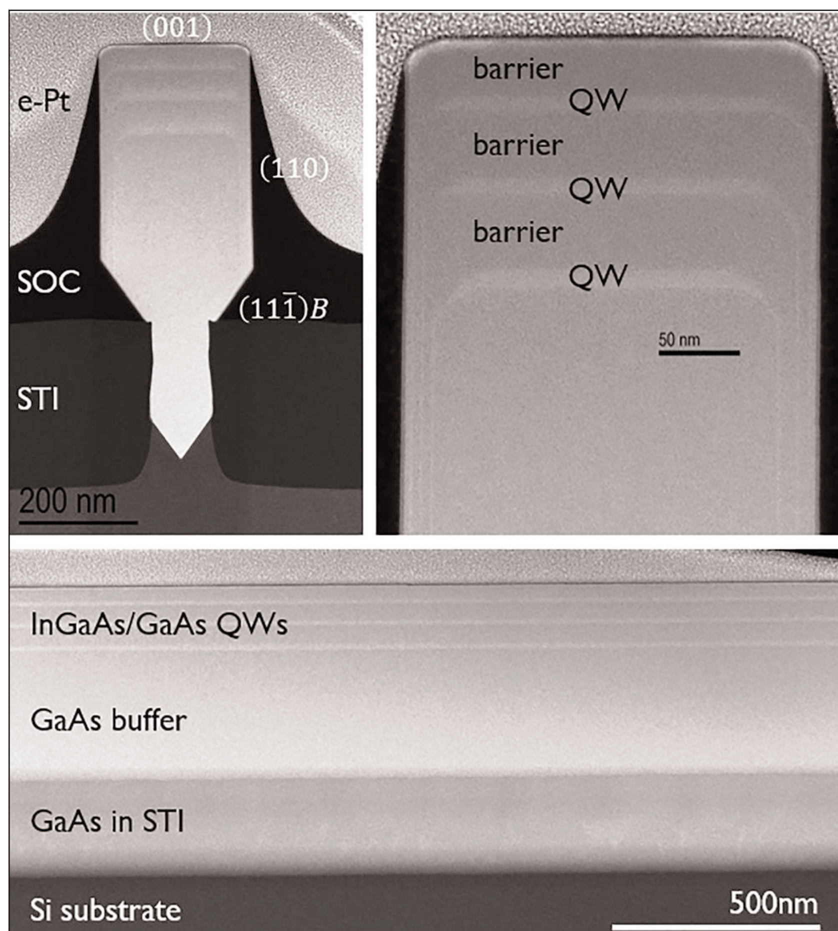

Figure 4. High-angle annular dark-field scanning transmission electron microscopy of box-shaped GaAs ridge with three InGaAs QWs. Top left: Cross-section of full ridge. Top right: Higher magnification of QW region. Bottom: Transverse section along trench. The GaAs inside STI shows slightly different contrast because some STI oxide was cut out during sample preparation.

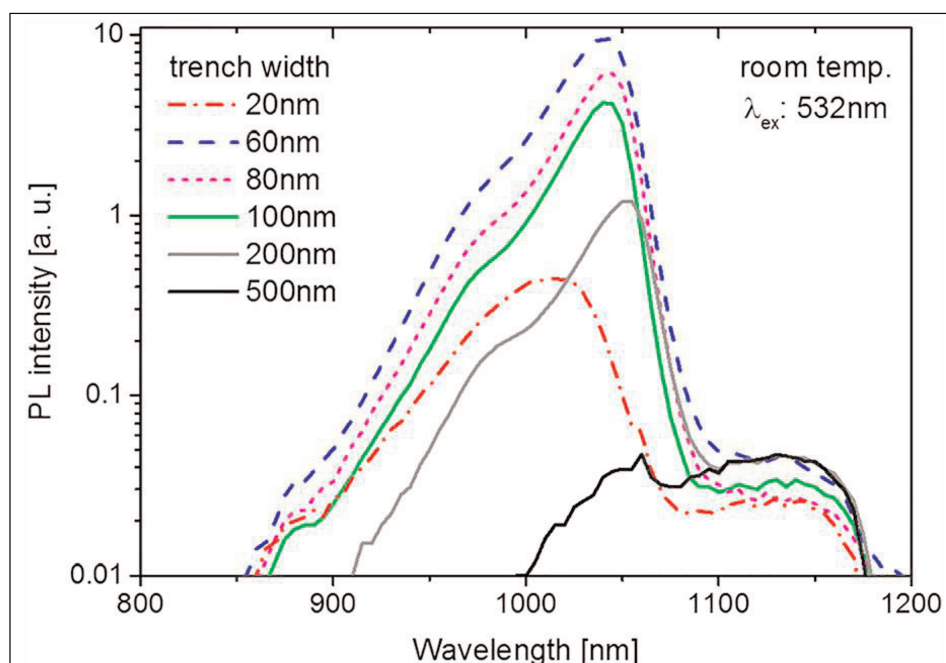

Figure 5. Room-temperature PL spectra from different trench widths in log-scale.

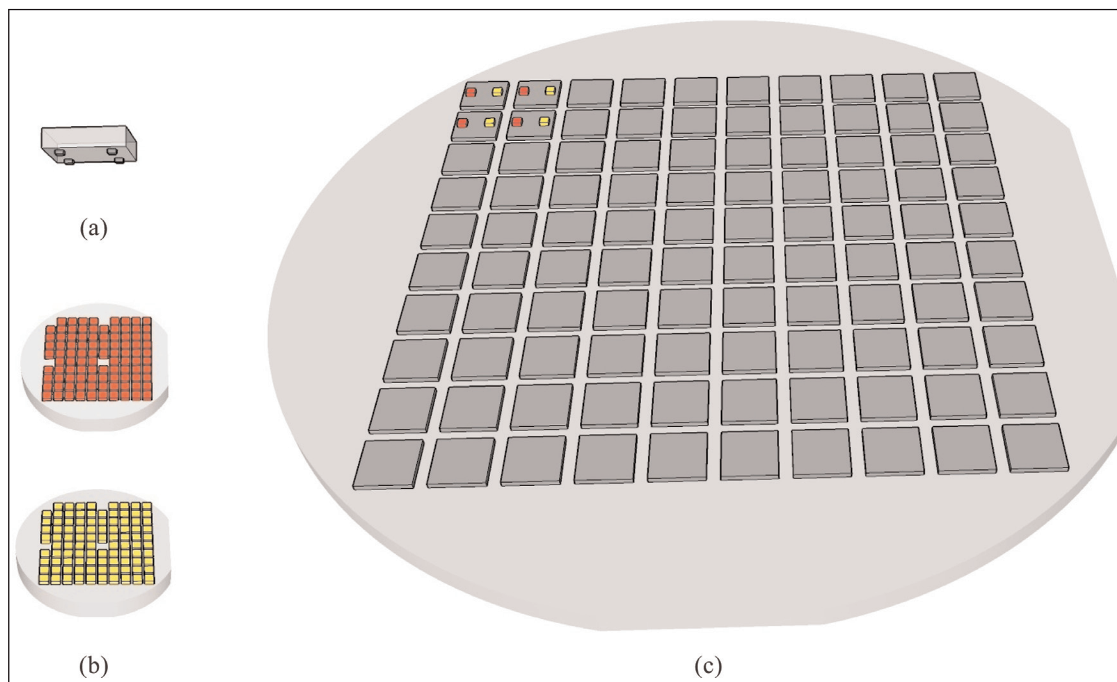

Figure 6. Area magnification in transfer printing III-V coupons from III-V source substrate to SOI target: (a) patterned stamp, (b) two source substrates with patterned coupons, and (c) SOI target substrate with four printed coupons of each source, top left.

Transfer printing

Ghent University/Imec in Belgium have also joined with X-Celeprint, Ireland/USA, to claim "the first III-V opto-electronic components transfer printed on and coupled to a silicon photonic integrated circuit". [Andreas De Groote et al, Optics Express, vol24, p13754, 2016]. "This work forms a stepping stone towards the cost-effective integration of III-V optoelectronic components onto silicon photonic integrated circuits, including lasers, semiconductor optical amplifiers and electro-absorption modulators," the team adds.

The transfer method uses a polydimethylsiloxane (PDMS) elastomer stamp to pick up and place 'coupons' from a source to target in parallel. The coupons consist of thin-film materials or even completed devices. The adhesion of the materials to the stamp is determined by the speed of contact. A fast speed picks up the coupon and a slow speed releases it. By patterning the stamp, numbers of coupons can be picked up and placed in a magnified fashion on the target substrate (Figure 6). This allows efficient use and co-integration of different expensive III-V materials and device sources.

The researchers comment: "While showing similarities with a pick-and-place technique, the main advantage of the transfer printing approach is that coupons can be transfer printed in a massively parallel way, by picking up and putting down large arrays of coupons at the same time. This allows for a high-throughput integration process."

The transferred coupons are ten to hundreds of microns in size, unlike in the usual wafer bonding methods where the dies are usually of the order of millimeters.

The coupons are transferred in a wafer-scale process, making alignment on SOI waveguide circuits non-critical, according to the researchers. Even so, with markers a three-standard-deviation (3σ) alignment accuracy of ±1.5μm can be achieved.

The researchers transferred an indium gallium arsenide phosphide (InGaAsP) multi-quantum well (MQW) light-emitting device onto a silicon-on-insulator (SOI) chip with a processed waveguide circuit (Figure 7). The MQW was sandwiched between 60nm InP barriers. The total membrane thickness was 200nm.

The III-V material for the light-emitting device was grown on InP substrate. The sacrificial release layer was 1μm InGaAs. The top sacrificial layer was 100nm InGaAs, followed by 1μm InP. These top layers were designed to prevent buckling of the membrane when adhered to the transfer stamp.

The coupons were defined by a double mesa etch. A photoresist layer was used to protect the transfer layers while the release layer was under-etched. The coupons were transferred to the SOI wafer, which was coated with divinylsiloxane-bis-benzocyclobutene (DVS-BCB) polymer as an adhesive. The DVS-BCB was cured at 250ºC for an hour. After the coupon was transferred and fixed, the photoresist was removed by oxygen plasma and the top sacrificial layers by a wet etch.

Different etch chemicals were tested for the release and finishing etch processes. The researchers comment: "The process should render a sufficiently strong bond to withstand strong acids and make sure that the III-V waveguide is close enough to the silicon waveguide in order to allow optical coupling through tapers."

The best release etch was found to be with cold iron chloride that delivered both full under-cutting of the layers and high selectivity against InP etch by a factor of more than 500. The wet etch took two hours to release the 40μm-wide coupons. The top sacrificial layers were removed with hydrochloric acid for InP and sulfuric acid mixed with hydrogen peroxide for the InGaAs.

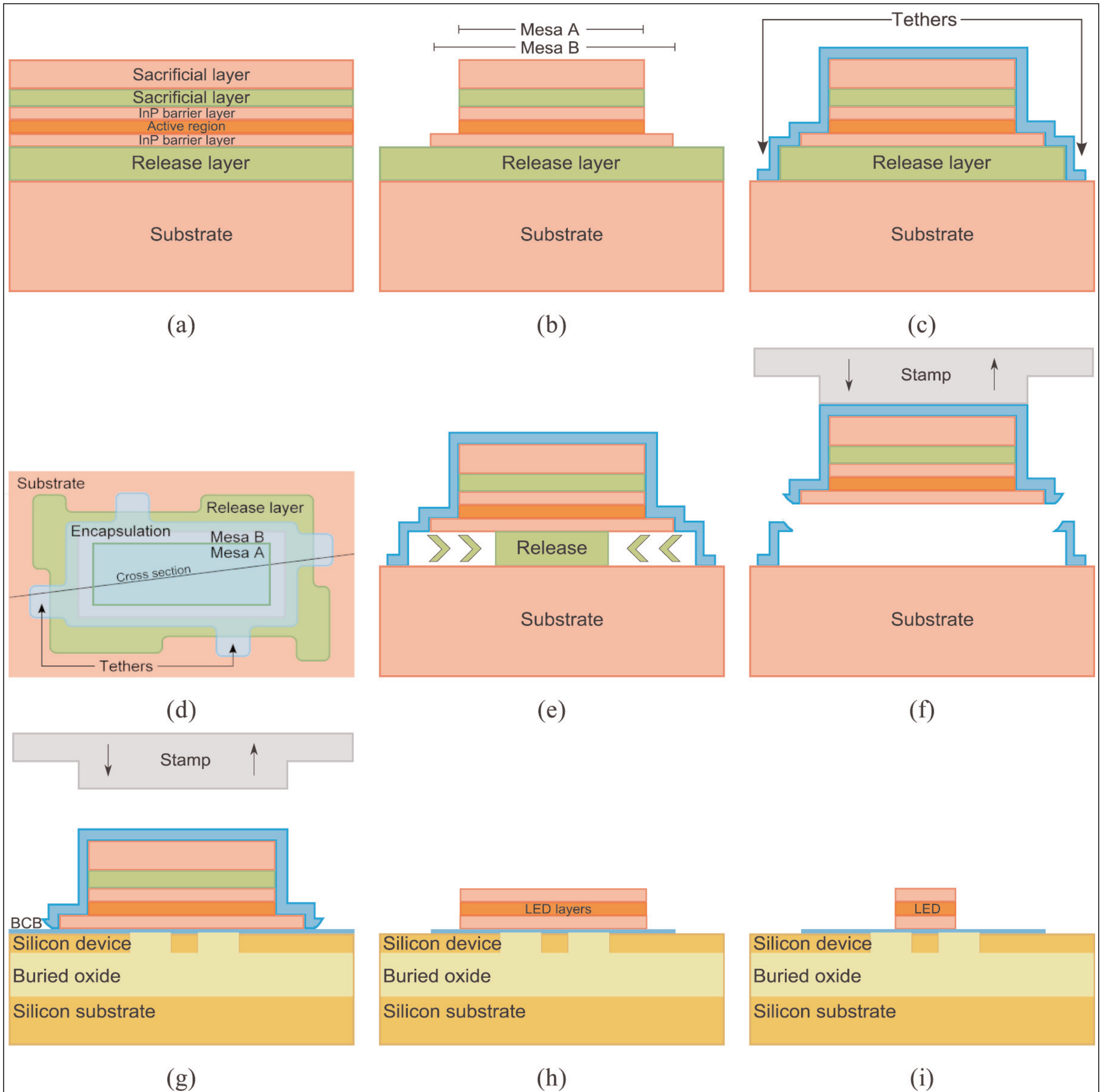

Figure 7. Process flow of transfer printed, optically pumped light-emitting device: (a) InP starting layer stack, (b) coupon patterning, (c) encapsulation and tether definition, (d) top view after encapsulation and tether definition. Further processing includes: (e) release etch, (f) pick-up of III-V coupon from source, (g) printing of coupon to SOI target, (h) removal of encapsulation and of sacrificial layers, (i) definition of light-emitting device.

The proof-of-principle setup consisted of a single-spatial-mode broadband light-emitting device integrated with SOI waveguides processed on 200mm wafers at Imec's CMOS pilot line. In this case, the III-V device was pumped with optical power from a 1310nm laser directed through the SOI waveguide system.

Measurements on the integrated III-V/SOI waveguide structure indicate a power efficiency of the emitted light at around 1550nm wavelength at the same order of magnitude as achieved with traditional III-V-on-silicon bonding. "The 3dB bandwidth of 130nm is large, and comparable as well to previously reported results," the team writes. ■

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

Continuous-wave room-temperature InAs quantum cascade laser

Doping profile used to red-shift optically pumped long-wavelength quantum well.

University of Montpellier in France has claimed the first continuous-wave (cw) operation at room temperature of a 15μm indium arsenide (InAs) quantum cascade laser (QCL) [Alexei N. Baranov et al, Optics Express, vol. 24, p18799, 2016]. "To our knowledge, the longest emission wavelength of RT cw operation for QCLs fabricated from other materials is 12.4μm," the team reports.

The thresholds are also claimed to be the lowest to-date for InAs QCLs.

"One of the reasons of this progress can be attributed to the reduction of optical losses both in the waveguide itself and in the laser active region due to the decreased doping and shorter operating wavelength and thus weaker free carrier absorption," the team comments.

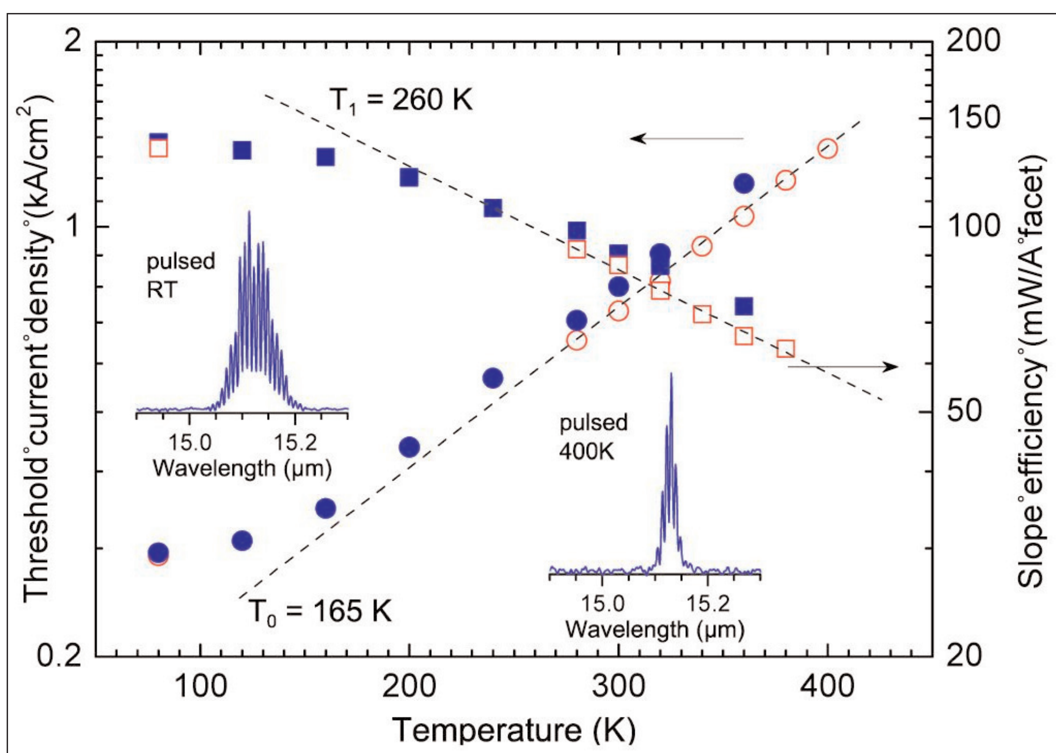

Figure 1. Threshold current density (circles) and initial slope of light-current curves (squares) in pulsed mode as a function of temperature for lasers with different ridge width: full symbols, 16μm; open symbols 20μm. Inset: emission spectra of 16μm-wide laser at room temperature and at 400K.

The cascade consisted of 55 active stages with InAs wells and aluminium antimonide (AlSb) barriers. The doping of the active region was reduced by 6x compared with a previous device reported by the same researchers. The QCL structure was grown by molecular beam epitaxy (MBE) on a (100) n-InAs substrate.

The material was fabricated into vertical deep mesa ridge lasers with non-alloyed titanium/gold contacts. The 3.6mm-long devices with cleaved uncoated facets were indium-soldered epi-side down on copper heat-sinks.

The emitted light in pulsed mode (100ns, 40kHz repetition) was around 15μm wavelength at room temperature. The pulsed threshold current density (J_{th}) varied between 1.22kA/cm^2 for a QCL with a 8μm-wide ridge and 0.73kA/cm^2 for one with a 20μm ridge. The researchers comment: "The higher J_{th} in narrow devices is due to a larger overlap of the optical mode with absorbing dielectric on the mesa walls." The team also points out that the threshold current for their previous devices was 4.3kA/cm^2 at room temperature.

The 300K slope efficiency from one facet was 90mW/A — a better efficiency of 135mW/A was found at 80K. The previous device had a 3.5W/A efficiency at 300K.

The one-facet peak output power for the 20μm device was 50mW at room temperature. This increased to 100mW at 80K and was still more than 5mW at 400K. The maximum pulsed-mode operating temperature

was 410K.

The output power at 80K under continuous-wave operation was 60mW/facet. Some of the best devices operated continuously up to 20°C. Comparing this with the maximum temperature of 400K for pulse-mode operation, the researchers estimate a thermal resistance of the devices at ~10K/W. The team suggests that better heat dissipation could be achieved by thick metalization of the ridge sidewalls. The sidewalls would also need to be suitably insulated with thin dielectric.

A 16μm-wide device had continuous-wave maximum output power of 5.5mW at 0°C and 0.3mW at 20°C. In this range, the threshold current density increased from 0.9kA/cm^2 to 1.25kA/cm^2.

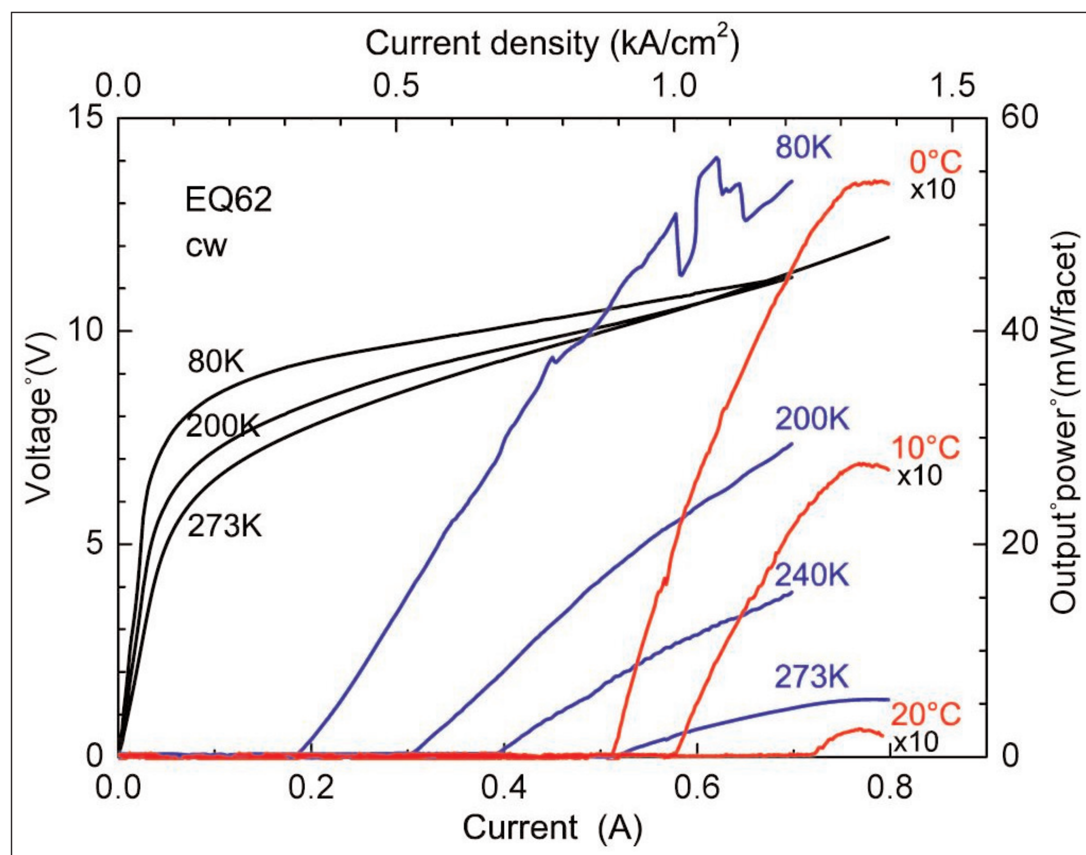

Figure 2. Voltage-current and light-current characteristics of 16μm-wide laser in cw regime at different temperatures. Output power at temperatures expressed in °C is multiplied by 10.

The researchers compare their devices with others produced with indium phosphide (InP), but with similar wavelength output: "The most recent InP-based QCLs emitting at 15μm and 14μm exhibited RT threshold current densities of 3.52kA/cm^2 and 2kA/cm^2, respectively, for devices with high reflection (HR)-coated facets. The corresponding slope efficiencies are 346mW/A for 55 cascades and 375mW/A for 70 cascades, all for HR-coated devices."

Therefore, the InAs devices have a desirable lower threshold, but an undesirable lower slope efficiency, compared with InP-based QCLs.

The improvements for the new QCLs over the group's previous work is attributed in part to better material quality from the Riber 412 MBE tool. The team comments: "This new equipment with big effusion cells provides better flux stability, of the order of 1%, compared with the smaller Riber Compact 21 machine, used previously to grow the reference wafer, where the InAs growth rate tended to decrease during the many hours long growth, resulting in mistuning of the QCL cascades and thus in a smaller gain. The lasers studied in this work could also benefit from the lower residual doping of InAs in the new machine. The cleaner environment results in decreased free-carrier absorption in the laser waveguide." ■

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Boosting transconductance in InGaAs finFETs

MIT claims record result when normalized according to fin width.

Researchers at Massachusetts Institute of Technology (MIT) in the USA have claimed record transconductance for III-V fin field-effect transistors (finFETs) when normalized according to fin width [Alon Vardi and Jesús A. del Alamo, IEEE Electron Device Letters, 1 August 2016]. Up to now, indium gallium arsenide (InGaAs) finFETs III-V have delivered disappointing results, particularly with very narrow fins.

Vardi and del Alamo report: "Our fabrication process closely follows CMOS requirements, particularly self-alignment of refractory gate and ohmic contacts, very low thermal budget, extensive use of [reactive ion etch] RIE and an entirely lift-off free process in the front end." The only lift-off step is a final back-end step for via opening and pad formation.

The researchers used a contact-first, gate-last approach that has given record transconductance in InGaAs quantum well metal-oxide-semiconductor field-effect transistors (MOSFETs). The channel material consisted of a 40nm $In_{0.53}Ga_{0.47}As$ layer in the heterostructure. The contacts consisted of molybdenum/tungsten.

The gate region was defined using silicon dioxide and molybdenum. The fins were etched with reactive ion etch, followed by a more exact digital etch process of several cycles, smoothing and trimming the sidewalls. Within 5 minutes of the fin etch, the gate region was coated with high-k dielectric by atomic layer deposition (ALD) and then the molybdenum gate metal was sputtered and etched.

Devices consisted of 10–50 parallel fins with fin-pitch 200nm. The finFETs were actually double-gate rather than triple-gate devices, since the hydrogen silsesquioxane (HSQ) photoresist used to define the fin etch was not removed during gate formation.

Vardi and del Alamo comment: "While theoretically inferior to tri-gate designs, practically, the greater simplicity of the process allows us to aggressively scale all device dimensions and implement a self-aligned process. This ultimately results in significantly better performance than prior InGaAs tri-gate MOSFET demonstrations." They also point out that with thinner fins the top gate offers diminishing returns in performance.

A device with 30nm gate length and 7nm fin width (Figure 1) achieved a peak transconductance of 900μS/μm and on-resistance of 320Ω-μm with 0.5V drain bias. The normalization is according to the standard conducting periphery — in this case the two gates per fin give 2x the channel height. The saturated subthreshold swing was 100mV/decade; the drain-induced barrier lowering was 90mV/V at 0.5V.

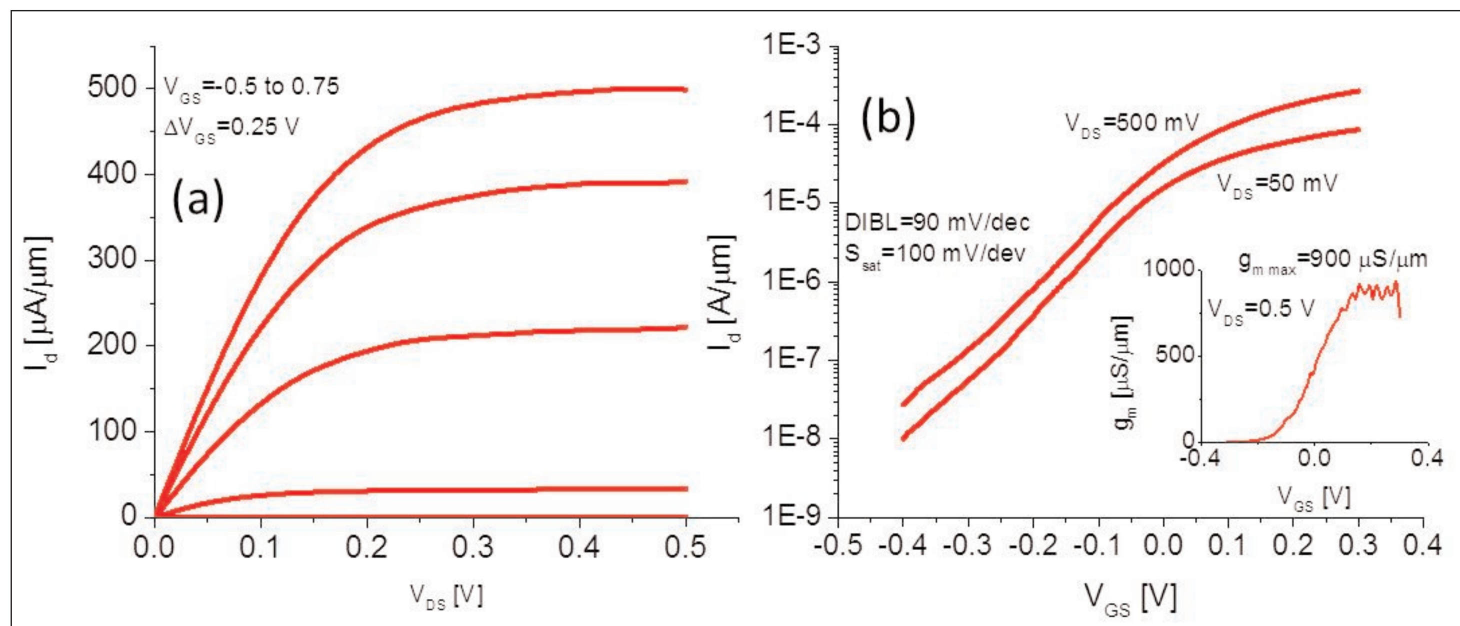

Figure 1. (a) Output and (b) subthreshold characteristics of InGaAs finFET with 7nm fin width, 30nm gate length. Inset: transconductance (g_m) characteristics.

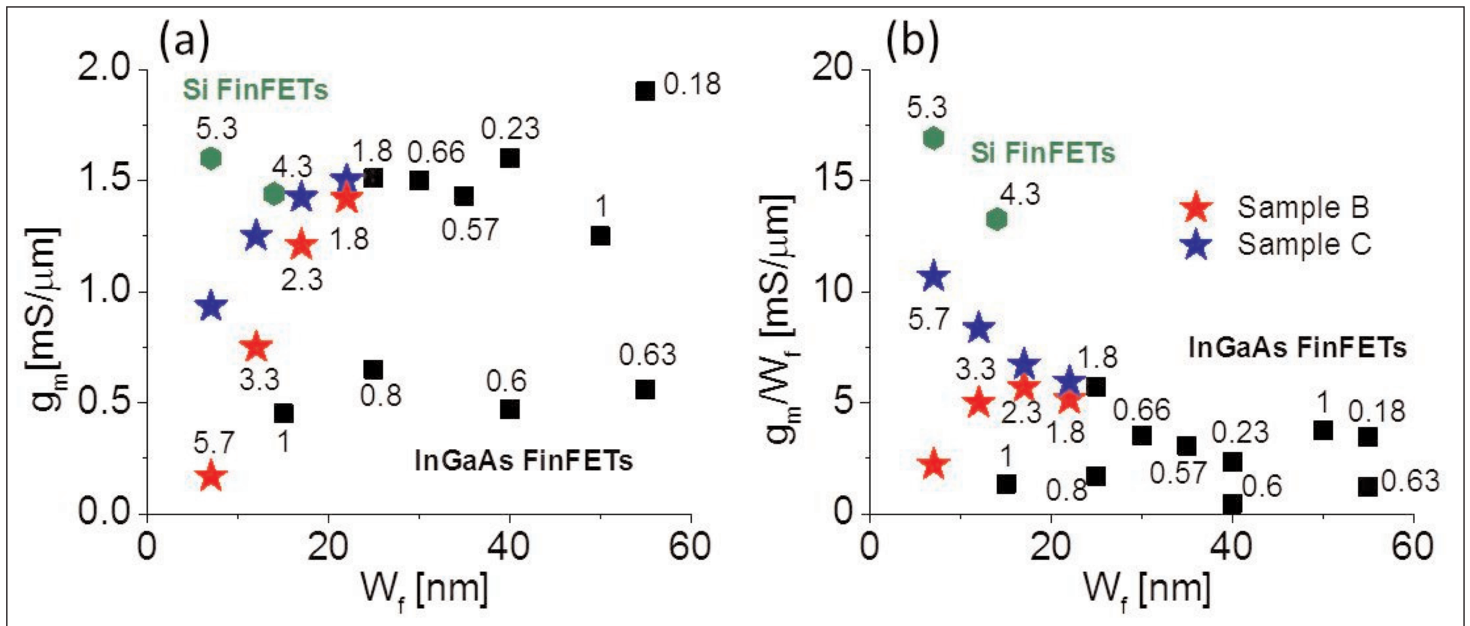

Figure 2. Benchmark of maximum gm versus fin width (W_f) for InGaAs finFETs and state-of-the-art silicon finFETs. On the left, g_m is normalized by gate periphery. On the right, g_m is normalized by fin footprint. Numbers next to each data point represent the aspect ratio of the conducting channel.

Increasing the fin width to 22nm increased the peak transconductance to 1500μS/μm. With 22nm-wide fins and 2μm gate length, the linear subthreshold swing reduced to as low as 68mV/decade, close to the theoretical minimum for planar devices of 60mV/decade at room temperature. The low swing is taken as indicating a high-quality semiconductor sidewall/gate dielectric interface.

In a range of devices with varying gate length and equivalent oxide thickness (EOT) of the high-k dielectric, Vardi and del Alamo found "classic finFET scaling behavior that has not experimentally been demonstrated before with InGaAs". In particular, transconductance increased with reduced gate length, while EOT reduction gave increased transconductance, threshold voltage roll-off mitigation, and enhancement of saturated subthreshold swing.

On the other hand, reducing fin width resulted in degraded transconductance. Vardi and del Alamo suggest this may be due to sidewall roughness leading to increased carrier scattering. Thinner fin widths, however, do lead to higher threshold voltages, although this is partly due to mobility degradation. Quantum effects are another possible contributing factor.

In benchmarking their transconductance results against other reports, including silicon-based finFETs, Vardi and del Alamo use two normalizations (Figure 2). Using the standard gate periphery normalization, silicon and InGaAs devices seem to have comparable performance. However, basing the normalization on fin width is more relevant for transistor density and the benchmarking shows a gap between Si and InGaAs. "This stems from the high aspect ratio of Si fins and reveals the significantly greater effectiveness in charge control modulation through the sidewalls in Si finFETs when contrasted with InGaAs finFETs," Vardi and del Alamo write. However, their new InGaAs finFETs show a factor of nearly two improvement in performance over previous reports, closing the gap with silicon. ■

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Carbon nanotube transistors outperform silicon

On-state current density exceeds that of GaAs pHEMTs.

For decades, researchers have tried to harness the unique properties of carbon nanotubes (CNTs) to create high-performance electronics that are faster or consume less power — resulting in longer battery life, faster wireless communication and faster processing speeds for devices like smartphones and laptops. But a number of challenges (such as constraints in CNT sorting, processing, alignment, and contacts) have impeded the development of high-performance transistors made of carbon nanotubes. Consequently, their performance has lagged far behind semiconductors such as silicon and gallium arsenide (GaAs) in computer chips and personal electronics.

Now, led by professors of materials science and engineering Michael Arnold and Padma Gopalan, researchers at University of Wisconsin–Madison have created carbon nanotube transistors that for the first time outperform state-of-the-art silicon transistors, it is claimed, achieving on-state current density 1.9 times higher than silicon transistors (G J Brady et al, 'Quasi-ballistic carbon nanotube array transistors with current density exceeding Si and GaAs', Science Advances vol2 (2016), no9, e1601240).

Specifically, the researchers have fabricated field-effect transistors (FETs) with a density of 47 CNTs per μm and a channel length of 100nm, yielding conductance as high as 0.46G0 per CNT. In parallel, conductance of the arrays reaches 1.7mS/μm, seven times higher than the previous state-of-the-art CNT array FETs made by other methods. Saturated on-state current density is as high as 900μA/μm, similar to or exceeding that of silicon MOFETs (at an equivalent gate oxide thickness and the same off-state current density) and exceeding the 630μA/μm of GaAs pseudomorphic high-electron-mobility transistor (pHEMT) technology.

"This breakthrough in carbon nanotube transistor performance is a critical advance toward exploiting carbon nanotubes in logic, high-speed communications, and other semiconductor electronics technologies," says Arnold. This advance could pave the way for carbon nanotube transistors to replace silicon transistors and continue delivering the performance gains the computer industry relies on, it is reckoned. The new transistors are particularly promising for wireless communications technologies that require a lot of current flowing across a relatively small area. Funding from the US National Science Foundation, the Army Research Office and the Air Force supported the work.

As some of the best electrical conductors ever discovered, carbon nanotubes have long been recognized as a promising material for next-generation transistors. CNT transistors should be able to perform five times faster or use five times less energy than silicon transistors, according to extrapolations from single nanotube measurements. The nanotube's ultra-small dimension makes it possible to rapidly change a current signal traveling across it, which could lead to substantial gains in the bandwidth of wireless communications devices.

But researchers have struggled to isolate purely carbon nanotubes, which are crucial, because metallic nanotube impurities act like copper wires and disrupt their semiconducting properties (like a short circuit).

The UW–Madison team used polymers to selectively sort out the semiconducting nanotubes, achieving a solution of ultra-high-purity semiconducting carbon nanotubes. "We've identified specific conditions in which you can get rid of nearly all metallic nanotubes, where we have less than 0.01% metallic nanotubes," says Arnold.

Placement and alignment of the nanotubes is also difficult to control. To make a good transistor, the nanotubes need to be aligned in just the right order, with just the right spacing, when assembled on a wafer. In 2014, the UW–Madison researchers overcame that challenge by developing the 'floating evaporative self-assembly' technique to give them this control.

The nanotubes must also make good electrical contacts with the metal electrodes of the transistor. Because the polymer used by the UW-Madison researchers to isolate the semiconducting nanotubes also acts like an insulating layer between the nanotubes and the electrodes, the team 'baked' the nanotube arrays in a vacuum oven to remove the insulating layer, yielding excellent electrical contacts to the nanotubes.

The researchers also developed a treatment that removes residues from the nanotubes after they are processed in solution.

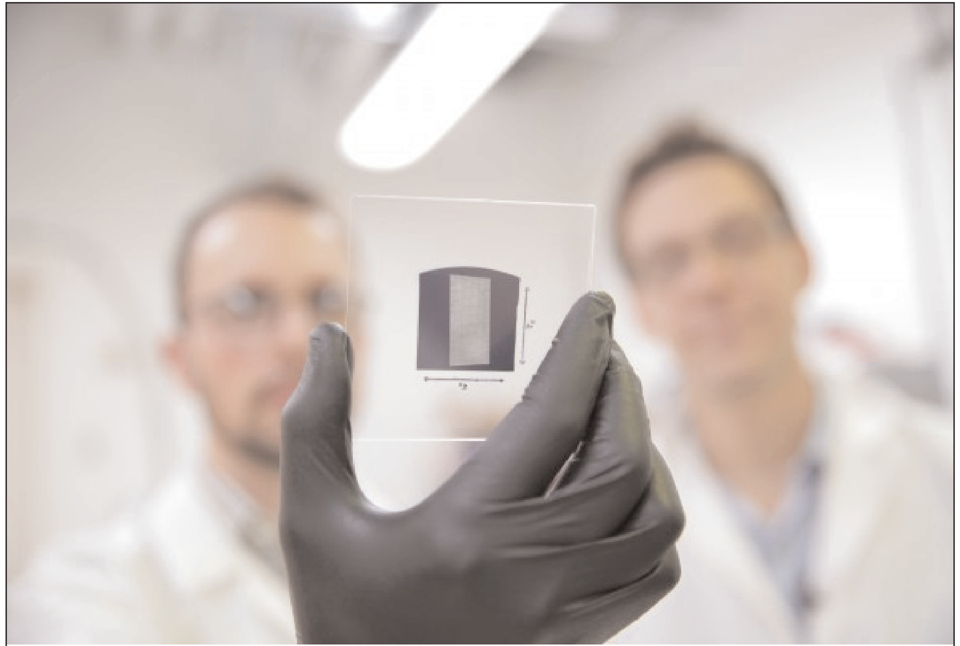
"We've shown that we can simultaneously overcome all of these challenges of working with nanotubes, and that has allowed us to create these ground-breaking carbon nanotube transistors that surpass silicon and gallium arsenide transistors," says Arnold.

The researchers benchmarked their carbon nanotube transistor against a silicon transistor of the same size,

geometry and leakage current. They are now continuing to work on adapting their device to match the geometry used in silicon transistors, which shrinks with each new generation. Work is also underway to develop high-performance radio frequency amplifiers that may be able to boost a cell-phone signal. While the researchers have already scaled their alignment and deposition process to 1-inch by 1-inch wafers, they are working on scaling the process up for commercial production.

Arnold says researchers can finally exploit the nanotubes to attain performance gains in actual technologies. "There has been a lot of hype about carbon nanotubes that hasn't been realized, and that has kind of soured many people's outlook," he adds. "It has just taken decades of work for the materials science to catch up and allow us to effectively harness these materials."

The researchers have patented their technology through the Wisconsin Alumni Research Foundation.



The UW–Madison engineers use a solution process to deposit aligned arrays of carbon nanotubes onto 1 inch by 1 inch substrates. The scalable and rapid deposition process was used to coat the entire surface of this substrate with aligned carbon nanotubes in less than 5 minutes.

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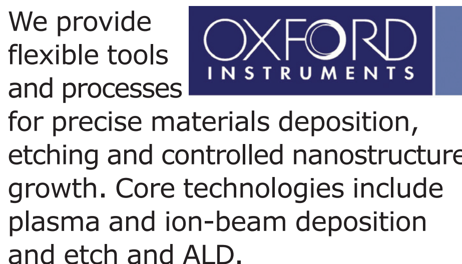

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Eden Prairie, MN 55344, USA
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www.svta.com

Veeco Instruments Inc
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7 Wafer processing materials

Air Products and Chemicals Inc
7201 Hamilton Blvd.,
Allentown, PA 18195, USA
Tel: +1 610 481 4911
www.airproducts.com/compound

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

Praxair Electronics
(see section 5 for full contact details)

8 Wafer processing equipment

EV Group
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www.logitech.uk.com

Oxford Instruments Plasma Technology
(see section 6 for full contact details)

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

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

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

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

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

9 Materials & metals

Goodfellow Cambridge Ltd
Ermine Business Park,
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Cambridgeshire
PE29 6WR,
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Tel: +44 (0) 1480 424800
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www.goodfellow.com

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10 Gas and liquid handling equipment

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

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

CS CLEAN SYSTEMS AG
Fraunhoferstrasse 4,
Ismaning, 85737,
Germany
Tel: +49 89 96 24 00 0
Fax: +49 89 96 24 00 122
www.cscleansystems.com

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

11 Process monitoring and control

k-Space Associates Inc
2182 Bishop Circle
East, Dexter,
MI 48130,
USA
Tel: +1 734 426 7977
Fax: +1 734 426 7955
www.k-space.com

k-Space Associates Inc specializes in in-situ, real-time thin-film process monitoring tools for MBE, MOCVD, PVD, and thermal evaporation. Applications and materials include the research and production line monitoring of compound semiconductor-based electronic, optoelectronic, and photovoltaic devices.

KLA-Tencor
One Technology Dr,
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Fax: +1 408 875 4144
www.kla-tencor.com

LayTec AG
Seesener Str. 10–13,
10709 Berlin,
Germany
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Fax: +49 30 89 00 180
www.laytec.de

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

12 Inspection equipment

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

13 Characterization equipment

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

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

14 Chip test equipment

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

15 Assembly/packaging materials

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

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

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

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

16 Assembly/packaging equipment

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

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

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

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

17 Assembly/packaging foundry

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

18 Chip foundry

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

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

19 Facility equipment

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

20 Facility consumables

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

21 Computer hardware & software

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

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

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

22 Used equipment

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

23 Services

Henry Butcher International
Brownlow House, 50–51
High Holborn, London WC1V 6EG,
UK
Tel: +44 (0)20 7405 8411
Fax: +44 (0)20 7405 9772
www.henrybutcher.com

M+W Zander Holding AG
Lotterbergstrasse 30,
Stuttgart,
Germany
Tel: +49 711 8804 1141
Fax: +49 711 8804 1950
www.mw-zander.com

24 Consulting

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

25 Resources

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

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

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2–6 October 2016
29th IEEE Photonics Conference (IPC 2016)
Waikoloa, Hawaii, USA
E-mail: c.c.scott@ieee.org
www.ipc-ieee.org

2–7 October 2016
International Workshop on Nitride Semiconductors (IWN 2016)
Hilton Orlando Lake Buena Vista, Orlando, FL, USA
E-mail: info@mrs.org
www.mrs.org/iwn-2016

3–7 October 2016
European Microwave Week (EuMW 2016), incorporating:
46th European Microwave Conference (EuMC)
11th European Microwave Integrated Circuits Conference (EuMIC)
13th European Radar Conference (EuRAD)
ExCel London, UK
E-mail: eumw2016@manchester.ac.uk
www.eumweek.com

10–13 October 2016
2016 IEEE SOI-3D-Subthreshold Micro-electronics Technology Unified Conference (S3S SOI/3D/SubVt) — 'Energy Efficient Technology for the Internet of Things'
Hyatt Regency San Francisco Airport, San Francisco, CA, USA
E-mail: manager@s3sconference.org
http://s3sconference.org

23–26 October 2016
2016 IEEE Compound Semiconductor Integrated Circuit Symposium (CSICS)
Austin, TX USA
E-mail: hpmoyer@hrl.com
https://csics.org

25–27 October 2016
SEMICON Europa 2016
Grenoble, France
E-mail: eweller@semi.org
www.semiconeuropa.org

26–28 October 2016
6th Annual World Congress of Nano Science & Technology (Nano S&T-2016) — 'Theme: Small is All, The Future of Nanotechnology'
Singapore
E-mail: stella@bitconferences.com
www.bitcongress.com/nano2016

7 November 2016
ITF2016 Japan
New Otani Hotel – Tokyo, Japan
E-mail: Annouck.Vanrompay@imec.be
www.itf2016.be/page.aspx/2218

7–9 November 2016
4th IEEE Workshop on Wide Bandgap Power Devices and Applications (WiPDA 2016)
Fayetteville, AR USA
E-mail: mantooth@uark.edu
www.wipda2016.org

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13–16 November 2016
11th International Conference on Advanced Semiconductor Devices & Microsystems (ASDAM '16)
Smolenice, Slovakia
E-mail: asdam@savba.sk
http://elu.sav.sk/asdam

3–7 December 2016
IEDM 2016:
62nd annual IEEE International Electron Devices Meeting
San Francisco Union Square Hilton Hotel, CA, USA
E-mail: info@ieee-iedm.org
www.ieee-iedm.org

13–14 December 2016
International MicroNanoConference 2016
Beurs van Berlage, Amsterdam, The Netherlands
E-mail: info@micronanoconference.org
www.micronanoconference.org

14–16 December 2016
SEMICON Japan 2016
Tokyo International Exhibition Center (Tokyo Big Sight), Japan
E-mail: jcustomer@semi.org
www.semiconjapan.org

28 January – 2 February 2017
SPIE Photonics West 2017
Moscone Center, San Francisco, CA, USA
E-mail: customerservice@spie.org
http://spie.org/SPIE-PHOTONICS-WEST-conference

19–23 March 2017
Optical Fiber Communication Conference & Exhibition (OFC 2017)
Los Angeles Convention Center, CA, USA
E-mail: OFC@compusystems.com
www.ofcconference.org

9–13 April 2017
SPIE Defense + Commercial Sensing 2017 (DCS)
Anaheim Convention Center, CA, USA
E-mail: customerservice@spie.org
http://spie.org/SPIE-DCS-conference

18–21 April 2017
SNEC's 11th International Photovoltaic Power Generation Conference & Exhibition (SNEC PV Power EXPO 2017)
Shanghai, China
E-mail: info@snec.org.cn
www.snec.org.cn

1–3 May 2017
13th International Conference on Concentrator Photovoltaics (CPV-13)
University of Ottawa, Canada
E-mail: info@cpv-13.org
www.cpv-13.org

22–25 May 2017
2017 CS ManTech (International Conference on Compound Semiconductor Manufacturing Technology)
Hyatt Regency Indian Wells Resort & Spa, Indian Wells, CA, USA
E-mail: lynn_fincher@msn.com
www.csmantech.org

28 May – 1 June 2017
29th International Symposium on Power Semiconductor Devices and ICs (ISPSD 2017)
Sapporo, Japan
http://eds.ieee.org/eds-meetings-calendars.html

25–30 June 2017
44th IEEE Photovoltaic Specialists Conference (PVSC44)
Marriot Wardman Park Hotel, Washington DC, USA
E-mail: info@ieee-pvsc.org
www.ieee-pvsc.org/PVSC44

10–12 July 2017
IEEE Photonics Society's 2017 Summer Topicals Meeting Series
San Juan, Puerto Rico
E-mail: i.donnelly@ieee.org
www.sum-ieee.org

22–25 October 2017
IEEE Compound Semiconductor Integrated Circuit Symposium (CSICS 2017)
Miami, FL USA
E-mail: l.lelong@ieee.org
https://csics.org

26–28 October 2017
International Conference on Advanced Materials and Nanotechnology
Osaka, Japan
http://advancedmaterials.conferenceseries.com/events-list/photonics-and-semiconductor-nanophysics

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

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