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COMPOUNDS & ADVANCED SILICON

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Cree increases SiC capacity expansion plan with fab in NY State

BluGlass and Bridgelux enter JDA • QSFP-DD800 MSA formed
II-VI completes Finisar acquisition • News from ECOC & CIOE

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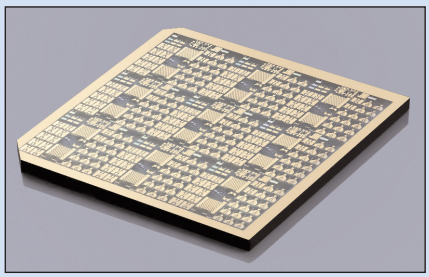

p11 Germany's FBH has reported a 1.8kV-breakdown β-Ga_2O_3 MOSFET with a record 155MW/cm^2 power figure of merit.

p24 BluGlass has entered into a JDA with Bridgelux to build on its RPCVD tunnel-junction technology in order to develop cascade LEDs.

p28 Osram's second generation of Eviyos LED for smart headlights boosts the number of individually controllable pixels from 1024 to 25,600.

Cover: Palo Alto Research Center (PARC) has opened new 'cleanroom-as-a-service' facilities as an open innovation lab for use by corporate research departments, government agencies and start-up companies to develop prototype electronic devices and novel technologies quickly and cost-effectively. **p22**

editorial

Investments in silicon carbide driven by adoption in automotive applications

After announcing in May that it was investing up to $1bn over five years (through to 2024) to expand its silicon carbide (SiC) capacity with the development of an automated 200mm SiC device fabrication facility ($450m) and a 'mega materials' substrate factory ($450m) at its US campus headquarters in Durham, North Carolina, Cree now says that its Wolfspeed business' power & RF device fab will be up to 480,000ft^2 and have 25% greater capacity (creating the world's largest SiC fab) and be sited instead in Marcy, near Utica, New York, comprising its 'North Fab' in a 'silicon carbide corridor' on the East Coast of the USA, leveraging its 30-year heritage of R&D in the Research Triangle of North Carolina and tapping into the technological base of resources in New York State's Mohawk Valley (see page 12).

Cree is investing about $1bn in construction, equipment and other related costs, while - through a partnership - New York State will provide a $500m grant from Empire State Development. Cree will also be eligible for additional local incentives and abatements as well as equipment and tooling from the State University of New York (SUNY). The firm hence expects to realize a net capital saving of about $280m on the previously announced $1bn capacity expansion.

Ramping in 2022 and automotive-qualified, Cree reckons that it will hence be able to meet the increasing demand for its Wolfspeed technology — supporting the growing electric vehicle (EV), 4G/5G mobile and industrial markets — as the power electronics industry transitions from silicon to silicon carbide technology.

Cree has also announced a partnership for its SiC MOSFET devices to be used by UK-based automotive propulsion technology provider Delphi Technologies' new 800V traction drive inverters (and subsequently DC/DC converters and chargers) — ramping production in 2022 — for a global premium automaker, enabling smaller, lighter and more powerful electronic systems in future EVs with extended driving ranges and faster charging times (see page 13).

Meanwhile, Europe's STMicroelectronics has been chosen to supply automotive-grade SiC power electronics (MOSFETs and rectifier diodes) to Renault–Nissan–Mitsubishi for more efficient and compact high-power on-board chargers (OBCs) — entering volume production in 2021 — that should cut battery-charging time and boost driving range in its next generation of EVs (see page 15).

US-based DuPont Electronics & Imaging (E&I) has agreed to divest its Compound Semiconductor Solutions (CSS) business for $450m to South Korean silicon wafer maker SK Siltron (part of SK Group), which will hence acquire silicon carbide wafer production technology for power electronics applications (see page 12).

The fact that major silicon device makers like STMicroelectronics and even silicon wafer makers like SK Siltron are investing heavily in SiC production is further evidence of the accelerating transition from silicon to silicon carbide for power electronics, driven particularly by the need for lighter, more compact and efficient and faster charging in electric vehicles.

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- event calendar and event previews;
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Mini-LEDs to continue to see higher penetration rates in high-end display markets, due to an edge in power consumption and color

Mini-LED backlight displays exploit significant advantage in brightness, reliability and performance

Mini-LED backlight displays all have a significant advantage in brightness, reliability and performance, as well as a chance to grab a slice of the high-end display market, according to the latest 'Mini-LED and HDR High-End Display Market Report' by LEDinside (a division of TrendForce). Mini-LED backlights may even extend the lifetime of LCD displays, seeing penetration rates of 20%, 15% and 10% in the IT, TV and tablet application markets, respectively, in 2024.

Comparing the features of organic light-emitting diode (OLED) and mini-LED backlight displays, the local dimming feature of mini-LED backlight displays may rival OLEDs in their ability to contrast colors, notes TrendForce. Mini-LEDs also have more competitive prices compared with TV and monitor product applications, since mini-LED backlight displays exhibit display effects nearly equal to those of OLEDs, but the power consumption is much lower than for OLEDs. So, these products give better value for money.

Epistar develops fast transfer technology to enter mini-LED backlight market

With the rise of mini-LED backlight technology, the original industry chain has changed, says the report. For example, panel manufacturers AUO and Innolux are both collaborating with their respective LED companies to develop mini-LED backlight modules: AUO has joined with Lextar, while Innolux is already working with companies such as AOT and Epileds, developing towards TV, IT and small- and medium-sized automotive product applications and hoping to keep their competitive edge in LCD products. CSOT, BOE and others have got involved in mini-LED backlights and display businesses by leveraging their edge in product technology and equipment CapEx. Chip manufacturer Epistar has worked with subsidiary Yenrich to release mini-LED light source modules to enter the backlight applications of high-end displays.

The key challenges of mini-LED backlight technology are cost, power consumption and die-bonding efficiency. In terms of the challenge of power consumption, as current mounts (and heat along with it), efficiency declines. So far, Epistar has offered two different solutions to help customers meet their goal of reducing power consumption or cost. For power consumption, with the decrease in chip size and drive current, customers can improve full-screen power consumption with enhanced backlight dimming zone control. For cost, Epistar has added an innovative reflector with LED chips to increase the beam angle. So far, Epistar has been able to produce LED chips with special beam angle of 150-170° to reduce both number of LED chips required and system production costs.

Innovations in mini-LED backlight technology may bring advantages in display effect, but the new structure also places a heavier burden in costs, and striking a fine balance between the two has become a problem that suppliers along the whole supply chain must work together to solve. The fastest way to reduce costs would be to combine the strengths of relevant suppliers for backplanes, LED chips and driver ICs and module assembly companies

In addition, with the reduction of LED chip size and the increase in number, LED die bonding is becoming increasingly difficult. Epistar and subsidiary Yenrich's self-developed 'Fast Transfer on X substrate' can precisely transfer mini- or micro-LED chips in large quantities on a variety of material substrates specified by customers.

TrendForce says that innovations in mini-LED backlight technology may bring advantages in display effect, but the new structure also places a heavier burden in costs, and striking a fine balance between the two has become a problem that suppliers along the whole supply chain must work together to solve. The fastest way to reduce costs would be to combine the strengths of relevant suppliers for backplanes, LED chips and driver ICs and module assembly companies and to develop mini-LED products with better value. Mini-LED chips will play an important role in that process, reckons TrendForce. Chip suppliers turned market leaders and technological vanguards will hold an even greater advantage in the future, the firm concludes.

www.ledinside.com

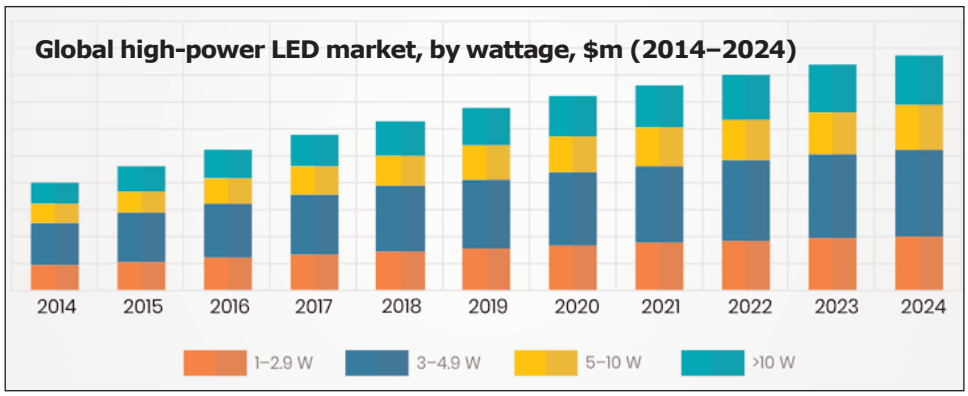
High-power LED market growing at 5.3% CAGR to $17,581.5m in 2024

The high-power light-emitting diode (LED) market was $12,647.2m in 2018 and will rise at a compound annual growth rate (CAGR) of 5.3% from 2019 to $17,581.5m in 2024, according to a report by P&S Intelligence. The major factors stimulating growth include rising adoption of energy-efficient lighting solutions and increasing government support for the adoption of LED lights globally.

Based on wattage, the high-power LED market is classified into 1–2.9W, 3–4.9W, 5–10W and >10W. Among these, the 5–10W category is expected to see the fastest growth due to the rising deployment of 5–10W high-power LEDs in general lighting applications, such as outdoor lighting and entertainment lighting.

By application, the high-power LED market is segmented into automotive, general lighting, backlighting, signs & signals, and others (including camera flash lighting, infrared emitters and ultraviolet LEDs). Of these, the automotive category is projected to register a CAGR of 5.4% due to increasing demand for high-power LEDs in both exterior and interior applications, such as fog lights, position lights, headlights, ambient lighting and dashboard lights. In addition, demand for high-power LEDs in backlighting application (including gaming, channel letter lighting and portable appliances) has risen significantly and is projected to grow steadily.

Geographically, the Asia–Pacific (APAC) region is expected to account for a substantial share of the high power LED market, due mainly to the growing adoption of high-power LEDs in general lighting, mainly in China and India. Also, several smart-city development projects are in the pipeline in these countries, which are expected to generate huge demand for high-power LED lights. For example,



China introduced a national development project in 2012 to build smart cities with modern technology. Further, the Chinese government aims to nurture 100 new smart cities to lead their urban planning and development by 2020.

Rising adoption of energy-efficient products, along with increasing government focus toward energy saving, is fueling the demand for energy-efficient lighting sources, predominantly high-power LEDs, which is likely to bolster the growth of the high-power LED market. High-power LEDs are particularly advantageous in general lighting and automotive applications as they work efficiently for long operating hours at low maintenance cost. Due to these advantages, local authorities of countries, such as the USA, India, China, and Australia, have commenced projects to replace their conventional lighting lamps used in outdoor lighting with LEDs. For example, in 2014, according to the US Department of Energy, the city of Los Angeles had completed a citywide street lighting replacement program and installed over 215,000 LED streetlights (saving about $9m in annual energy costs).

Furthermore, in 2016, the Institute of Public Works Engineering Australasia (IPWEA) and the Australian government together showcased a strategic roadmap to promote LED lights to increase energy efficiency under the Street Lighting and Smart Controls Programme. Hence, an increasing number of government initiatives to reduce energy consumptions is expected to bolster high-power LED market growth in the future.

The high-power LED market is highly competitive and fragmented, with the presence of a large number of global and regional players. Some of the key players include Cree Inc, Osram Licht AG, Nichia Corp, Samsung Electronics Co Ltd, Seoul Semiconductor Co Ltd, Everlight Electronics Co Ltd, Lumileds Holding B.V., MLS Co Ltd, LG Innotek Co Ltd, Broadcom Inc, and Epistar Corp. These companies are adopting product launches, as a key strategy, to maintain their stronghold in the market, says the report.

For example, in May 2018, Samsung Electronics introduced LED components for horticultural lighting. Its new horticulture LED lineup features a newly developed red LED package, in addition to key existing Samsung white LED package and module families to include horticultural lighting specifications.

Most recently, in May 2019, Lumileds introduced two new additions to its LUXEON chip-on-board (COB) LED family. The LUXEON COB Core Range and the LUXEON COB with CrispWhite Technology can deliver a minimum of color rendering index (CRI) of 95 for applications such as indoor lighting and retail lighting.

www.psmarketresearch.com/market-analysis/high-power-led-market

Qorvo prices offering of $350m senior notes

Qorvo Inc of Greensboro, NC, USA (which provides core technologies and RF solutions for mobile, infrastructure and defense applications) has priced its offering of $350m worth of senior notes (maturing in 2029). The offering has been upsized from the $300m initially announced on 25 September.

Paying interest semi-annually at a rate of 4.375%, the notes will mature on 15 October 2029, unless earlier redeemed in accordance with their terms. Qorvo expected to close the sale of the notes on or about 30 September, subject to satisfaction of customary closing conditions.

The notes will be issued to qualified institutional buyers and to certain non-US persons .

Qorvo expects to use the net proceeds of the offering for general corporate purposes.

www.qorvo.com

Qorvo's IDP president recognized with Tech Titans Award

Qorvo says that James Klein, president of Infrastructure and Defense Products (IDP), has been recognized with the Technology Association of North Texas' Tech Titans Award. Tech Titans recognizes individuals in North Texas currently transforming the high-tech industry for the greater good.

Headquartered in Richardson, Texas, Qorvo's IDP business has a significant presence in North Texas, with three facilities that manufacture up to 80 million semiconductor components per week.

Under Klein's leadership, Qorvo's IDP revenue grew by double digits for 13 consecutive quarters as it expanded into diverse, high-growth markets.

IDP president James Klein.

Currently, IDP serves large markets including wireless connectivity, broadband, aerospace, defense, the Internet of Things (IoT) and, most recently, programmable power management through the acquisition of Active-Semi International Inc of Dallas, TX, USA. Klein helped to establish Qorvo's technology and product leadership in gallium nitride (GaN), expanding its use from defense radar and electronic warfare to commercial markets including 5G base stations and broadband cable networks.

Qorvo has added more than 1200 jobs to the Dallas area. "James' strategic leadership of Qorvo's IDP business unit is a model for other businesses in the Texas area and beyond," comments Tech Titans' president & CEO Bill Sproull.

www.techtitans.org
www.qorvo.com

Altum RF announces RF Test Lab in Sydney office

Expansion includes full RF measurement capabilities

Altum RF of Eindhoven, The Netherlands (a start-up designing high-performance millimeter-wave to digital solutions for next-generation markets and applications) has announced the expansion of its office in Sydney, Australia with an RF Test Lab.

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

Altum RF's Australia office is located adjacent to the Sydney Innovation and Technology Precinct and now includes full RF test and characterization infrastructure up to 65GHz, with future plans to expand capabilities to 125GHz. The RF lab also ensures ESD-safe measurements.

"Adding full RF measurement capabilities at our Sydney office demonstrates our commitment to growing our product portfolio with the highest-performing and most advanced technology," says CEO Greg Baker. "This investment not only supports the design team's efforts, it also allows for enhanced application support to our customers."

- At European Microwave Week (EuMW 2019) in Paris, France (1–3 October), Altum RF is showcasing its product offering, including demonstration boards and literature.

Also, the firm's leaders are available to answer questions about specific products, future plans and their decades of expertise designing and delivering RF, microwave and millimeter-wave semiconductors.

www.eumweek.com
www.altumrf.com

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FBH presents III-V electronics portfolio at European Microwave Week

In a joint booth with 'Research Fab Microelectronics Germany' (FMD) at European Microwave Week (EuMW 2019) in Porte de Versailles Paris, France (1–3 October), Berlin-based Ferdinand-Braun-Institut, Leibniz-Institut für Höchstfrequenztechnik (FBH) is presenting its portfolio of III-V-based electronics (components for the digitization of mobile communications, for industrial and biomedical systems, and for space applications), including a selection of new developments in power amplifiers, circuits and heterointegrated chips.

In addition to its components for 5G, space communications, and terahertz systems for imaging techniques, FBH is showing a live demonstrator for pulsed laser sources. Using a particularly fast-switching gallium nitride (GaN)-based driver, the pulse length and intensity can be flexibly adjusted between 200ps and 20ns. The system can be flexibly equipped with laser diodes of various wavelengths (630–1180nm). For example, in light detection & ranging (LiDAR) systems, wavelength-stabilized laser diodes emitting at 905nm with 100W peak output power and pulse widths of 3–10ns are used.

Components for 5G and for satellite communications and sensors

Information and communication technologies account for 5% of global energy consumption — in the telecoms sector alone, demand is rising by 10% each year. The projected 5G systems will use higher frequencies, enabling larger signal bandwidth. FBH is presenting two approaches to improve their energy efficiency: a fully digital transmitter architecture and supply voltage modulation for linear amplifiers.

For future mobile communications, FBH is developing digital power amplifiers with efficient amplifier chips based on its 0.25µm GaN-HEMT process. FBH has hence realized the first fully digital transmitter chain that transmits broadband signals with maximum efficiency and linearity (47% at >52dB ACLR). The compact digital transmitter is particularly suitable for multi-antenna systems (massive MIMO) where it can be mounted on the rear side of the antenna.

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As a second approach, systems are realized whose supply voltage is modulated and which are suitable for 5G and satellite communications. Their specialty is the efficient amplification of signals with high modulation bandwidths. Together with the European Space Agency (ESA), FBH has developed a novel envelope tracking (ET) demonstrator for communication in space at 1.62GHz. The amplifier has a peak output power of more than 90W with a modulation bandwidth of 40MHz. With an 8.6 PAPR (peak-to-average power ratio) signal, overall efficiency reaches 40%.

Concepts using modulated supply voltage are now also transferred to millimeter-wave amplifiers, which is an interesting option for 5G base stations. FBH has developed a corresponding module consisting of two identical MMICs connected in series. Each consists of a single-stage amplifier with an integrated two-stage voltage switch (class G). The module operates in the 20–26GHz range with 14dB gain and more than 2W/mm at 20V supply voltage.

For satellite sensors, FBH is also developing a modular MIMO radar at 85–95GHz based on FBH's indium phosphide (InP) transfer-substrate double heterojunction bipolar transistor (DHBT) process. The imaging radar will be used to locate and track objects in the vicinity of satellites. For this purpose, a complete chipset was developed and integrated into a module. The chipset uses novel monolithic microwave integrated circuits (MMICs) with a high output power of >15dBm, a low noise figure (NF) <9dB and frequency converters down to the baseband.

Terahertz detectors and arrays for imaging systems

The terahertz (THz) range offers good spatial resolution and can penetrate most non-metallic materials. It is therefore suitable for a wide range of industrial and safety-relevant applications. However, there are still no imaging systems available with sufficiently high sensitivity and readout speed in this frequency range. Among other things, sensitive, fast and cost-effective THz detectors are missing that offer the potential to be used in THz cameras.

FBH has developed such detectors, which can easily be assembled into arrays. The III–V-based THz detectors offer superior values for the equivalent noise power NEP <25pW/sqrt(Hz) with a highest sensitivity of >100mA/W at 500GHz. These values are said to exceed the best THz detectors available in CMOS technology. The plan is now to develop THz cameras with similar values and an image refresh rate of more than 500 frames per second.

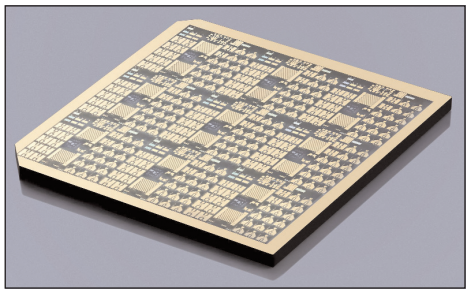
www.eumweek.com
www.fbh-berlin.com

FBH reports 1.8kV-breakdown gallium oxide MOSFET with record power figure of merit of 155MW/cm²

Improvements achieved by optimizing epi structure and gate topology

Ferdinand-Braun-Institut, Leibniz-Institut für Höchstfrequenztechnik (FBH) of Berlin, Germany has developed gallium oxide (ß-Ga_2O_3) metal-oxide-semiconductor field-effect transistors (MOSFETs) that provide a high breakdown voltage combined with high current conductivity (K. Tetzner et al., 'Lateral 1.8 kV β-Ga_2O_3 MOSFET With 155 MW/cm2 Power Figure of Merit', IEEE Electron Device Letters, vol. 40, no.9 (September issue), p1503).

Powerful electronic components are indispensable for future communications, for both the digital transformation of society and for artificial intelligence applications, notes FBH. On a footprint as small as possible, they should offer low energy consumption and achieve ever higher power densities, thus working more efficiently. This is where conventional devices reach their limits. Researchers all over the world are therefore investigating new materials and components that can meet these requirements.



Gallium oxide chip with transistors and structures for measurement purposes, manufactured at FBH using projection lithography

With a breakdown voltage of 1.8kV and a record power figure of merit of 155MW/cm², the new ß-Ga_2O_3-MOSFETs achieve what are said to be unique performance figures close to the theoretical material limit of gallium oxide. At the same time, the breakdown field strengths achieved are significantly higher than those of established wide-bandgap semiconductors such as silicon carbide or gallium nitride.

To achieve these improvements, the FBH team optimized the layer structure and gate topology. The basis was provided by substrates from the Leibniz-Institut für Kristallzüchtung with an optimized epitaxial layer structure. As a result, the defect density could be reduced and electrical properties improved. This leads to lower on-state resistances. Since the gate is the central 'switching point' of a field-effect transistor (controlled by the gate–source voltage), its topology has been further optimized, allowing a reduction in the high field strengths at the gate edge. This in turn leads to higher breakdown voltages.

www.fbh-berlin.com

https://ieeexplore.ieee.org/document/8768350

Cree increases capacity expansion plan by 25%; largest SiC device making facility to be built in New York State

200mm power & RF 'North Fab' in NY State and mega materials factory at North Carolina HQ to establish SiC corridor on East Coast

Cree Inc of Durham, NC, USA has announced plans to establish a silicon carbide corridor on the East Coast of the USA with the creation of the world's largest silicon carbide fabrication facility. The firm will build a new automotive-qualified 200mm power & RF wafer fabrication facility in Marcy, NY, complemented by its mega materials factory expansion currently underway at its Durham headquarters.

Part of a previously announced project to increase capacity for its Wolfspeed silicon carbide and gallium nitride (GaN) business, the new fabrication facility will be a bigger, highly automated factory with greater output capability. Through a strategic partnership with the office of Governor Andrew M. Cuomo and other state and local agencies and entities, the decision to build in New York will allow for both continued future expansion of capacity and significant net cost savings for Cree, it is reckoned.

Cree will hence be able to meet the increasing demand for its Wolfspeed technology — supporting the growing electric vehicle (EV), 4G/5G mobile and industrial markets — as the industry transitions from silicon to silicon carbide technology.

"Silicon carbide is one of the most pivotal technologies of our time, and is at the heart of enabling innovation across a wide range of today's most groundbreaking and revolutionary markets, including the transition from the internal combustion engine to electric vehicles and the rollout of ultra-fast 5G networks," says CEO Gregg Lowe. "This state-of-the-art, automotive-qualified wafer fabrication facility builds on our 30-year heritage of commercializing breakthrough technologies that help our customers deliver next-generation applications. We look forward to connecting our North Carolina and New York innovation hubs to drive the accelerated adoption of silicon carbide," he adds.

"We're excited to become part of Cree's efforts to drive the transition from silicon to silicon carbide, and this partnership will be a key part of our work to strengthen the research and scientific assets that New York State will use to attract the industries and jobs of tomorrow," says Empire State Development acting commissioner and president & CEO-designate Eric J. Gertler. "The Mohawk Valley offers a unique combination of valuable high-tech and scientific assets, and this is an important next step in growing our advanced manufacturing infrastructure and investing in our upstate economy."

As part of the partnership, Cree is investing about $1bn in construction, equipment and other related costs for the New York fab. New York State will provide a $500m grant from Empire State Development and Cree will be eligible for additional local incentives and abatements as well as equipment and tooling from the State University of New York (SUNY). The firm hence expects to realize a net capital saving of about $280m on its previously announced $1bn capacity expansion through 2024. In addition, it will provide 25% increased output compared with the previously planned facility. Ramping in 2022, the new facility will be up to 480,000ft^2 upon completion (about a quarter of which will be cleanroom space), providing future expansion capacity as needed.

Creation of silicon carbide corridor

With a mega materials factory in Durham and a wafer fabrication facility near Utica, Cree says it will establish a 'silicon carbide corridor', leveraging its 30-year heritage of R&D in the Research Triangle of North Carolina and tapping into the technological base of resources in New York's Mohawk Valley.

Cree plans to partner with local community and four-year colleges in North Carolina and New York to develop training and internship programs to prepare its workforce for the high-tech employment and long-term growth opportunities in both locations that the revised expansion plan presents.

www.cree.com

DuPont divests Compound Semiconductor Solutions business to SK Siltron

Delaware-based DuPont Electronics & Imaging (E&I) has agreed to sell its Compound Semiconductor Solutions (CSS) unit to silicon wafer supplier SK Siltron of Seoul, South Korea. The deal is expected to close by the end of 2019.

"The DuPont CSS business has state-of-the-art technologies for silicon carbide (SiC) wafer production to serve the power electronics market, but it is not a strategic priority for the E&I business," says DuPont Electronics & Imaging's president Jon Kemp. "Given its strategic focus, we believe SK Siltron will be a better owner and that the CSS business will thrive under SK Siltron's ownership," he concludes.

www.dupont.com/electronic-materials.html

Delphi partnering with Cree for automotive SiC devices

Cree's SiC MOSFETs to be used in Delphi's 800V inverters for premium global automaker, ramping production in 2022

Automotive propulsion technology provider Delphi Technologies PLC of London, UK and Cree Inc of Durham, NC, USA have announced a partnership to utilize silicon carbide (SiC) device technology to enable faster, smaller, lighter and more powerful electronic systems for future electric vehicles (EV).

The aim is for Cree's SiC-based metal–oxide–semiconductor field-effect transistor (MOSFET) technology — coupled with Delphi's traction drive inverters, DC/DC converters and chargers — to extend driving range and deliver faster charging times of EVs, while also lowering weight, conserving space and reducing cost. Cree's SiC MOSFETs will initially be used in Delphi's 800V inverters for a premium global automaker. Production will ramp in 2022.

"Delphi Technologies is committed to providing pioneering solutions to vehicle manufacturers," says the firm's CEO Richard F. (Rick) Dauch. "Our collaboration with Cree will create a significant benefit to automakers as they work to balance meeting stricter global emissions regulations with consumer appetite for electric vehicles," he adds. "Overcoming driver anxiety related to electric vehicle range, charging times and cost will be a boon for the industry."

The adoption of SiC-based power solutions is rapidly growing across the automotive market as the industry seeks to accelerate its move from internal combustion engines to EVs. By 2030, 30 million high-voltage electrified light vehicles will be sold, representing 27% of all vehicles sold annually, forecasts IHS. Inverters are one of the highest-value electrification components and their efficiency has an industry-changing impact on many aspects of vehicle performance.

The aim is for Cree's SiC-based MOSFET technology — coupled with Delphi's traction drive inverters, DC/DC converters and chargers — to extend driving range and deliver faster charging times of EVs

"Cree's technology is at the heart of the dramatic change underway in EVs, and we are committed to supporting the automotive industry as it transitions from silicon-based designs to more efficient, higher-performing silicon carbide solutions," says Cree's CEO Gregg Lowe. "This partnership with Delphi Technologies will help drive the adoption of silicon carbide in the automotive sector," he adds. "Cree is continuing to expand capacity to meet market demands with our industry-leading power MOSFETs."

Cree recently announced a silicon carbide capacity expansion to generate up to a 30-fold increase in capacity. The firm offers silicon carbide and gallium nitride (GaN) power and radio-frequency solutions through its Wolfspeed business unit.

Operating at 800V, Delphi's new silicon carbide inverter is targeted at providing vehicle engineers with additional flexibility to optimize other powertrain systems. Options include more range or a smaller battery; ultra-fast charging or smaller, lighter, cheaper cables; and greater harvesting of vehicle kinetic energy when braking, further extending vehicle range.

www.delphi.com
www.cree.com

Qorvo GaN technology to upgrade US Army radar system

Powerful amplifier chosen by Lockheed Martin to improve range, reliability and life-cycle costs

Qorvo Inc of Greensboro, NC, USA (which provides core technologies and RF solutions for mobile, infrastructure and defense applications) says that one of its gallium nitride (GaN) power amplifiers has been selected by Lockheed Martin to provide GaN modules for production of the US Army's Q-53 radar system. The insertion of GaN technology into this multi-mission mobile radar is expected to provide superior efficiency, power density, reliability and life-cycle cost over the gallium arsenide (GaAs) amplifiers currently used in the system.

The S-band monolithic microwave integrated circuit (MMIC) high-power amplifier (HPA) is built on Qorvo's gallium nitride on silicon carbide (GaN-on-SiC) technology. The GaN HPA delivers more than twice the saturated output power and a 15-point improvement in power-added efficiency (PAE) over the GaAs predecessor.

These capabilities support the required functions of the phased-array Q-53 radar, such as long-range counterfire acquisition. The amplifier's compact size and exceptional performance supports a wide range of challenging operating conditions. GaN-on-SiC technology has the added benefit of increasing system reliability and reducing life-cycle ownership costs.

"GaN-based amplifiers are providing RF system engineers with the flexibility to achieve significantly higher power and efficiency than GaAs while using fewer parts," notes James Klein, Qorvo's president of Infrastructure and Defense products. "The Q-53 radar system exemplifies just how closely Qorvo works with its defense customers to bring commercial technology to military applications that operate across the spectrum with the highest levels of reliability and functionality," he adds.

Lockheed Martin has used an open GaN foundry model leveraging relationships with commercial suppliers, like Qorvo, that utilize the power of the expansive telecoms market. This process takes advantage of the commercial industry's investment in GaN, enables competition and ultimately reduces costs.

www.qorvo.com

STMicroelectronics to supply silicon carbide power electronics to Renault–Nissan–Mitsubishi for high-speed on-board chargers in next-generation EVs

OBCs using ST's MOSFETs and rectifier diodes to enter volume production in 2021

STMicroelectronics of Geneva, Switzerland has been chosen to supply high-efficiency silicon carbide (SiC) power electronics to Renault–Nissan–Mitsubishi (Alliance) for on-board chargers (OBCs) in its upcoming electric vehicles (EVs).

Renault–Nissan–Mitsubishi plans to use the new SiC power technology to build more efficient and compact high-power OBCs that will further increase the attractiveness of EVs by cutting battery-charging time and enhancing driving range. As Renault–Nissan–Mitsubishi's chosen partner for SiC technology, ST will provide design-in support to help maximize OBC performance and reliability.

ST says that it is also to supply Renault–Nissan–Mitsubishi with associated components, including standard silicon devices. The OBCs with ST's SiC are scheduled to enter volume production in 2021.

EVs need an OBC to handle charging from standard roadside charge points when a dedicated home-charging system or super-charger is not available. The time to recharge is determined by the OBC power rating, and the units in existing EVs have ratings of 3-9kW.

Renault–Nissan–Mitsubishi has already created a 22kW OBC for the Renault Zoe model, which can fully recharge the battery in about 1 hour. Now, by upgrading the OBC to leverage the superior efficiency and small size of ST's SiC power semiconductors (MOSFETs and rectifier diodes), Renault–Nissan–Mitsubishi can further reduce the size, weight and cost while increasing energy efficiency to make future models more attractive for users. The new, compact and high-power OBC gives designers more freedom to style the vehicle and optimize packaging, weight distribution and vehicle drivability.

"As the pioneer and global leader in zero-emission electric vehicles, our objective remains to be the number one provider of mainstream mass-market and affordable EVs around the world," says Philippe Schulz, Alliance VP Design Electric & Hybrid Powertrain. "The small size, light weight and high energy efficiency we can achieve using ST's SiC technology in our OBC, combined with the increased battery efficiency, will enable us to accelerate the adoption of electric vehicles by reducing charging times and extend the range of our EVs," he adds.

"ST has successfully developed manufacturing processes and established a portfolio of qualified, commercialized SiC products also in automotive-grade version," says Marco Cassis, president, Sales, Marketing, Communications and Strategy Development, STMicroelectronics. "Building on our long cooperation, we are now working with Renault-Nissan-Mitsubishi to realize the many advantages SiC can bring to EVs," he adds. "Moreover, this commitment helps ensure success by increasing the economies of scale to deliver superior-performing SiC-based circuits and systems that are also cost-effective and affordable."

www.st.com/content/st_com/en/products/sic-devices.html

EPC partners with Solace Power to incorporate eGaN FETs in 250W wireless power platforms

Efficient Power Conversion Corp (EPC) of El Segundo, CA, USA — which makes enhancement-mode gallium nitride on silicon (eGaN) power field-effect transistors (FETs) for power management applications — is collaborating with Solace Power, a developer of intelligent wireless power-based solutions featuring proximity sensing and data, to enable 250W wireless power solutions designed for 5G, aerospace, automotive, medical and industrial applications. Solace Power's intelligent wireless platform uses EPC's 200V eGaN power transistors. This modular platform shares the same Equus architecture and enables up to 250W of transmitted power with six degrees of spatial freedom.

"We're excited to collaborate with EPC to further push the limits of our capacitive wireless power platform and to deliver previously unachievable solutions with a higher power requirement," says Solace Power's CEO Michael Gotlieb. "Solace focuses on delivering complete, modular systems which are pre-tested for CISPR/FCC compliance and optimized in-house for rapid development in real-world applications," he adds. "These new solutions solve the most important challenges for applications requiring 200W or more."

For wireless power applications with higher power demands than traditional consumer devices, existing silicon-based transistors become inefficient, notes EPC. To address this limitation, Solace selected a 200V GaN-based power transistor from EPC for the 250W solution.

"Wireless power is ready to be incorporated into our daily lives, and the modular platform that Solace Power has developed, using highly efficient, low-cost GaN transistors, will improve design cycle times and help new industries implement wireless power quickly and inexpensively," says EPC's CEO & co-founder Alex Lidow.

www.epc-co.com

Transphorm adds first PQFN88-packaged GaN FETs to Gen III product line

Transphorm Inc of Goleta, near Santa Barbara, CA, USA — which designs and manufactures JEDEC- and AEC-Q101-qualified high-voltage (HV) gallium nitride (GaN) field-effect transistors (FETs) for high-voltage (HV) power conversion applications — has announced its first Gen III PQFN88 transistors. The new 650V GaN FET devices are available in two versions, the TP65H070LSG (source tab) and TP65H070LDG (drain tab), and offer an on-resistance of 72mΩ.

Transphorm claims that its Gen III devices (launched in June 2018) came onto the market as the highest-quality, highest-reliability [Q+R] GaN FETs available. They pair a custom-designed low-voltage MOSFET with the GaN FET to offer:

- quieter switching;
- higher performance at increased current levels with minimal external circuitry;
- increased noise immunity (threshold voltage at 4V); and
- increased gate robustness (at ±20V).

The Gen III drain and source PQFN88 packages include wider pins for increased board-level reliability (BLR), which increases the reliability of multi-layer printed circuit board (PCB) designs. Offering the drain and source tab configurations also accommodates both high- and low-side switch locations. This provides increased radiated immunity as the large pad is soldered to the non-switching node. Further, adding PQFN88 devices to the existing list of Gen III TO-XXX FETs gives engineers an opportunity to explore GaN-driven surface-mount applications using Transphorm's latest technology.

"Our focus continues to be on increasing GaN FET reliability while delivering higher power density," says Philip Zuk, VP of technical marketing worldwide & North America sales. "As market interest in high-voltage GaN technology continues to grow, we also aim to arm our customers with device options that fit each potential application. To that end, the introduction of the 72mΩ source and drain PQFN88 devices allows us to meet all three objectives as we fill out our current product family."

The adoption rate of high-voltage GaN power electronics is on the rise, notes Transphorm, which has announced several customers with diverse end products [e.g. server and industrial power supplies, gaming PC supplies, portable solar generators, etc].

The 650V TP65H070LSG and TP65H070LDG (72mΩ) FETs are currently available for $7.47 in 1000-unit quantities. Supporting design resources include:

- TP65H070L series datasheet;
- TP65H070L series spice model;
- 1.2 kW half-bridge buck or boost evaluation kit [TDHBG1200DC100-KIT];
- TP65H070L half-bridge daughter card [TDHB-65H070-DC]; and
- 'Recommended External Circuitry for Transphorm GaN FETs' app note.

www.transphormusa.com/en/product/tp65h070lsg
www.transphormusa.com/en/product/tp65h070ldg

Transphorm and Mouser announce global distribution agreement

Transphorm Inc of Goleta, near Santa Barbara, CA, USA — which designs and makes JEDEC- and AEC-Q101-qualified 650V and 900V gallium nitride field-effect transistors for high-voltage power conversion applications — has signed a global distribution agreement for semiconductor and electronic component distributor Mouser Electronics Inc to distribute its GaN FETs and evaluation tools.

Mouser now offers devices from Transphorm's range of 900V TO-220 and 650V TO-247 and TO-220 GaN FETs. The devices feature low crossover losses, reduced gate charge and smaller reverse recovery charge, offering similar field reliability to silicon carbide (SiC) FETs and improved performance compared with silicon MOSFETs. Compared with competing GaN transistors, Transphorm's FETs also offer what is claimed to be the industry's highest threshold voltage (4V) and gate robustness rating (±20V).

Also available are Transphorm's automotive-qualified GaN FETs (including the TPH3205WSBQA), the industry's first GaN solution to earn AEC-Q101 qualification, and the TP65H035WSQA (the first 175°C -rated AEC-Q101-qualified device). As with non-automotive applications, in-vehicle power systems using the 650V GaN FETs can gain up to 40% more power density while reducing overall system costs by as much as 20% compared with similar silicon-based solutions, it is reckoned.

Lastly, Mouser stocks Transphorm's evaluation platforms, allowing designers to study switching characteristics and efficiency. The kits support various power system topologies, including inverters, half-bridge buck or boost (through-hole and SMD solutions), and the bridgeless totem-pole PFC. They also cover a range of power ratings. Examples include the 1.2 and 2.5kW half-bridge evaluation platforms and the 2.5 and 4kW bridgeless totem-pole PFC evaluation platforms.

www.mouser.com
www.transphormusa.com

Gen III GaN FET powering Wentai's 1.6kW Titanium ATX PC gaming power supply

LED lighting & power supply OEM Wentai Technology Corp of Taipei, Taiwan has developed a Titanium ATX gaming power supply unit (PSU) series called Aidan whose flagship product, the Aidan-T1616, uses Transphorm's TP65H050WS Gen III 50mΩ GaN FET in an interleaved CCM boost PFC. The result is a fully modular, low-noise 1616W 80 PLUS Titanium PSU with close to 95% efficiency.

The Aidan ATX PSU series targets consumer computing markets requiring ultra-high power such as PC gaming, E-sports, AI and cryptocurrency mining. Compared with Wentai's silicon-based 1.28kW PSU, the T1616 offers 328W more power and about 1% higher efficiency at 50% full load — all within the same form factor. This equates to a 20% increase in power density.

"The high-performance PC market uniquely serves use cases such as immersive gaming, AI and virtual currency mining that requires a large amount of reliable power in comparison to everyday PC use," notes Wentai's senior R&D director Aidan Liao. "GaN provided the right technological advantage for us to conceive the Aidan PSU's design to answer that need," he adds. "Transphorm's GaN provided the right quality, reliability and performance advantage for us to ultimately deliver on our vision with a top-quality, fairly priced power supply."

Mitsubishi Electric develops first multi-cell GaN-HEMT bonded directly to single-crystal diamond substrate

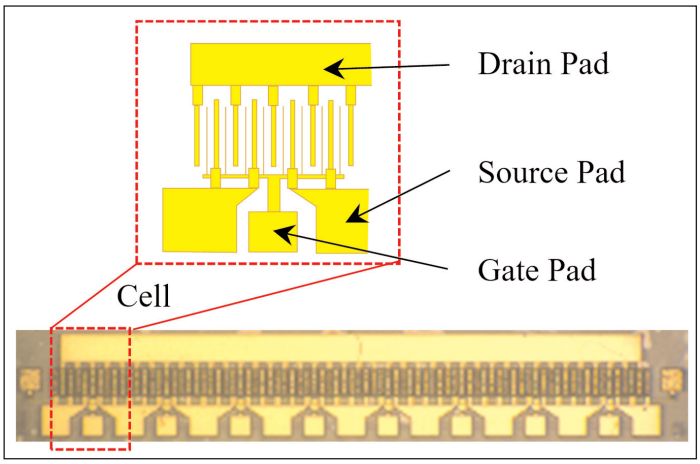
Refinements target improving PAE of high-power amplifiers in mobile communication base stations and satcom systems, prior to commercial launch in 2025

At the International Conference on Solid State Devices and Materials (SSDM) at Nagoya University, Japan (2–5 September), Japan's Mitsubishi Electric Corp announced that — in collaboration with the Research Center for Ubiquitous MEMS and Micro Engineering, National Institute of Advanced Industrial Science and Technology (AIST) — it has developed what is reckoned to be the first gallium nitride high-electron-mobility transistor (GaN HEMT) with a multi-cell structure (multiple transistors cells arranged in parallel) bonded directly to a single-crystal diamond heat-dissipating substrate.

Mitsubishi Electric handled the design, manufacture, evaluation and analysis of the GaN-on-diamond HEMT and AIST developed the direct bonding technology. Part of this achievement is based on results obtained from a project commissioned by Japan's New Energy and Industrial Technology Development Organization (NEDO).

In recent years, high-power, high-efficiency GaN HEMTs have been adopted for high-power amplifiers in mobile communication base stations and satellite communications systems, helping to make such equipment smaller, lighter and more efficient. However, due to heat generation during high-power operation, the output performance inherent in GaN HEMTs cannot be realized and their reliability decreases.

Most existing GaN HEMTs that use a diamond substrate for heat dissipation are created using a GaN epitaxial layer foil from which silicon substrate has been removed and onto which diamond is deposited at high temperature. HEMTs are then fabricated on the diamond substrate of the flattened GaN wafer.



New GaN-on-diamond HEMT: view from above and cell structure.

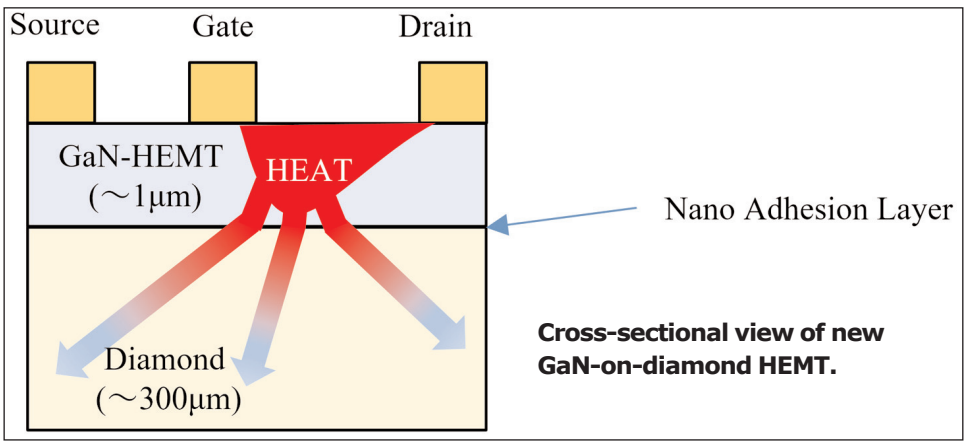
However, because the thermal expansion coefficients of GaN and diamond are different, the wafer can warp greatly during the manufacturing process, making it difficult to fabricate large multi-cell GaN-HEMTs.

In the latest research a multi-cell GaN HEMT was fabricated then the silicon substrate was removed. The back surface of the GaN HEMT was then polished to make it thinner and flatter, after which it was bonded directly onto a diamond substrate using a nano adhesion layer. A multi-cell structure was used for the parallel alignment of eight transistor cells of a type found in actual products. Finally, a multi-cell GaN-on-diamond HEMT — the world's first — was fabricated using a substrate with high heat dissipation made of single-crystal diamond.

Using a single-crystal diamond (with high thermal conductivity of 1900W/mK) for superior heat dissipation suppresses temperature degradation, reducing the temperature rise in the GaN HEMT from 211.1°C to 35.7°C. This improves output per gate width from 2.8W/mm to 3.1W/mm as well as raising power efficiency from 55.6% to 65.2%, realizing significant energy conservation.

The new GaN-on-diamond HEMT should be able to improve the power-added efficiency (PAE) of high-power amplifiers in mobile communication base stations and satellite communications systems, helping to reduce power consumption. Mitsubishi Electric aims to refine the GaN-on-diamond HEMT prior to its commercial launch, targeted for 2025.

www.mitsubishielectric.com



Cross-sectional view of new GaN-on-diamond HEMT.

Eta launches polished epi-ready 100mm n-type GaN wafers

Eta Research of Lingang Free Trade Zone, Shanghai, China, which was founded in 2015 to develop free-standing gallium nitride (GaN) wafers, is now selling n-type 100mm GaN wafers with an epitaxial-ready polish.

Eta has completed the R&D necessary to commercialize GaN wafers, resulting in its unique hydride vapor phase epitaxy (HVPE) equipment, wafer separation process, and polishing process. In 2018, the firm demonstrated as-grown GaN wafers of 100mm diameter that can be cut to 2" and 3" wafers as the finished size. This year it developed almost 5" as-grown GaN wafers that can be cut and processed into 100mm wafers.

Eta says that it places a strong emphasis on the importance of the crystal quality and lattice curvature. The typical rocking curve full-width half-maximum (FWHM) of the as-grown wafers is 50–60 arcsec for both the (002) and (102) reflections. The threading dislocation density has been measured as 1E6/cm^2 based on the cathodoluminescence (CL) of polished wafers. The lattice curvature is important as a measure of the offcut variation across the wafer. The center point offcut is specified at 0.35° toward the GaN m-direction, and that can be modified according to the customer's requirement. The lattice curvature radius is greater than 10m, with the target around 30m or larger.

The firm has developed its own polishing process for GaN, resulting in atomic force microscope (AFM) average roughness over 10μm images of <0.3nm. It has grown MOCVD GaN epilayers and device structures on the GaN wafers. The MOCVD-grown layers are said to show good surface morphology and have x-ray diffraction (XRD) rocking curve FWHMs similar to that of the substrate.

Currently, small quantities of 100mm GaN wafers are for sale, as well as 2" and 3" wafers. At the end of 2019, more HVPE capacity will be brought online in the new production factory located in Tongling, Anhui Province, China. The firm expects to be able to supply high-volume customers in the near future. Further, working with their epitaxial growth partners, Eta can offer GaN wafers with MOCVD epilayers for interested customers.

www.etaresearch.com

Start-up Diamond Microwave Ltd signs licensing agreement for GaN-based SSPAs

Diamond Microwave Ltd (DML) of Shipley, UK, a technology startup specializing in compact gallium nitride (GaN)-based solid-state power amplifiers (SSPAs) for application such as radar, communications and electronic warfare (EW), has signed a licensing deal with Diamond Microwave Devices Ltd (DMD) to continue to grow the commercial base for DMD's compact high-power microwave amplifiers, and to take DMD's proprietary technology into new markets.

"We are delighted to have formed this commercial partnership with DMD, and we look forward to focusing on the exploitation of the DMD amplifier technology in the global marketplace for high-power microwave systems," says Dr Richard Lang, a director and shareholder of DML (formerly the CEO of DMD).

www.diamondmic.com

Edwards holds official opening for new North America Semiconductor Technology Center in Hillsboro

UK-based semiconductor vacuum and abatement equipment maker Edwards Vacuum has held a grand opening for its new North America Semiconductor Technology Center at 6220 NE Century Boulevard in Hillsboro, OR, USA.

The eco-friendly 75,000ft^2 facility is located close to the firm's key accounts in the 'Silicon Forest', enabling Edwards to provide rapid service and support, customer training, and enhance its R&D and customer collaboration efforts. The approximately 200 attendees included Edwards' customers and suppliers, top management, and local political and industry dignitaries. Congresswoman Suzanne Bonamici and Hillsboro's Mayor Steve Callaway offered remarks.

"Not only is this new headquarters located close to some of our key accounts but this area, the 'Silicon Forest' and the greater Northwest, is an excellent place to recruit top-notch employees for engineering, R&D and manufacturing positions," comments Scott Balaguer, VP & general manager of Edwards' Semiconductor division North America.

"We are bringing high-volume manufacturing capability to North America to be closer to our customers and will be designing and building our integrated vacuum and abatement systems and other products here in Hillsboro, creating local jobs and contributing to the local economy in the process," he adds.

We are bringing high-volume manufacturing capability to North America to be closer to our customers

"Edwards strives to be an environmental leader, both within the local community and the semiconductor industry, by applying 'green' technology in our customers' fabs and within our own facilities," Balaguer continues. "The new building is designed to be highly energy efficient and employee friendly. It utilizes a high-performance heating, ventilation and air conditioning (HVAC) system and all LED lighting with advanced occupancy sensors... In addition, we plan to purchase power through a renewable program."

www.edwardsvacuum.com

kSA Emissometer for MOCVD wafer carrier characterization gains UV PL capabilities

k-Space Associates Inc of Dexter, MI, USA — which supplies in-situ, ex-situ and in-line metrology tools for the thin-film, semiconductor, photovoltaic (PV), solar, automotive, glass and building materials industries — says that the kSA Emissometer ex-situ metrology tool for metal-organic chemical vapor deposition (MOCVD) carrier characterization now has ultraviolet (UV) photoluminescence (PL) capabilities for even better carrier evaluation.

The new UV PL feature allows wafer carrier manufacturers, reactor manufacturers and epi houses to further evaluate their wafer carriers before use and throughout their lifecycle. The system uses a 365nm-wavelength LED focused on the wafer carrier and a filtered photodetector focused on the excitation point. The filter cuts off light for wavelengths shorter than 409nm. This results in the ability to evaluate contamination on the wafer carrier.

The kSA Emissometer is used to determine the quality of the carrier bake after the deposition run, quantitative determination of real surface emissivity for temperature set-point adjustments, and micro-crack detection. It also provides statistical analysis of each individual pocket and web for carrier quality evaluation.

"This tool gives carrier manufacturers, reactor manufacturers and epi houses a competitive edge because it allows them to quantify their carrier quality, ultimately leading to increased device uniformity and increased yield," says CEO Darryl Barlett.

www.k-space.com/products/ksa-emissometer

Picosun appoints CEO

Atomic layer deposition (ALD) thin-film coating technology firm Picosun Group of Espoo, Finland has appointed Jussi Rautee as its new chief executive officer, starting on 1 October.

The appointment continues the changes made at Picosun this year. In June Picosun received a significant investment from Finnish investors and expanded its ownership base by adding CapMan Growth, First Fellow Partners and Tesi (Finnish Industry Investment Ltd).

Current CEO Kustaa Poutiainen will continue as chairman of the board of Picosun Group, and Juhana Kostamo, managing director of Picosun Oy, will continue as deputy CEO of the Group.

"Picosun is growing fast all around the world, and our ALD technology finds constantly new markets and applications," says Poutiainen. "Jussi Rautee has strong experience in growth leadership in the realm of big, multi-national corporations," he adds.

Rautee holds an M.Sc. in Engineering from Finland's Tampere University of Technology. Previously, he worked in several senior leadership roles at ABB Group in Finland, Australia, USA and most recently in Poland, gaining a track record in executing growth strategies, leading large global operations and organizations, and developing people.

"It is great to join Picosun Group to take ALD to yet new application areas and industries," comments Rautee. "Together, we can further strengthen the company's position in the growing market," he adds.

www.picosun.com

Palo Alto Research Center opens new 'cleanroom as a service' facilities

Palo Alto Research Center (PARC, a Xerox company) of Palo Alto, CA, USA has opened new cleanroom facilities as an open innovation lab for use by corporate research departments, government agencies and start-up companies to develop prototype electronic devices and novel technologies quickly and cost-effectively.

The shared 'cleanroom-as-a-service' centre is designed to enable partners to develop and test new thin-film electronics and optoelectronic devices, providing end-to-end processes to design and fabricate a wide variety of active devices. This makes the PARC Cleanroom one of the few facilities worldwide that can prototype display and imaging thin-film transistor backplanes that are compatible with manufacturing facilities, it is claimed.

The PARC Cleanroom is equipped with a wide range of processing tools (e.g. for deposition, electroplating, etching, wafer bonding and

sputtering). In addition, PARC Cleanroom clients can draw on PARC's expertise in working with semiconductor thin-film materials including amorphous silicon, metal oxides, low-temperature polysilicon and microelectromechanical systems (MEMS).

"The new cleanroom gives PARC's partners a new-found ability to develop and test exciting products in the areas of printed organic semiconductors, flexible electronics, nanowire devices, and solar cells," says Bob Street, PARC senior research fellow & manager of the Printed Electronic Devices area.

"Many large technology manufacturers already have advanced cleanrooms in place, but very few facilities are readily available to those who need small- and medium-sized research and development capabilities to develop next-generation electronic devices," says Noble Johnson, PARC research fellow & manager of the Optoelectronic Materials and Devices area. "Using these advanced tools, our expert staff is poised to help clients with their prototype designs, simulation and fabrication."

In the field of optoelectronics, PARC specializes in the growth and processing of aluminium gallium indium nitride (AlGaInN) materials, using metal-organic chemical vapor deposition (MOCVD). Dedicated facilities at the PARC Cleanroom are also available for the fabrication of laser diodes and light-emitting diodes that operate in the visible and UV spectrums.

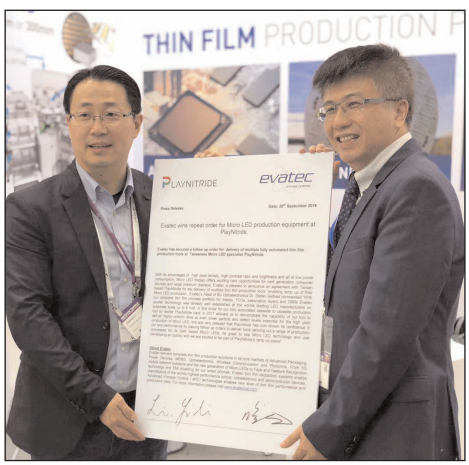
www.parc.com

Evatec wins repeat order for thin-film production equipment from micro-LED firm PlayNitride

Evatec AG of Trübbach, Switzerland (which makes thin-film production equipment for advanced packaging, power device, MEMS, optoelectronics, wireless communication and photonics applications) has secured a follow-up order for the delivery of multiple fully automated thin-film production tools to Taiwan-based micro-LED specialist PlayNitride Inc, enabling the ramp up of its gallium nitride (GaN)-based micro-LED production.

With their advantages of high pixel density, high contrast ratio and brightness (all at low power consumption), micro-LED displays offer new opportunities for next-generation consumer devices and large premium displays.

"With our complete thin-film



process portfolio for metals, transparent conductive oxides (TCOs), passivation layers and DBRs, Evatec sputter technology was already well established at the world's leading LED manufacturers on substrate sizes up to 8 inch," says Dr Stefan Seifried, head of Evatec's Optoelectronics business unit. "A first order for our fully automated cassette-to-cassette production tool by leader PlayNitride back in 2017 allowed us to demonstrate the capability of our tool to deliver highly uniform films at even lower particle and defect levels essential for the high-yield production of micro-LED," he adds. "Playnitride has now shown its confidence in our tool performance by placing follow-up orders to deliver tools carrying out a range of production processes for its GaN-based micro-LEDs. It is great to see micro-LED technology and use developing so quickly."

www.playnitride.com
www.evatecnet.com

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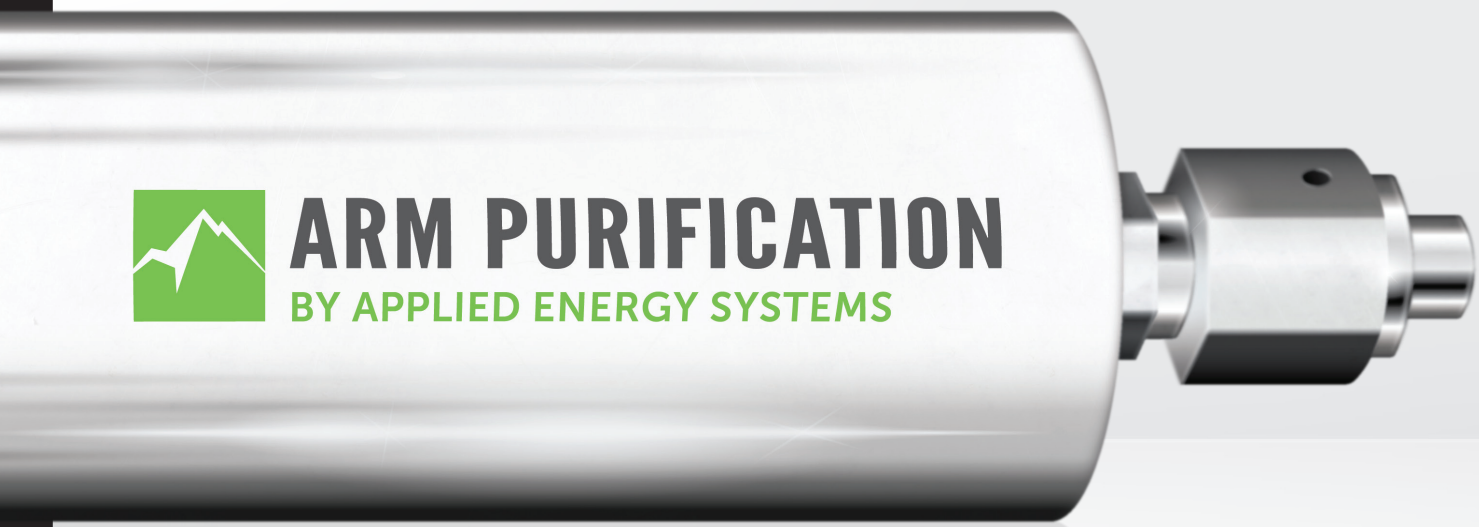

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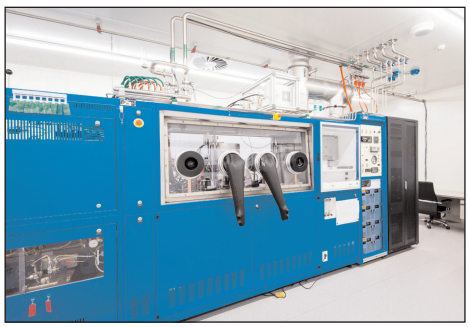
BluGlass–Bridgelux JDA to evaluate RPCVD and tunnel junction technologies for cascade LEDs for general lighting market

Foundry revenue to fund BluGlass' development work

BluGlass Ltd of Silverwater, Australia — which was spun off from the III-nitride department of Macquarie University in 2005 — has entered into a joint development agreement (JDA) with Bridgelux Inc of Fremont, CA, USA (a vertically integrated manufacturer of solid-state light sources for lighting applications) to build on BluGlass' remote-plasma chemical vapor deposition (RPCVD) tunnel-junction technology in order to develop cascade LEDs, establish a path for mainstream applications in the growing general lighting market.

For over 15 years, Bridgelux has designed and produced LED lighting solutions for the general lighting market that are said to be high performing, energy efficient, cost effective and easy to integrate. Its focus on technology development has yielded proprietary innovations in LED design and manufacturing processes that enable its products to accelerate the mass adoption of LED lighting.

BluGlass' unique RPCVD technology is a low-temperature, ammonia-free



process that is claimed to offer performance advantages for electronics manufacturers including higher-performing, lower-cost devices. The firm recently demonstrated patented 'active as grown' RPCVD tunnel junctions for LED wafers. It is reckoned that these tunnel junctions could solve the industry challenge of efficiency droop, by combining multiple LEDs in a single vertical LED stack, generating greater light output for less power.

The joint development program aims to integrate BluGlass and Bridgelux's technologies in high-performance commercial LED applications, and to ultimately drive commercial adoption of RPCVD-enabled cascade LEDs for general lighting through the future provision of RPCVD equipment and process licensing. The terms of the JDA are non-exclusive and will provide foundry revenue to BluGlass for its development work.

"Bridgelux is a leader in solid-state lighting innovation and is always working on developing new technologies for the LED lighting industry," says Bridgelux's CEO Tim Lester. "We look forward to exploring the potential of RPCVD with BluGlass," he adds.

"We are delighted to have Bridgelux as a development partner to help deliver the competitive advantages of RPCVD tunnel junctions into this important high-growth market," says BluGlass' CEO & managing director Giles Bourne. "Bridgelux is an innovative leader producing premium lighting to high-end markets around the globe. This commercial partnership marks an exciting milestone for BluGlass."

www.bridgelux.com
www.bluglass.com.au/brr

AquiSense's UV-C LED technology playing increasing role in aerospace projects

Nikkiso Group company AquiSense Technologies LLC of Erlanger, KY, USA (which designs and manufactures water, air and surface disinfection systems based on UV-C LEDs) says that it has participated in ten distinct aerospace projects. In 2015 the firm was selected to participate in BIOWYSE, a European Union Horizon 2020 project dedicated to designing and testing a water monitoring and treatment system for next-generation manned space stations. Since then, several other aerospace projects have sought water treatment technology from AquiSense, including product design and hardware supply to both private space companies (such as Bigelow Aerospace, Thales Alenia Space Italia, KBR Wyle, and Aero Sekur) and various NASA groups (including those at the Jet Propulsion Laboratory, Johnson Space Center, and Marshall Space Flight Center). These projects range from keeping growth systems clean in space-bound greenhouses, to decreasing the maintenance burden from nuisance biofilm formation in enclosed systems, to disinfecting the water that astronauts drink on the International Space Station (ISS).

"The driving factor for all of these projects is our leading knowledge of system design and the application of UV-C LEDs in unique environments," says Rich Simons Ph.D., product development scientist at AquiSense Technologies Europe. "These types of applications are exciting for us as they drive innovation for our technology and allow us to better understand the possibilities and limits of UV-C LED disinfection."

www.aquisense.com

Seoul Semiconductor sues Conrad over mobile-phone flashlight LEDs

South Korean LED manufacturer Seoul Semiconductor Co Ltd has filed a lawsuit in the District Court of Mannheim, Germany, alleging that LEDs for mobile-phone flashlights sold by European electronic products retailer Conrad Electronic S.E. are infringing its patent for 'Roughened Light Extraction Surface' technology, which efficiently extracts light emitted from the internal LED structure by treating LED chip surfaces, significantly improving light intensity and brightness (a fundamental technology for LED chip fabrication).

This litigation constitutes the second lawsuit against Conrad involving mobile phone products following a lawsuit filed in July for infringement regarding backlight LED units.

The patent has already been the subject of an injunction from a German court in December 2018 against LED products from a top-10 global LED maker. The patented technology has now been registered in 12 major countries, including the USA, Europe and Asia, and has been widely used for automobile headlamps, UV and outdoor lighting, as well as mobile phone flashlights.

Seoul says it has already warned global mobile-phone makers to cease using LED products suspected of infringement. The firm investigates mobile phones incorporating such products and will consider any legal enforcement necessary if such infringement continues unabated.

To protect its patent rights, Seoul has already filed three patent infringement lawsuits against distributors of suspected infringing products in Europe alone. It plans to expand its enforcement further, given the confirmation of its technology from the German courts, where Seoul has obtained permanent injunctions against infringement of their patents. Such patented technologies are widely applicable to high-power and mid-power LEDs, the firm adds.

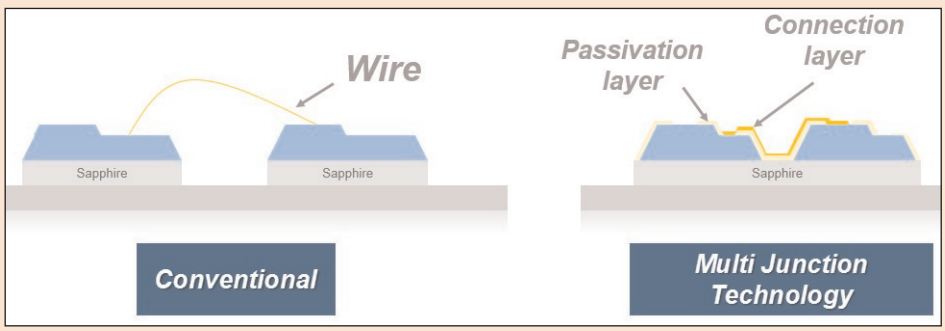
"Seoul will continue enforcement actions against manufacturers, distributors and end-brand companies that do not respect intellectual property," says Seoul's founder Chung Hoon Lee. "We will also take all necessary actions against companies that lure our employees away in an attempt to gain unlawful access to Seoul's trade secrets."

Seoul Semiconductor wins permanent injunction in USA against operator of 1000bulbs.com

South Korean LED manufacturer Seoul Semiconductor Co Ltd has won a patent infringement lawsuit against Service Lighting And Electrical Supplies Inc, an operator of 1000bulbs.com (the largest online light bulb distribution channel).

The Texas Northern District federal court issued a permanent injunction against the sales of more than 50 lighting products, as well as any colorable variations of those products unless they have been licensed, according to the parties' stipulation. The court will therefore prohibit the sale of similar products if they prove to be mere colorable variations of the accused products, says Seoul Semiconductor.

In the litigation, Seoul Semiconductor asserted 10 patented technologies significant for LED bulb components, such as a Multi-Wavelength Insulation Reflector which is widely used for '0.5W to 3W'-level mid-power LED packages, Multi Junction Technology for mounting and integrating many LEDs within a small area, LED Driver technology for current conversion and control, and LED packages with enhanced durability. In particular, Multi Junction Technology is essential for manufacturing 12V/18V high-voltage lighting products, and Seoul Semiconductor is the pioneer of this technology.



Recently, the German court also issued two permanent injunction judgments against the sale of products infringing Seoul's patents and also ordered the distributor to recall such products in December 2018 and August 2019, respectively.

"We hope that Seoul's success story based on significant R&D efforts could show a good example to young entrepreneurs and small businesses struggling to have their talents recognized in the market," comments Seoul Semiconductor's founder Chung Hoon Lee. "We will continue necessary actions against companies that we suspect of infringing our patents of unlawful access to our trade secrets by luring employees," he adds.

www.SeoulSemicon.com

Plessey produces record 2.5µm-pixel-pitch 4Megapixel GaN-on-Si micro-LED display

Using its propriety monolithic gallium nitride on silicon (GaN-on-Si) technology, UK-based Plessey, which develops embedded micro-LED technology for augmented-reality and mixed-reality (AR/MR) display applications, has produced a record 2.5µm-pixel-pitch micro-LED display.

The ultra-fine, ultra-high-resolution 2000x2000-pixel display uses micro-LEDs, a technology that is playing a critical role in the development of next-generation wearables, AR/VR hardware and heads-up displays (HUDs). They require about 20% of the power of typical LCOS (liquid crystal on silicon) or DLP (digital light processing) displays and can achieve five times brighter images than organic light-emitting diodes (OLEDs), allowing comfortable outdoor viewing.

"Pixel pitch is key to the physical size of large field displays and to the resolution of the viewed image," notes Clive Beech, senior director, business development. "These are key attributes in AR systems. The 2k2k display scale can be realised in a compact physical form factor and the 2.5µm pixel pitch achieves image features with smooth borders and fine detail," he adds. "An example of Plessey's latest scalable pixel architecture, these micro-LED display products will enable many new innovations and exciting applications in both augmented reality (AR) and mixed reality (MR) smart glasses."

The low thermal resistance of the silicon substrates allows highly efficient heat extraction, resulting in lower junction temperatures with high reliability, says Plessey. The GaN-on-Si technology also allows what is said to be high energy efficiency, high resolution and unsurpassed contrast. With its similarity to large-scale silicon IC processing, the technology can be scaled to progressively larger wafers, improving cost, uniformity and yield and taking advantage of the latest advances in silicon wafer processing tools of the volume IC industry.

Plessey says that other recent milestones in its monolithic micro-LED emissive display program include the development in March of native green GaN-on-Si LEDs that naturally emit blue light. May's SID Display Week 2019 event saw the world's first monolithic GaN-on-Si micro-LED emissive display with an 8µm pitch bonded to a backplane for a full active matrix.

Plessey notes that its ongoing micro-LED display development roadmap includes the production of a full RGB display all on one wafer by 2020's Consumer Electronics Show (CES).

www.plesseysemiconductors.com/products/microleds

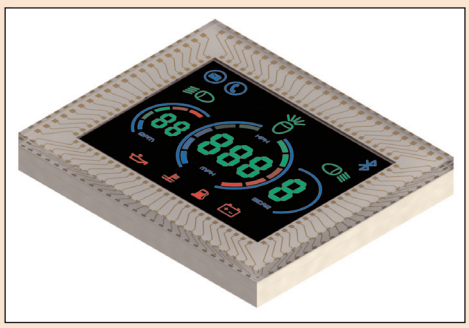
Plessey launches micro-LED direct-drive display platform

Plessey has introduced a micro-LED Direct-Drive display platform and development kit, based on its proprietary monolithic gallium nitride-on-silicon (GaN-on-Si) technology.

The Direct-Drive displays provide OEMs and product developers with a solution to either retrofit existing products or develop new concept designs, around a compact, flexible and highly efficient micro-LED display.

Direct-Drive displays target specialized applications that require symbolic content, instead of individually addressed pixelized content. Due to their small form factor, they can be easily integrated into smart glasses, and head-mounted displays for navigation, sport & leisure, and optical instruments.

The symbolic content is fully customizable using monochrome or fully colourized segments with pixel capabilities down to 2µm, allowing for ultra-fine, ultra-high-resolution detail. The display is self-emissive, and it can be driven directly from an external source, requiring no backplane (which simplifies the manufacturing process and improves power consumption).



The Direct-Drive development kit is a starter package designed to be a fast, easy and scalable platform, allowing developers to explore, evaluate and interact with small-form-factor micro-LED displays.

Direct-Drive will come ready to plug and play, and will include:

- Direct-Drive display (less than 5mm x 5mm);
- embedded driver with open-source firmware;
- the driver allows the die to be driven at a current of up to 2A;
- ATMEGA processor;
- rechargeable (USB) ultra-small battery;
- integrated Bluetooth connection;
- available protocols: I2C/UART/SDI/USB; and
- technical documentation to support integration.

"With a total input power of 250mW, Plessey's native-green segments can emit 2 million nits of brightness," notes optical engineering manager Dr Samir Mezouari. "For AR applications, the Direct-Drive displays can achieve a much higher brightness than OLED with a power consumption as low as 50mW, allowing daytime viewing and a longer battery life."

Lumileds launches high-efficacy LUXEON 3030 HE Plus mid-power LED for 3V indoor and outdoor lighting

Lumileds LLC of San Jose, CA, USA has launched the LUXEON 3030 HE Plus Mid Power LED, which offers what is claimed to be industry-leading luminous efficacy of 210lm/W (at a color temperature of 4000K, 80CRI) in a standard 3.0mm x 3.0mm package for 3V applications, including indoor troffers and panel lights, as well as outdoor area lights. As color control is an essential feature of these indoor applications, a four-quadrant color bin structure has been developed for the LUXEON 3030 HE Plus, which can offer 2 MacAdam ellipse by kitting.

LUXEON 3030 HE Plus LED.

"This new 3030 LED combines high efficiency and tight color control in one of our most cost-effective, proven surface-mount packages," says Mei Yi, product marketing manager of Mid Power products. Customers can design in the new LUXEON 3030 HE Plus based on the LUXEON 3030 product line's proven maturity in the market for many years, from both the performance and quality perspective, the firm adds.

The LUXEON 3030 HE Plus is available initially in correlated color temperatures (CCTs) of 4000K, 5000K, 5700K and 6500K with a color rendering index (CRI) of 80, and is nominally driven at a current of 65mA.

By the end of 2019 Lumileds will add warm color temperatures of 2700K, 3000K and 3500K (80CRI) to the product line.

www.lumileds.com/products/mid-power-leds/luxeon-3030-he-plus

Lumileds launches high-flux and -efficacy LUXEON 5050 Square light-emitting surface LED for directional lighting

Lumileds has unveiled the LUXEON 5050 Square LES (light-emitting surface) LED, a square, multi-die emitter that delivers what is claimed to be industry-leading flux and efficacy for directional lighting applications.

The new LED builds on the legacy of the LUXEON 5050 Round emitter for streetlights and downlights, while boosting flux by 25% and delivering what is claimed to be the highest efficacy of any 5050 package on the market. It is also said to outperform competing modules in corrosion resistance testing, enabling significantly lower flux degradation and less color shift when used in harsh environments.

"The LUXEON 5050's EMC (epoxy molding compound) package demonstrates corrosion resistance that is comparable to a ceramic package," says LUXEON 5050 product manager Mei Yi.

LUXEON 5050 Square LED (right), with the LUXEON 5050 Round LED.

"Standard industry testing in a sulfur environment also shows the LUXEON 5050 Square demonstrated significantly less flux loss and color shift than competing 5050 size emitters. This enables a much more robust design in the end application."

The brighter emitter in a standard 5050 footprint allows for drop-in replacement in existing systems or the design of new, robust fixtures with the highest flux and efficacy combinations. Typical flux of the LUXEON 5050 Square is 825lm at 170lm/W when a 5000K 70CRI emitter is driven nominally at 160mA. The efficacy translates to more efficient fixtures or the use of fewer emitters for a more compact design. Fixture size is further reduced by the low-thermal-resistance substrate (1.4°C/W), which reduces heat-sink requirements.

The LUXEON 5050 Square is initially offered in a color temperature range of 2200-6500K at a minimum color rendering index (CRI) of 70 in voltage options of 6V and 30V. The LUXEON 5050 Round is offered across the same range of color temperatures at 70CRI, 80CRI and 90CRI with 6V and 24V options. Lumileds has also just released a 2% upgrade to the LUXEON 5050 Round, further building on its flux and efficacy. All emitters are hot tested at 85°C to ensure performance under real-world conditions.

www.lumileds.com/products/high-power-leds/luxeon-5050

Osram developing 25,600-pixel second-generation Eviyos hybrid LED for smart headlights

About two years after unveiling the world's first hybrid LED for smart headlights (the first-generation Eviyos — featuring 1024 individually controllable pixels — to be launched at the beginning of 2020), Germany's Osram is developing the second generation of Eviyos, with 25,600 individually controllable pixels on a single chip with a footprint of just 40mm^2 (targeted for market launch in 2023). The individual light pixels are brought together to a pixel pitch of only 40µm, creating a particularly space-saving component for future multi-functional, intelligently controllable headlamps that can do more than just illuminate the road.

"With more than 25,000 individually controllable pixels, the second generation of Eviyos will bring HD-quality projections onto the road," says Wolfgang Lex, VP & general

manager Automotive at Osram Opto Semiconductors. "In the future, vehicles will be able to visually display warnings or symbols to vehicle occupants or other road users," he adds. "Car owners can also be greeted by a variety of welcome scenarios when approaching their vehicle thanks to this product." In addition to the high resolution, the second generation of Eviyos will offer advantages over comparable solutions, especially in terms of energy efficiency and space, reckons Osram.

An essential feature of the Eviyos family is that only the pixels that are needed are illuminated for a particular situation, so only the required energy is consumed (crucial, especially for electric vehicles). The second generation of Eviyos is currently under development, but it already shows how automotive lighting can change in the coming years, says Osram. They can fade out areas with unprecedented precision, while other areas shine in full light. This technology also opens the door to new fields of application beyond classic lighting. Depending on the application, customers will be able to combine several Eviyos with each other or other conventional LEDs.

www.osram-os.com

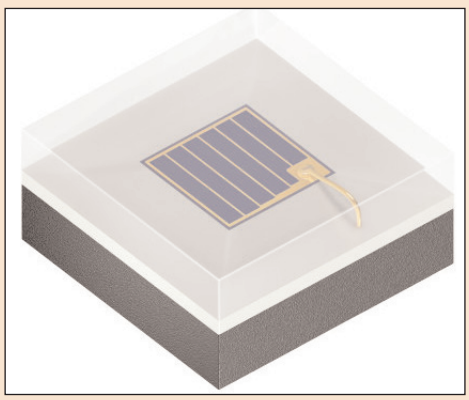
Osram launches IR LEDs for face recognition in smartwatches

Osram Germany has launched the SFH 4170S and SFH 4180S infrared light-emitting diodes (IREDs) to meet the demand for small biometric products.

Smartwatches are becoming increasingly popular and can do more and more. In contrast to smartphones, where the screen can't seem to be big enough, smart watches focus on being smaller in size. For manufacturers of mobile devices, the size of the individual components therefore plays a central role in the design of their products.

The particularly compact dimensions of the specially developed Oslon P1616 package (1.6mm x 1.6mm x 0.85mm) make the SFH 4170S and SFH 4180S IREDs the smallest Osram components for biometric applications, requiring about 50% less space than similar existing products.

Despite the small dimensions, the IREDs maintain an outstanding



power of 1150mW at 1A and a radiation intensity of 280mW/sr. These characteristics are particularly important for 2D face recognition. This identification method focuses on two-dimensional features of the user's face, e.g. the length of the bridge of the nose, the distance between the eyes or the distance from corner to corner of the mouth. To reliably compare the image stored in the system with the current picture, the infrared camera must be able to capture the best possible images, making homogeneous illumination of the face with an infrared light source a central aspect of this application.

Depending on where the IREDs are ultimately used, customers can choose between the 850nm (SFH 4170S) or the 940nm (SFH 4180S) version. While the SFH 4170S benefits from the very high sensitivity of the sensors in this wavelength range, the SFH 4180S avoids the 'red glow' effect, which can be seen by the human eye and is particularly unpopular in consumer applications.

"Biometric identification will become an increasingly important part of our lives in the future," says product manager Arne Fleißner. "With our two new IREDs, we are making space-saving integration into our customers' end devices much easier and are thus also helping to protect users' sensitive data."

www.osram.com

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

II-VI and LITE-ON partner on volume manufacturing & marketing of packaged lasers for mass-market LiDAR

First product to launch in mid 2020

Engineered materials and optoelectronic component maker II-VI Inc of Saxonburg, PA, USA has signed a strategic agreement with Taiwan-based optoelectronic component packaging firm LITE-ON Technology Corp to partner on volume manufacturing and commercialization of packaged lasers for mass-market light detection & ranging (LiDAR).

The rapid proliferation of LiDAR in automotive, commercial and industrial applications is driving demand for low-cost lasers that can be manufactured in very high volumes. II-VI and LITE-ON aim to leverage their respective high-volume manufacturing platforms for semiconductor lasers and optoelectronic packaging to jointly commercialize over time a broad portfolio of lasers spanning from near-infrared (NIR) to shortwave infrared (SWIR), with the first product to launch in mid 2020.

"II-VI is an established leader in highly reliable semiconductor laser diodes that serves a diverse range of end markets including communications, materials processing, aerospace & defense, life sciences and consumer electronics," comments Sander Su, associate VP, OPS SBG, LITE-ON Technology. "By leveraging our deep experience in low-cost packaging and high-volume manufacturing, as well as our sales channels in automotive, commercial and industrial markets, we will be able to meet the window of opportunity for high-volume LiDAR applications," he reckons.

"LITE-ON leverages its global manufacturing footprint and sales channels to ship billions of light-emitting diodes each year in automotive and consumer electronics, making them an ideal partner for II-VI," comments Dr Karlheinz Gulden, VP, Laser Devices & Systems business unit, II-VI Inc. "We look forward to develop the most vertically integrated LiDAR laser sources on the market, driving our competitive leadership in terms of performance and value."

II-VI's broad portfolio of products for LiDAR includes laser sources, filters, mirrors, lenses, windows and thermoelectric coolers. The firm showcased its portfolio of products for automotive applications at AutoSens 2019 in Brussels, Belgium (17–19 September).

www.ii-vi.com
www.liteon.com

DustPhotonics raises $25m Series B funding led by Intel

New investment to fund roadmap and expand operations and global market presence

DustPhotonics of Modi'in, Israel, which was founded in 2017 and develops and manufactures pluggable optical modules for data-center, enterprise and high-performance computing (HPC) connectivity, has announced a Series B investment of $25m led by Intel Capital and joined by WRVI Capital. This also includes a continued investment from veteran entrepreneur Avigdor Willenz. This latest round should help to fund DustPhotonics' roadmap and expand its operations and global market presence.

"Our optical transceiver products address the key and challenging requirements for hyperscale applications, and we will also leverage our electro-optic technology in high-density, future architectures," says CEO & co-founder Ben Rubovitch.

As data rates double with every successive generation, so does the complexity for meeting the demand of lower cost, lower power and higher reliability, notes DustPhotonics. Technology innovations, like AuraDP, provide a significant value differentiation enabling superior performance and sustainable 100, 400 and 800Gb/s products, claims the firm.

"High-speed optical connectivity is essential to enabling the performance and scale of today's data centers," comments Hong Hou, VP of the Data Center Group and general manager of the Silicon Photonics division at Intel. "The DustPhotonics products complement our leading optical transceiver portfolio through short-reach, standards-based interconnects based on VCSEL [vertical-cavity surface-emitting laser] technology," he adds.

This latest round should help to fund DustPhotonics' roadmap and expand its operations and global market presence

"DustPhotonics is uniquely positioned to address the ever-growing need for high-performance connectivity," comments WRVI Capital's founding managing partner Lip Bu Tan.

"The cloud is leading the entire communications industry and, as a result, the optical industry continues to grow as data centers, enterprises and 5G network operators invest to expand their fiber infrastructure," notes Dale Murray, principal analyst of LightCounting Market Research.

www.dustphotonics.com

II-VI completes Finisar acquisition

Compound Semiconductors and Photonic Solutions segments formed

After obtaining anti-trust clearance from China's State Administration for Market Regulation (SAMR) on 20 September, engineered materials and optoelectronic component maker II-VI Inc of Saxonburg, PA, USA has completed its acquisition (announced on 9 November 2018) of fiber-optic communications component and subsystem maker Finisar Corp of Sunnyvale, CA, USA.

Finisar shareholders will receive on average $15.60 in cash and 0.2218 shares of II-VI common stock per share of Finisar stock, depending on each shareholder's election.

The financing for the transaction was $1.9bn of cash raised in a combination of Term Loans A and B with a combined interest rate of L+251 and $1.1bn of the II-VI's stock. Finisar shareholders will own about 32% of the combined firm. II-VI expects to achieve $150m in run-rate synergies over the next three years.

"Our company is taking a giant leap forward in our scale to serve a significantly increasing addressable market," says II-VI's CEO Dr Vincent D. Mattera Jr. "The powerful combination of II-VI and Finisar makes us the global leader in optical communications and continues our leadership in our other key end-markets, with a world-class product portfolio and deep technology expertise that enables us to offer more tightly integrated solutions and exceptional overall value," he reckons.

"With nearly 80 years of combined business leadership in photonics and compound semiconductors, it makes sense for Finisar to join the II-VI family to continue to deliver the best products and solutions possible," comments Finisar's chief operating officer & co-CEO Todd Swanson. "II-VI and Finisar are ready to merge into one highly efficient and seamless company with a common culture, vision and mission."

Led by a proven leadership team drawn from the combined firm, II-VI's executive officers are: Dr Vincent D. Mattera Jr (CEO), Walter R. Bashaw II (president), Mary Jane Raymond (chief financial officer), Dr Giovanni Barbarossa (chief strategy officer, II-VI Inc and president, Compound Semiconductors), Jo Anne Schwendinger (chief legal & compliance officer, corporate secretary) and Dr Christopher Koeppen (chief technical officer). II-VI will continue to leverage a board consisting of executives from highly diverse industries.

II-VI will be organized into two segments:

- Compound Semiconductors, led by its president Dr Giovanni Barbarossa (II-VI's chief strategy officer) and
- Photonic Solutions, led by its president Sunny Sun.

The Compound Semiconductors segment is expected to be a market leader in differentiated materials and devices such as those based on gallium arsenide, indium phosphide, gallium nitride and silicon carbide, by independently driving investments that advance its technology roadmaps.

The Photonic Solutions segment leverages II-VI's compound semiconductor technology platforms to deliver components and subsystems that are differentiated based on knowledge of end-user applications for key end-markets.

II-VI now has a global workforce of over 25,000 in 70 locations worldwide.

www.finisar.com
www.ii-vi.com

II-VI launches 400mW micro-pump laser for high-temperature operation in next-generation coherent transceivers

II-VI Inc has launched its 400mW micro-pump laser for high-temperature operation.

Next-generation coherent transmission applications continue to demand amplifiers that can operate efficiently in space-, power- and thermally constrained environments. II-VI's single-mode uncooled micro-pump laser maintains a high output power of 400mW, with only 1W of power consumption, in environments where temperatures can reach 85°C.

"Last year, we nearly doubled the output power of our micro-pump lasers to 400mW, far ahead of the competition," says chief marketing officer Dr Sanjai Parthasarathi. "This product now provides both the most compact solution with the widest range of environmental performance in the market today, enabling our customers to significantly shrink the size and reduce the power consumption of transceiver-embedded amplifier designs, enabling new, highly compact transceivers operating at very high bit rates up to and beyond 1Tbps."

The micro-pumps are available with 80μm PM980 and 125μm HI 1060 single-mode fibers, which can achieve a very tight bend radius to match the micro-pump's small 10mm x 4.4mm package footprint.

II-VI exhibited at the European Conference on Optical Communication (ECOC 2019) in Dublin, Ireland (23–25 September), showcasing the most recent additions to its broad portfolio of differentiated solutions for optical networks. The product showcase included what is claimed to be one of the industry's broadest and most vertically integrated portfolios of products for ROADM line-cards and highly compact optical amplifier solutions tailored to enable high-bit-rate DWDM transceivers.

www.ecoc2019.org
www.ii-vi-photonics.com

Finisar presents optical communication solutions driving next-gen data centers & carrier networks at ECOC

At the European Conference on Optical Communication (ECOC 2019) in Dublin, Ireland (23–25 September), fiber-optic communications component and subsystem maker Finisar Corp of Sunnyvale, CA, USA introduced several new product and technology solutions, and demonstrating the latest form factors, laser technology and test equipment for high-speed connections in hyperscale data centers, 5G wireless networks, and optical test systems.

400GBASE-SR4.2 QSFP-DD transceivers for high-speed data centers

Finisar and Foxconn Interconnect Technology showcased what is claimed to be the first interoperability demonstration of 400G SR4.2 QSFP-DD optical transceivers. The IEEE-compliant transceivers use eight fibers and an MPO-12 optical connector, which provide a low-total-cost solution for 400G data-rate upgrades using the installed base of multimode cabling deployed for 100G SR4 in data centers today. The IEEE P802.3cm task force has made a baseline proposal for 400GBASE-SR4.2 which includes support for up to 70m on OM3 and 100m on OM4 multimode fiber, aligned with the 400G BiDi MSA. This is the second short-reach 400G multimode transceiver announced by Finisar, following the 400G SR8 OSFP module demonstrated at March's Optical Fiber Communication conference (OFC 2019) in San Diego.

100G PAM4 VCSEL technology for hyperscale data centers

Finisar unveiled what is claimed to be the first public technology demonstration of a multimode vertical-cavity surface-emitting laser (VCSEL) transmitting at 100G data rates using PAM4 modulation. This technology demonstration is reckoned to be a milestone towards product developments that can enable 800G short-reach optical modules and active optical cables (AOCs) needed for next-generation hyperscale data centers. Traditionally, multimode transceivers and AOCs that utilize VCSEL technology have offered the lowest cost for short-reach interconnect applications, a trend that is expected to continue with 800G+ products that are based on 100G PAM4 per lane. Attendees can observe the optical performance of the prototype VCSELs over multimode fiber using a high-speed scope.

5G wireless front-haul Ecosystem featuring tunable SFP28 transceivers

Finisar showcased various optical transceiver modules for 5G wireless front-haul networks. Driven by the anticipation of very large-volume deployments, wireless front-haul applications will require cost-efficient high-data-rate solutions. Such applications in 5G networks are expected to require primarily 25G data rates, and Finisar is already offering several products covering 300m, 2km and 10km reaches. For 10km, Finisar provides both duplex and bidirectional transceiver solutions to help customers with optical fiber constraints. For C-RAN applications, Finisar is demonstrating LAN-WDM and O-band CWDM solutions, which enable more efficient wireless front-haul networks with a minimum number of optical fibers.

As part of its 5G product offering, Finisar also demonstrated full C-band DWDM wavelength-tunable SFP28 modules operating at 25Gb/s over 15km of single-mode fiber. These transceivers are said to provide significant advantages over fixed-wavelength solutions for carriers upgrading their networks to the latest wireless standards. Leveraging DWDM technology allows more efficient use of the limited installed fiber in the front-haul network. Finisar's wavelength-tunable SFP28 transceivers also provide operational efficiencies and savings over fixed-wavelength products. These products will be available with Finisar's patented Flextune wavelength self-tuning functionality.

Finisar and Foxconn Interconnect Technology showcased what is claimed to be the first interoperability demonstration of 400G SR4.2 QSFP-DD optical transceivers

WaveAnalyzer 1500S high-resolution optical spectrum analyzer

The WaveAnalyzer 1500S demonstrates high-speed and high-resolution measurements on optical signals for L-band of telecoms, including OSNR and WDM analysis. This instrument has been designed to support developers of next-generation optical systems. In addition, the WaveAnalyzer 200A portable optical spectrum analyzer will demonstrate spectral measurements in a compact, portable, battery-operated platform. This instrument supports troubleshooting in data-center interconnects as well as mobile measurements in a lab environment.

Finisar IC-TROSA Type-2 demonstration

In the booth of the Optical Internetworking Forum (OIF), Finisar participated in a demonstration highlighting the progress of the OIF's 400ZR and IC-TROSA (transmitter receiver optical subassembly) projects, which aim to reduce the size, cost and power dissipation of 400G coherent optics. Finisar is providing an IC-TROSA Type-2, containing all the optical building blocks for a coherent module in a single miniaturized package. The demonstration highlights key aspects of IC-TROSA integration.

www.oiforum.com
www.ecoc2019.org
www.finisar.com

Mellanox launches LinkX 200G & 400G cables & transceivers at CIOE and ECOC

Mellanox Technologies Ltd of Sunnyvale, CA, USA and Yokneam, Israel (a supplier of end-to-end Ethernet and InfiniBand interconnect solutions for servers, storage systems and hyper-converged infrastructure) has announced new 400G DR4 500m transceivers and 400G direct attach copper (DAC) splitters and 100G SFP-DD DAC cables for server/storage interconnects. In addition, new 200G 'active' DAC cables for HDR InfiniBand and 200GbE Ethernet were introduced to extend copper cable reach up to 4m. Lastly, new QSA56 port adapters enable single-channel SFP cables and transceivers to be connected to 200G switch or network adapter ports. QSA56 supports cables and transceivers from 0.5m to 10km.

Mellanox demonstrated these LinkX products and showcased the full line of 100/200/400G cables and transceivers at the China International Optoelectronic Expo (CIOE 2019) in Shenzhen, China (4 September) and at the European Conference on Optical Communications (ECOC 2019) in Dublin, Ireland (21 September).

"We've had tremendous adoption of our full line of LinkX 25/50/100G cables and transceivers with web-scale, cloud computing, and OEM customers in China and worldwide," says Steen Gundersen, vice president LinkX interconnects, Mellanox. "We are just at the beginning of the transition to 200G, and 400G will soon follow. Customers select Mellanox because of our expertise in high-speed interconnects, our capacity to ship in volume, and the high quality of our products," he adds.

All Mellanox cables and transceivers are designed for very low bit error ratios (BER) of 1E–15 (about 1000 times better than the IEEE industry standard). Error-free connectivity for both Ethernet and InfiniBand is particularly important for latency-sensitive applications such as high-performance computing (HPC) networking, storage, artificial intelligence and hyperscale computing.

At ECOC, together with Ixia (A Keysight Business) using its A400GE-QDD test system and Mellanox 400G DR4 and 200G SR4 transceivers, a live demonstration exhibited better than IEEE-specified FEC (forward error correction) error density and BER performance.

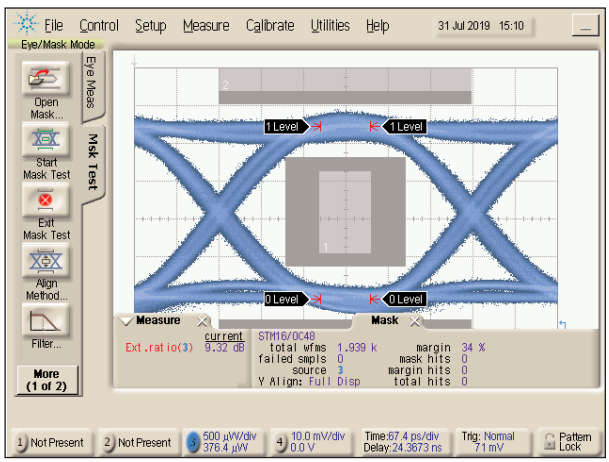
"Ixia is pleased to continue working closely with Mellanox for ECOC live demonstration of interconnect solutions such as 400G DR4 QSFP-DD and 200G QSFP56 products," says Nelson Murga, senior systems architect at Ixia Solutions Group, Keysight Technologies. "Using both Ethernet and PRBS signals over Mellanox's interconnects with our test system validates performance that exceeds the requirements of the 400GbE and 200GbE standards."

www.mellanox.com

CST Global reports eye-diagram performance of XG-PON 1270nm 2.5G lasers up to 85°C

III-V optoelectronic foundry Compound Semiconductor Technologies Global Ltd (CST Global) of Glasgow, Scotland, UK (a subsidiary of Sweden's Sivers IMA Holdings AB) says that samples of its 1270nm 2.5Gb/s lasers have shown outstanding eye-diagram performance, with eye mask margins of 34% and extinction ratios up to 9.3dB.

Significantly, the lasers performed over and above the requirements of the ITU-G.987 specification for XG-PON (10 Gigabit-capable passive optical networks) at temperatures up to 85°C and have exceeded 2000 hours in accelerated life testing. Designed for the global fiber-to-the-home (FTTH) market - which is rising at a compound annual growth rate (CAGR) exceeding 7%, from $7.3bn in 2019 — the lasers are available in TO-can and die-on-tape formats.



"Our next-generation XG-PON 1270nm 2.5G lasers address the worldwide FTTH market," says Euan Livingston, vice president of sales & marketing at CST Global, who attended the China International Optoelectronic Exposition (CIOE 2019) in Shenzhen, China (4–7 September). "We are seeing increased demand in this market, especially in China, where the strong preference for UK-sourced materials gives us a unique position as a supplier," he reckons. "The TO-can and die-on-tape formats provide our customers with flexibility in both their design cycle testing and in meeting production demands in 2019 and beyond."

www.compoundsemi.co.uk

Open Eye Consortium members get 53Gbps-per-lane single-mode spec for fully analog PAM-4 data centers

MSA consortium expands to nine new contributing members

The Open Eye Consortium multi-source agreement (Open Eye MSA) has announced the availability of its 53Gbps-per-lane single-mode specification to its members, which defines the requirements for fully analog PAM-4 solutions for 50G SFP, 100G DSFP, 100G SFP-DD, 200G QSFP and 400G QSFP-DD and OSFP single-mode modules.

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

Multi-vendor interoperability demonstrations of products based on the new specification were showcased at the China International Opto-electronic Exposition (CIOE 2019) in Shenzhen, China (4–7 September) and at the European Conference on Optical Communications (ECOC) in Dublin, Ireland (22–26 September). Further, the Open Eye MSA has already begun work on defining the multi-mode specification, targeted for release in Spring 2020.

The Open Eye MSA extends membership to Anritsu, Dust Photonics, Fujitsu Optical Components, HG, Inopticals, Marvell, MultiLane, SAMTEC, and Tektronix.

MACOM and Semtech Corp initiated the formation of the Open Eye MSA with 28 current members in Promoter and Contributing membership classes.

Promoters include: Applied Opto-electronics Inc, Cambridge Industries Group (CIG), Juniper Networks, Luxshare-ICT, MACOM, Mellanox, Molex, and Semtech Corp.

Contributors include: Anritsu, Accelink, Cloud Light Technology, ColorChip, Dust Photonics, Fujitsu Optical Components, HG, InnoLight, Inopticals, Keysight Technologies, Marvell, Maxim Integrated, MultiLane, O-Net, Optomind, SAMTEC, Source Photonics, Sumitomo Electric and Tektronix.

www.openeye-msa.org

CIG launches 400G, 200G and 100G modules for data-center applications

At the European Conference on Optical Communication (ECOC 2019) in Dublin, Ireland (23–25 September), Shanghai-based Cambridge Industries Group (CIG, a ODM/JDM/OEM supplier for the ICT industry) has announced a full line-up of 400G, 200G and 100G optical modules for data-center applications. The product line consists of the following:

- 400G QSFP56-DD FR4/LR4 and DR4;
- 200G QSFP56-FR4, both digital (DSP) and analog (CDR) versions; and
- next-generation 100G QSFP28-DR1/FR1/LR1, CWDM4, LR4.

"Adding a full line of 400G, 200G and 100G optical modules into our product offering reaffirms our commitment to bring innovative high-quality, low-cost and low-power technologies into the industry," says CEO Gerry Wong. "Specifically, CIG was one of the first companies to introduce 400G QSFP56-DD FR4 modules into the market. Earlier this year, CIG announced the world's first 200G analog CDR-based optical module for data-center interconnect application which, together with our large-scale, high-quality automated manufacturing capabilities, allows CIG to quickly meet the needs of the telecom and datacom markets," he adds.

"Sales of next-generation Ethernet transceivers are on track to exceed $200m in 2019 and reach $4bn by 2024," notes Vladimir Kozlov Ph.D., founder & CEO of LightCounting Market Research. "Our market forecast report assumes that suppliers will be able to scale up production volumes and reduce cost to enable rapid adoption of next-generation Ethernet transceivers."

CIG says that it is applying its expertise in optical module design and manufacturing to 400G and 100G products and the new 200G modules targeted for data-center applications. PAMSoft, a suite of firmware and software developed by CIG, was able to extend the reach of 200G FR4 modules' PAM-4 signals from 2km to more than 10km. PAMSoft also provides an end-to-end manufacturing platform enabling one-click automated operation to tune, test and calibrate the modules, thus shortening the manufacturing time 10-fold.

CIG's 400G FR4, 100G single-wavelength (100G DR1 and FR1) and legacy 100G (100G LR4 and CWDM4) modules are generally available. 400G DR4 modules will be available in fourth-quarter 2019. 200G FR4 modules based on analog CDR or DSP are under development and expected to sample in early Q4/2019. General availability is expected in late fourth-quarter 2019.

www.ecoc2019.org
www.cigtech.com

CIG demos first 200G FR4 optical module for data-center interconnect market, fully compliant with Open Eye MSA

At China International Optoelectronic Exposition (CIOE 2019) in Shenzhen, China (4–7 September), Shanghai-based Cambridge Industries Group (CIG, a ODM/JDM/EMS supplier for the ICT industry) gave a live demonstration of a complete, first-ever, 200G FR4 optical module. The module is fully compliant with Open Eye MSA specifications and interoperable with multiple vendors' products including digital signal processor (DSP)-based 200G optical modules.

"This live demonstration of our new analog CDR [clock & data recovery]-based 200G FR4 module, in addition to our DSP-based modules, reaffirms our commitment to bring low-cost and low-power technologies to the industry," says CEO Gerry Wong. "CIG is the first in the world to introduce this product into the data-center interconnect market and, together with our large-scale, high-quality automated manufacturing capabilities, we are capable of quickly meeting the needs of the DCI market," he claims.

The module adopts the 50Gbps PAM-4 format and advanced technologies in analog CDR chipsets. This enables lower cost, lower power and lower latency compared with DSP-based modules, the firm says. Low latency is especially important because mission-critical applications such as real-time application or high-frequency trading require very low-latency transmission.

CIG says it is applying its expertise in optical module design and manufacturing for 25Gbps, 100Gbps and 400Gbps products into the new 200Gbps modules targeted for data-center applications. The product is in the early sampling stage, for general availability in early 2020.

www.cigtech.com
www.openeye-msa.org

MACOM demos Open Eye MSA-compliant analog chipset

At the China International Optoelectronic Exposition (CIOE 2019) in Shenzhen, China (4–7 September), MACOM Technology Solutions Inc of Lowell, MA, USA gave a live demonstration of a complete 200G optical module solution designed in collaboration with an industry-leading optical manufacturer, leveraging MACOM's Open Eye MSA-compliant analog chipset. The chipset is optimized for volume-scale use in high-density cloud data-center links.

Targeted for faster, power-efficient and lower-cost optical interconnects, the chipset aims to provide a clear pathway to 200G throughput speeds utilizing industry leading analog components. MACOM's fully analog transmit & receive chipset consists of the MAOM-38053 four-channel transmit CDR with integrated laser driver and, on the receive side, features MACOM BSP56B photodetectors, a MATA-03819 quad TIA and the MASC-38040 four-channel receive CDR.

MACOM is applying its expertise in 25Gbps and 100Gbps solutions to 50Gbps PAM-4 applications and specifically to 200G QSFP and 2 x 200G OSFP/QSFP-DD modules to bring the benefits of low-power and low-latency solutions in addition to existing digital signal processing (DSP) architectures, to cloud data centers.

All of these MACOM analog chipset products are Open Eye MSA-compliant and interoperable with multiple vendors. The chipset is sampling to customers now and can be utilized for both single-mode and multi-mode fiber applications.

www.macom.com

High-speed analog PON and 100G data-center components at CIOE

At the China International Optoelectronic Exposition (CIOE 2019) in Shenzhen (4–7 September), MACOM explained how its portfolio of optoelectronic and photonic components is enabling high bandwidth and low latency, addressing the high-performance analog interfaces between electrical and optical domains, and providing solutions aimed at meeting the demanding size, power and signal integrity requirements of high-speed next-generation PON, wireless and wireline telecoms, and cloud data-center networks.

The portfolio includes high-performance modulator drivers, transimpedance amplifiers (TIAs), clock/data recovery circuits (CDR), crosspoint switches, avalanche photodiodes (APDs), PIN photodiodes, Fabry–Perot (FP) and distributed feedback (DFB) lasers, mixed-signal PHYs and PAM-4 for enterprise and telecom optical systems operating up to 100/200/400Gbps and beyond.

Specifically, at CIOE, MACOM highlighted the following:

- PON components: 10/25Gbps-PON ONU/OLT;
- Telecom portfolio: 25Gbps CDR, TIA and driver portfolios, 25Gbps FP lasers, APD photodiodes and 50Gbps PAM-4 chipset;
- Data-center components: 100Gbps CWDM4, DR1/FR1/LR1 and 100/200/400Gbps PAM-4; and
- Long-haul and metro components: 64GBaud driver and TIA.

www.cioe.cn/en

CIG expands 5G wireless product range for front-haul, mid-haul and back-haul applications

At China International Optoelectronic Exposition (CIOE 2019) in Shenzhen, China (4–7 September), Shanghai-based Cambridge Industries Group (CIG, a ODM/JDM/EMS supplier for the ICT industry) announced a full suite of products for 5G wireless front-haul, mid-haul and back-haul applications, and a live demonstration of its 25G SFP28 ER 40km product.

Next-generation 5G wireless networks require transmission speeds of 10–25G; reaches spanning 300m, 10km, 20km and 40km; operation temperatures up to the industrial temperature range; and BiDi or CWDM products for markets where fiber is scarce.

The new suite of products includes:

- 25G SFP28 I-temp 300m, LR/10km, 20km, ER/40km;
- 25G SFP28 BiDi I-temp 10km, 20km, 40km; and
- 25G SFP28 CWDM I-temp 10km.

"CIG is dedicated to meet the needs of 5G wireless markets with our full suite of 5G products," says Rose Hu, senior VP, marketing. "With our packaging technologies for the uncooled directly modulated lasers (DML), we strive to quickly bring low-cost, low-power and high-reliability optical transceiver modules to the markets to serve our 5G wireless customers," she adds.

"5G is one of the key large infrastructure programs in China, where it is seen as critical for boosting economic growth," comments John Lively, senior principal analyst, LightCounting Market Research. "Wide deployment of 5G will be a game changer, enabling many new applications and services," he adds. "CIG has addressed the optical transceiver needs of the 5G wireless network with the development of its 25G I-temp devices."

www.cioe.cn/en
www.cigtech.com

Skorpios demos 400G CWDM8 transceiver at ECOC

At the European Conference on Optical Communication (ECOC 2019) in Dublin, Ireland (23–25 September), Skorpios Technologies Inc of Albuquerque, NM, USA (which provides integrated silicon photonics products based on proprietary, wafer-scale heterogeneous integration process) is demonstrating its 400G CWDM8 transceiver product, as well as providing an update on its 100G CWDM4 QSFP28 product and unveiling its new product roadmap (which includes FR4/FR8 and ZR products).

Skorpios says that the 400G CWDM8 transceiver further demonstrates the disruptive nature of its heterogenous photonic integrated circuit (HPIC) technology platform:

- **Integration**: demonstrates what is claimed to be the first heterogeneously integrated (III–V and silicon) 400G Tx device with 8 lasers, 8 modulators, in a 3mm x 5mm package.
- **Scalability**: The Tx device has two lasers implemented on each of four pieces of III-V material, demonstrating how the HPIC technology platform can easily scale to massively higher bandwidths.
- **Bandwidth and performance**: Skorpios' HPIC III–V EAM modulators are capable of 50G NRZ and PAM4-based optical transmissions using the same architecture and are easily upgradeable to 100G per wavelength.
- **Platform flexibility**: Proves Skorpios has the technology platform capable of delivering highly integrated optical engines and modules to the market, including 400G CWDM8, 400G FR4, 400G ZR and more.

Skorpios says that it continues to make significant progress with its 100G CWDM4 QSFP28 module. The firm has completed over 2000 hours of successful reliability testing and is in system qualification with tier-1 switch vendors. Skorpios is accepting purchase orders for its 100G product at what is said to be differentiated pricing enabled by its unique technology platform.

Skorpios also provided an update to its new product roadmap, which features 400G FR4, 800G FR4x2, 800G FR8, 400ZR and 800ZR products. The firm plans to ship 400G FR4 modules in first-quarter 2020 and to sample 800G FR8 modules in fourth-quarter 2020.

"Our 400G demo and shipment of our 100G product underscore the power, scalability and disruptive nature of Skorpios' HIPIC technology platform," reckons James Czilli, VP of engineering.

www.ecoc2019.org
www.skorpiosinc.com

Lumentum showcases portfolio at ECOC

Lumentum Holdings Inc of Milpitas, CA, USA presented its full spectrum of optical communications solutions at the European Conference on Optical Communications (ECOC 2019) in Dublin, Ireland (23–25 September).

Coherent network transmission

Leveraging its highly integrated indium phosphide (InP) photonic integrated circuit (PIC) technology, Lumentum provides scalable and flexible coherent optical network solutions that enable higher speeds for next-generation mobile backhaul, data-center interconnect (DCI), metro/regional, and long-haul networks.

- Line-side coherent CFP2 modules for 100G/200G+ transmission: Lumentum is exhibiting both 100G/200G CFP2-ACO and CFP2-DCO coherent pluggable transceiver modules that leverage the firm's experience in high-speed InP PICs.
- Coherent building blocks: High-speed coherent components for 100G and beyond including integrated coherent TROSAs (transmitter-receiver optical sub-assemblies) with up to 64GBaud symbol rates, high-bandwidth integrated driver modulators, and micro and dual ITLAs (integrable tunable laser assemblies).
- Line-side direct-detect modules for 10G/25G tunable transmission: With more than 10 years of deployments and billions of device hours in the field, Lumentum is established in tunable transmission for 10G and beyond. A broad range of tunable transmission products is on display.

TrueFlex ROADM portfolio

Lumentum efficiently and cost-effectively enables the implementation of next-generation colorless, directionless, contentionless (CDC) reconfigurable optical add/drop multiplexer (ROADM) solutions which support continuously increasing optical network capacity needs. The firm's TrueFlex ROADM portfolio is said to provide improved performance, lower total cost of ownership, and future proofing of networks against evolving network patterns.

- Next-generation TrueFlex contentionless twin 8x24 wavelength-selective switch (WSS): A winner in the Optical Subsystems category in 2019 by Lightwave Innovation Reviews and the newest addition to the ROADM portfolio, it enables simplified add/drop port scaling to support capacity growth in CDC networks and eliminates the need for erbium-doped fiber amplifier (EDFA) arrays in many network designs.

Also, Lumentum is featuring the TrueFlex monitoring portfolio and the TrueFlex Micro WSS platform including the high-port-count Micro Twin 1x20 and 1x35, the Micro 1x9, Micro Twin 1x9, and the Nano 1x9.

High-speed datacom laser chips

Lumentum showcased its portfolio of datacom laser chips, available at scale to address growing market demands. Chip products include directly modulated lasers (DMLs), electro-absorptively modulated lasers (EMLs) and vertical-cavity surface-emitting lasers (VCSELs) that enable next-generation hyper-scale data centers, 5G wireless networks, and client-side access solutions.

- DMLs: High reliability and a pioneering cavity design allow operation over the wide temperature ranges demanded by the latest 5G wireless systems.
- EMLs: PAM4-optimized EMLs enable next-generation 400G and single-lambda 100G solutions that reduce the cost per bit. The firm's laser chips enable a wide variety of standards-compliant modules for high-speed networking.
- VCSELs: Lumentum VCSELs for short-reach applications utilize the firm's experience in high-volume 3D sensing applications to deliver high-performance and cost-effective solutions to data centers and can be supplied as a single bare die, or 1x4 arrays.

Telecom pump lasers

Lumentum displayed its latest 980nm single-mode pump lasers that enable increased output power, density and efficiency, and reduced footprint and power consumption in optical amplification applications. Also on display were the latest Raman pump lasers.

- Next-generation high-power and high-reliability 980nm pump lasers: The latest 980nm pumps offer a range of maximum output powers of 800–1000mW in a variety of form factors.

SDN open networking platform

Lumentum highlighted its SDN platform, consisting of network-ready optical hardware that can rapidly accelerate time-to-market for applications such as mobile backhaul, data-center interconnects (DCI), open line systems, and ROADM mesh-networking. Configurable SDN elements on display included 8x24 and 16x24 add/drop CDC ROADMs and optical fiber monitoring solutions.

Open and disaggregated transport network live demonstration

The Open Networking Foundation (ONF) performed a live open and disaggregated transport network (ODTN) demonstration using Lumentum's optical network elements. The live demo showcased use of the ONOS SDN controller for disaggregated transport networks, covering the provisioning of data connectivity services and demonstrating advanced automatic failure recovery and resiliency, at both the data and control-plane level.

- 'Reliable optical networks with ODTN, resiliency and failover in data plane and control plane'.

Workshop presentations

Speaking engagements addressed industry trends including the rapid growth of next-generation ROADM networks and advances in InP-based source lasers for high-speed fiber-optic applications.

- 'The Many Reasons for Today's Growth of ROADM Networks', by chief technology officer Brandon Collings;
- 'High-speed InP Devices', by Kazuhiko Naoe, director, Device Development Center.

www.lumentum.com

Source Photonics launches portfolio of 50Gb/s optical transceivers for 5G mid-haul applications

Source Photonics Inc of West Hills, CA, USA (which provides optical connectivity products for data centers, metro and access networks) has announced a comprehensive portfolio of 50Gb/s products serving 5G mid-haul applications.

The firm product portfolio leverages 30 years of high-speed optical transceiver development and high-volume shipments into wireless, data-center and routing applications, resulting in a broad portfolio of optical transceivers supporting data rates ranging from 125Mb/s to 400Gb/s and transmitting between 300m and 40km.

Source Photonics has leveraged early investments in signal integrity, firmware development and uncooled high-speed directly modulated laser (DML) packaging to release what is claimed to be the industry's broadest 50G product portfolio.

Selected as the mid-haul data rate, 50Gb/s provides mid-haul bandwidth requirements not supported by 25Gb/s while also offering meaningful economic advantages over traditional 100Gb/s transceivers. Furthermore, 50Gb/s data-rate products support bi-directional applications, where fiber availability is scarce. Bi-directional capability is not yet available on multi-channel 100Gb/s products.

"We are pleased to announce a comprehensive portfolio of 50Gb/s products, which includes 50G QSFP28 LR & ER and 50G BiDi QSFP28 LR & ER to support 5G mid-haul applications," says Dr Supriyo Dey, senior director of product line management (PLM). "This shows our commitment to support our customers with the growing demand for 50Gb/s products to enable the 5G ramp," he adds.

Source Photonics has leveraged early investments in signal integrity, firmware development and uncooled high-speed directly modulated laser (DML) packaging to release what is claimed to be the industry's broadest 50G product portfolio

Source Photonics' portfolio of 5G mid-haul transceivers includes:

- 50G QSFP28 LR supporting 50GE link up to 10km on duplex single-mode fiber;
- 50G QSFP28 ER supporting 50GE link up to 40km on duplex single-mode fiber;
- 50G BiDi QSFP28 LR supporting 50GE link up to 10km on simplex single-mode fiber; and
- 50G BiDi QSFP28 ER supporting 50GE link up to 40km on simplex single-mode fiber.

Source Photonics gave a live demonstration of the 50G BiDi QSFP28 ER over 40km fiber at the European Conference on Optical Communication (ECOC 2019) in Dublin, Ireland (23–25 September).

www.sourcephotonics.com
www.ecoc2019.org

Source Photonics demos full 400G product portfolio at ECOC

Source Photonics demonstrated its complete 400G portfolio with industry partners at the European Conference on Optical Communication (ECOC 2019) in Dublin, Ireland (23–25 September).

Source Photonics has supplemented its portfolio of single-mode products for data-center and routing applications by adding a wide range of new products leveraging its multi-year investment in 28Gbaud and 53Gbaud PAM4 (4-level pulse amplitude modulation) technology and supporting 400G applications for reaches from 500m up to 40km in small-form-factor transceivers.

Source Photonics' portfolio of data-center and routing products includes:

- 400G-DR4 supporting 400GE links over 500m as well as an enhanced reach of up to 2km (4x100G-FR) with support for breakout into 100G-DR/FR;
- 400G-LR8 supporting 400GE links up to 10km; and
- 400G-ER8 supporting 400GE links up to 40km as a technology demonstration.

"Successful interoperability between optical transceivers and hosts is crucial to rolling out the next higher-data-rate connectivity," says Ed Ulrichs, director of product line management (PLM). "Together with our partners in the industry, we aim to bring next-generation solutions to our customers and provide the high-speed connectivity they require."

Successful interoperability between optical transceivers and hosts is crucial to rolling out the next higher-data-rate connectivity

Source Photonics also demonstrated error-free traffic through a link involving Viavi's ONT 603 unit and QCT's QuantaMesh BMS T9032-IX9 switch connected with various Source Photonics 400G optical transceivers.

Source Photonics gave live traffic demonstrations of its latest 400G optical transceivers at ECOC.

The firm is accepting orders now for production shipments.

www.ecoc2019.org

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QSFP-DD800 MSA formed to boost pluggable transceiver speeds to 800Gbps

Backward compatibility with QSFP-DD, QSFP28 and QSFP+ modules and cables to address demands of 25.6Tb/s-scale systems supporting dense 100GbE or 400GbE interfaces

Several industry leaders have announced a new QSFP-DD800 Multi-Source Agreement (MSA) Group to advance the development of high-speed, double-density quad small-form-factor pluggable (QSFP-DD800) modules to support 800Gbps connectivity. The MSA group will help to address the increased global bandwidth consumption by enabling very high-bandwidth interfaces.

The MSA founder-promoters include Broadcom, Cisco, Finisar, Intel, Juniper Networks, Marvell, Molex and Samtec.

The new QSFP-DD800 interface expands on the QSFP-DD, a pluggable form factor with an eight-lane electrical interface widely adopted by the latest Ethernet switches. This MSA will enable QSFP-DD800's eight electrical lanes to operate at 100Gbps each, by providing technical solutions for 800Gbps module and connector systems. It will also define a module, connector, stacked connector and a hybrid connector that is a BiPass/Flyover variant that can eliminate the signal losses on a traditional PCB. The primary objective of the MSA Group is to define the specifications and promote industry adoption of the QSFP-DD800. The new QSFP-DD800 specification is intended to be backward compatible with QSFP-DD, QSFP28 and QSFP+ modules and cables in order to address the upcoming industry demands of 25.6Tb/s-scale systems supporting dense 100GbE or dense 400GbE interfaces.

"Through continued strategic collaborations with our MSA promoters, we are developing the physical specifications that will enable the interoperability of optical transceiver modules, connectors, cages and DAC cables from multiple vendors to assure a robust ecosystem," says Scott Sommers, founding member & MSA co-chair.

"Leveraging the technical innovations from QSFP-DD, the time is right to collaborate with our MSA partners to lay the foundations for the next-generation systems and modules," says fellow founding member & MSA co-chair Mark Nowell. "The QSFP-DD form factor continues to be the cornerstone for the next step in pluggable module performance and density, while extending the industry's investment, experience, cost structure and backward compatibility from prior generations."

Many MSA members demonstrated 400Gbps QSFP-DD products at the European Conference on Optical Communication (ECOC 2019) in Dublin, Ireland (23–25 September).

www.qsfp-dd800.com
www.ecoc2019.org

SFP-DD MSA releases first management interface spec

The Small Form Factor Pluggable Double Density (SFP-DD) Multi Source Agreement (MSA) Group is has released its first management interface specification (MIS). The SFP-DD MIS may be used by 2-lane pluggable modules with host to module management communication based on a two-wire interface (TWI).

Developed to allow host and module software implementers to utilize a common code base across a variety of form factors, the SFP-DD MIS provides a set of core functionality that all modules must implement and a set of optional features whose implementation is advertised in the module memory map. This approach allows host software implementers to read and react to optional module capability advertisements while ensuring interoperability with all modules at a basic level.

SFP-DD MSA promoters include Alibaba, Broadcom, Cisco, Dell EMC, Finisar, HPE, Huawei, Intel, Juniper Networks, Lumentum, Mellanox, Molex and TE Connectivity. Contributors include Accelink, Amphenol, AOI, Foxconn Interconnect Technology, Fourte, Genesis, Hisense, Infinera, Innolight, Maxim Integrated, Multilane, Nokia, Senko, Source Photonics, US Conec and ZTE.

A characteristic common to all SFP-DD MIS-compliant modules is that management data is transferred over a TWI, using a 256-byte addressable memory window, with mechanisms to dynamically page data of a much larger management memory space into the upper half of the host-addressable memory window. SFP-DD MIS-compliant pluggable modules are 2-lane module form factors.

"With this new release, the management interface specification will enable the adoption of the SFP-DD form factor as the next generation of SFP-DD modules, connectors and cage systems," says Scott Sommers, founding member & MSA chairman.

Many MSA members demonstrated SFP-DD at the European Conference on Optical Communication (ECOC 2019) in Dublin, Ireland (23–25 September).

www.sfp-dd.com

OIF approves IC-TROSA Implementation Agreement

Specifications speed delivery of higher level of integration for transmit & receive optical components

The Optical Internetworking Forum (OIF) has approved the Integrated Coherent Transmitter-Receiver Optical Subassembly (IC-TROSA) Implementation Agreement (IA). IC-TROSA integration was demonstrated during the OIF Physical and Link Layer (PLL) interoperability demo at the European Conference on Optical Communication (ECOC 2019) in Dublin, Ireland (23–25 September).

"The IC-TROSA project took an aggressive approach to coherent optical component integration and has delivered two new package designs incorporating TX and RX integration, common digital controls and performance monitoring all in a small-form-factor package," says IC-TROSA IA technical editor Scott Grindstaff, director R&D at ADVA. "Additionally, package specific features such as fiber-free interface and solder reflow compatibility have been incorporated."

The optical sub-assembly supports high-bandwidth and high-order dual-polarization quadrature amplitude modulation (QAM) operations and is suitable for data-center interconnect (DCI), metro and long-haul applications. As module sizes decrease, coherent optics components need similar size reductions to enable next-generation multi-terabit switches, line cards and transport platforms.

"The IC-TROSA IA is a solution for density requirements for line cards, front-pluggable and future on-board coherent 400G+ optical modules," says Karl Gass, OIF PLL Working Group, Optical vice chair. "It aims to standardize a photonic package for coherent applications that is easy to use while leaving the internal implementation to the vendor."

The IC-TROSA Type-1 is optimized for silicon photonics technology and uses a surface-mount package with a ball grid array (BGA) electrical interface. Advantages include an increased electrical bandwidth and solder reflow capability. The IC-TROSA Type-2 is optimized for indium phosphide (InP) technology and uses a gold-box package with flex-cable electrical interface. Advantages include an integrated tunable laser and a duplex LC optical connector.

The IC-TROSA's low power dissipation and miniature footprint enables small-form-factor digital coherent optics (DCO) transceivers in a QSFP-DD or OSFP form factor, as well as very high-density coherent line-card or daughtercard designs. Devices can support multiple modulation formats, including QPSK, 8QAM, and 16QAM, at symbol rates up to 64Gbaud, enabling data transmission up to 600Gb/s.

www.oiforum.com/technical-work/current-work/#IC-trosa

OIF demos 400ZR, CEI-112G and IC-TROSA interoperability at ECOC

At the European Conference on Optical Communication (ECOC 2019) in Dublin, Ireland (23–25 September), 12 member companies of the Optical Internetworking Forum (OIF) — ADVA, Amphenol, Cadence Design System, Credo, Finisar, Inphi, Keysight Technologies, Marvell, Molex, MultiLane, TE Connectivity and Yamaichi Electronics — gave live multi-vendor interoperability demonstrations of 400ZR, Common Electrical I/O (CEI)-112G and IC-TROSA (transmitter receiver optical sub-assembly).

"Understanding and seeing first-hand how key technologies — 400ZR, CEI-112G and IC-TROSA — are each specified to enable interoperable deployment across the ecosystem is critically important to building market confidence and accelerating adoption," says Steve Sekel, chair of the OIF Physical and Link Layer (PLL) Interoperability Working Group.

400ZR & IC-TROSA demo

OIF's 400ZR project aims to not only facilitate cost and complexity reduction for 400GbE over 80km DWDM networks, but also to bring forward a wave of necessary components and complementary applications. The IC-TROSA features all of the optical building blocks for a coherent module in a single package. The demonstrations will highlight important aspects of IC-TROSA integration as well as real-time EVM (error vector magnitude) measurements with the updated script for 400ZR. In addition, a hardware-based 400ZR installation will show a typical application case.

CEI-112G demo

OIF is developing electrical interface specifications for 112Gbps per differential pair. The CEI-112G demonstrations feature multi-party silicon supplier interoperability over mated compliance board channels, a full host to module channel and direct attach copper (DAC) cable channels, all demonstrating the technical viability of 112Gbps operation, along with multiple industry form factors including OSFP and QSFP-DD.

Market Focus

OIF presented 'Deployment of the 400ZR Ecosystem' on 24 September during the ECOC Market Focus Service and Content Provider Optical Transmission track. OIF expert and OIF Physical and Link Layer Working Group, vice chair Optical, Karl Gass is presenting.

www.oiforum.com/meetings-events/oif-ecoc-2019

www.ecoc2019.org

Scintil Photonics raises €4m in first-round funding

Fabless silicon photonic firm to accelerate industrialization of InP-on-Si technology and product development

Scintil Photonics of Grenoble, France, a fabless developer of silicon photonic fully integrated circuits (comprising multi-wavelength lasers, waveguides, wavelength filters & photodetectors), has raised €4m ($4.4m) in first-round funding led by Supernova Invest, Innovacom and Bpifrance (Banque Public d'Investissement) and joined by Credit Agricole Alpes Développement and endowment Fund Foreis (which focuses on the microelectronics sector).

The firm's solutions combine silicon (Si) and indium phosphide (InP) materials using wafer-scale bonding of InP on Si and rely on commercial silicon foundry processes to build fully integrated photonic circuits.

Proceeds will be used to develop prototypes (800Gb/s transceiver photonic circuits) in commercial foundries in order to sample strategic customers in the data-center market. The team and development partnerships, including those with CEA-Leti in France and the University of Toronto in Canada, will be strengthened.

Founded in November 2018 by CEO Sylvie Menezo (previously with CEA-Leti) and chairman Pascal Langlois (former CEO of Tronics Microsystems) and incubated at CEA-Leti, Scintil received initial start-up funding as a winner of i-Lab 2018, a French government-sponsored innovation competition hosted by French national investment bank Bpifrance.

"Integrating lasers onto silicon photonic circuits, mass produced in commercial silicon photonics foundries using standard manufacturing processes, is a key technology asset of Scintil," says Menezo. "This will open up many opportunities, not only in optical communications, but also in computing and sensing applications, such as LiDAR [light detection & ranging]. We look forward to engaging with prospective customers and demonstrating the functionality and performance enhancements that Scintil Photonics can bring," she adds. "With this first funding round, Scintil will be able to have its demonstrator and prototype circuits manufactured in commercial foundries, which will greatly accelerate our time to market."

Drawing on 15 years of research on InP lasers, silicon photonics and 3D packaging conducted at CEA-Leti, Scintil says that its technology enables higher-speed optical communication through the integration of multi-wavelength lasers with silicon photonics standard technology, and also reduces implementation costs by avoiding several packaging steps. Improving data-center efficiency is one of industry's major challenges. Besides developing solutions for high-speed data transmission, Scintil also targets sensing applications, such as LiDAR (an enabling technology for autonomous detection and mobility).

"We firmly believe in Scintil Photonics' ability to implement the seamless integration of III–V semiconductor material on silicon," comments Supernova Invest's investment director Christophe Desrumaux. "In particular, the collective manufacturing of lasers — reducing the cost of mass-producing fully integrated photonic circuits while improving the energy efficiency and other critical parameters — is a key differentiator in penetrating the market of data-center transceivers and sensors. It matches perfectly Supernova Invest's ambition to support game-changing deep-tech startups," he adds.

"Scintil Photonics aims to develop optical data interconnections over 800Gb/s at a very competitive cost and is uniquely positioned to address industry challenges in very high-speed data communication. This investment is an excellent illustration of our commitment to supporting Deep Tech companies," says Marion Aubry, investment director at Bpifrance's Digital Venture team.

"Today, 80% of data transmission occurs over short distances and inside data centers. For this type of application, higher bit rates, cost and power consumption are critical factors," notes Innovacom partner Vincent Deltrieu. "Scintil Photonics' technology and products address those challenges, and the company is a great example of the highly innovative digital start-ups and disruptive technologies Innovacom successfully supports," he adds.

www.scintil-photonics.com

AOI showcases 400G portfolio at ECOC

Applied Optoelectronics Inc (AOI) of Sugar Land, TX, USA — a designer and manufacturer of optical components, modules and equipment for fiber access networks in the Internet data-center, cable TV broadband, fiber-to-the-home (FTTH) and telecom markets — showcased its latest transceiver products at ECOC 2019.

"As the industry moves to 400G connections, AOI supports a wide range of 400G intradatacenter optical transceivers," says David Chen, assistant VP of marketing & sales. At ECOC, AOI demonstrated 400G transceivers for both the Octal Small Form-factor Pluggable (OSFP) and Quad Small Form-factor Pluggable – Double Density (QSFP-DD) form factors with a broad portfolio of single-mode and multi-mode solutions."

www.ao-inc.com

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NeoPhotonics announces general availability of 30–40mW CW DFB lasers for silicon photonics-based 400G data-center transceivers

NeoPhotonics Corp of San Jose, CA, USA (a vertically integrated designer and manufacturer of hybrid photonic integrated opto-electronic modules and subsystems for high-speed communications) has announced general availability (GA) of its non-hermetic 30–40mW distributed feedback (DFB) laser sources for use in silicon photonics 100G-per-wavelength CWDM4 FR4 and 1310nm DR1 and DR4 transceivers. The lasers are available with and without integral spot-size converters (SSC).

NeoPhotonics' low-loss SSC technology enables direct attachment of the indium phosphide laser to a silicon photonics waveguide, increasing manufacturing scalability and reducing costs. The efficient, high-power DFB lasers can operate at up to 75°C and are compliant with Telcordia GR-468-CORE, making them suitable for use in non-hermetic silicon photonics-based small-form-factor pluggable modules, such as 400G QSFP-DD.

Silicon photonics (SiPho) has emerged as a promising technology for optical data transmission over intermediate reaches of about 500m (DR) to 2km (FR) inside data centers. A SiPho photonic integrated circuit (PIC) can combine four different high-speed modulators on a single chip, but it requires a light source to be modulated. A separate laser (or laser array) generating sufficient optical power at the specified wavelength(s) to overcome losses in the silicon modulator and waveguides must be coupled to the SiPho chip. NeoPhotonics' family of high-power DFB lasers is designed to efficiently couple to the SiPho modulator chip and they do not require hermetic packaging, making them suitable for next-generation transceiver modules.

A high-speed SiPho modulator chip, due to its high V_p, generally needs a driver amplifier with a large voltage swing, which is also supplied by NeoPhotonics. The firm's GaAs-based quad driver chip combines four separate drivers in a single compact, low-power chip designed to support compact pluggable modules such as OSFP and QSFP-DD.

"Silicon photonics is rapidly transforming the data-center transceiver marketplace by bringing the scale and cost structure of semiconductor electronics to optics, and our laser sources and drivers are helping to unleash the potential of SiPho," says chairman & CEO Tim Jenks.

www.neophotonics.com

NeoPhotonics makes available ultra-narrow-linewidth tunable C++ LASER μITLA with 50% wider tuning range for coherent transmission

NeoPhotonics has announced general availability (GA) of its ultra-narrow-linewidth tunable C++ LASER micro-ITLA (integrated tunable laser assembly), which has a tuning range of 6THz (covering the full 'Super C-band'), which is 50% more spectrum than a standard 80-channel, 50GHz-spaced laser.

The C++ LASER supports full gridless tuning and accommodates any channel spacing, including 50, 75, 100, 125 and 150GHz. The new laser is based on the same proven and reliable high-performance external-cavity architecture as NeoPhotonics' micro-ITLA product line. The C++ LASER maintains comparable ultra-narrow linewidth, low phase noise and low power consumption (for which the current product is known) over a full 6THz tuning range.

New coherent transmission systems use higher baud rates (e.g. 64 or 96Gbaud) to enable a long-haul 200Gbps or 400Gbps transmission systems. However, these higher-baud-rate systems require wider DWDM channel spacings, which result in a lower number of available channels within a fixed total bandwidth, and therefore the total fiber capacity is compromised. Similarly, data-center interconnect and metro systems use these higher baud rates to achieve data rates of 400Gbps-and-above per channel and encounter these same limitations.

The C++ LASER can tune over 80 channels with a 75GHz-per-channel spacing, for example, to fully capture the increase in fiber capacity generated by these newer modulation approaches. Similarly, it can tune over 120 channels on a standard 50GHz grid spacing.

The availability of this new laser dovetails with recent developments in fiber amplifiers as well as NeoPhotonics' C++ ICR (intradyne coherent receivers) and C++ CDM (coherent driver modulators), completing the eco-system necessary to support transmission over the Super C-band.

"We are pleased to announce GA of our C++ LASER, which along with our C++ ICR and C++ CDM, enables an increase in fiber capacity of up to 50%," says chairman & CEO Tim Jenks. "The ability of our C++ LASER to tune over the full 6THz range of the 'Super C-band' is a testament to the robustness of our external-cavity tunable laser technology, which maintains industry-leading linewidth and phase noise along with high optical power output with low electrical power consumption over the entire range."

Synopsys releases enhanced portfolio of photonic design solutions, supporting faster development of photonic devices, systems and PICs

Synopsys Inc of Mountain View, CA, USA — which provides electronic design automation (EDA) software, semiconductor IP and services for chip and electronic system design — has released version 2019.09 of its comprehensive Photonic Solutions portfolio, which includes the RSoft products for photonic device design, the OptSim and ModeSYS tools for photonic system design, and the OptSim Circuit and OptoDesigner tools for photonic integrated circuit (PIC) design.

The firm says that its Photonic Solutions offer a seamless design flow from concept to manufacturing to enable innovations in consumer and industrial communication, sensing and imaging applications. The latest updates to the portfolio enable more efficient development of applications ranging from light sources and meta-lenses to optical communication systems and PICs.

Photonic device design

The RSoft photonic device tools are claimed to comprise the industry's widest portfolio of simulators for passive and active devices in optical communications and optoelectronics. New features in version 2019.09 include:

- The RSoft–LightTools Bidirectional Scattering Distribution Function (BSDF) interface for multi-domain device simulation now supports faster ray tracing of user-defined optical properties; it also supports non-uniform incident angles for more efficient use of computer resources in critical angular regions.
- A new interface with OptoDesigner allows users to load and simulate PIC design files directly in the RSoft CAD Environment.
- New Python APIs help to construct CAD files for complex structures, such as meta-lenses and grating couplers.
- An expanded Custom PDK Utility allows users to add to a process design kit (PDK) active device models such as phase shifters and modulators; it also enables users to design and create layouts for custom circuits such as ring modulators in OptSim Circuit and OptoDesigner.

Photonic system design

The OptSim and ModeSYS tools simulate the performance of optical communication system links through comprehensive simulation techniques and component models. New features in release 2019.09 include:

- The ability to simulate design files in multiple OptSim windows simultaneously, as well as to pre-assign signal types to compound component input and output ports.
- New application notes and design files to jumpstart designs for BPSK modulation, visible light communication, and 100GBASE-SR4 SWDM4 transmission.

Photonic integrated circuit design

Synopsys is driving the advancement of photonic integrated circuit technologies with its PIC Design Suite, which includes the OptSim Circuit and OptoDesigner tools. New features in version 2019.09 include:

- Enhanced algorithms for inter-domain conversions (time and frequency) in OptSim Circuit that speed simulation times by up to 2x.
- New design rule checks (DRCs) in OptoDesigner that speed calculations by up to 20x.
- Significant improvements to the PIC layout versus schematic (LVS) flow to support large port count photonic devices and netlist extraction.
- Updates to the bidirectional interface between OptSim Circuit and OptoDesigner to support automated electrical connections in layout.

"By working closely with industry leaders, we have updated our Photonic Solutions tools to deliver faster simulations, enhanced algorithms, and improved interfaces to help our customers develop better-performing, cost-effective photonic devices and systems," says Tom Walker, group director of Synopsys' Photonic Solutions. "Our goal with each release is to enable the industry to accelerate adoption of photonics and PIC technology across a broad variety of applications."

www.synopsys.com

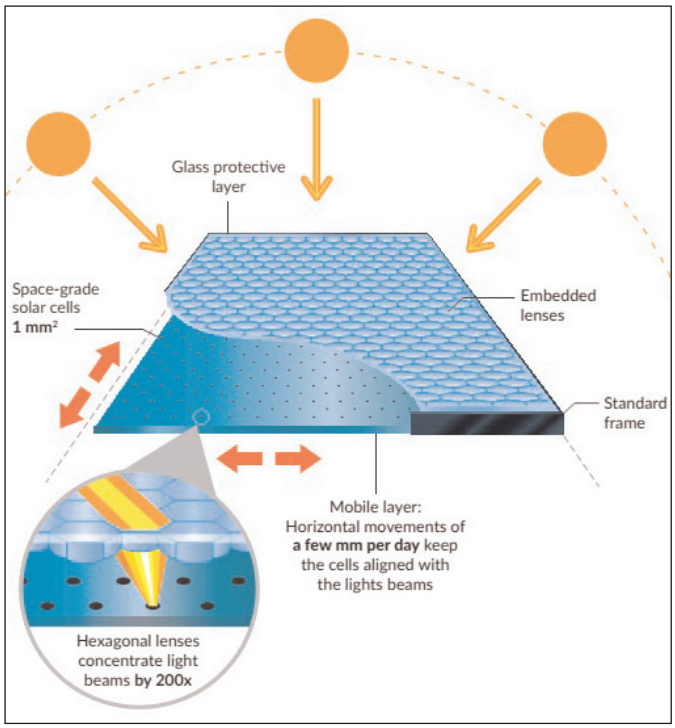
EU grants HIPERION project €10.6m

Project to establish pilot assembly line to demonstrate hybrid multi-junction/silicon solar module technology

In the framework of its Horizon 2020 research and innovation program under the 'Increase the competitiveness of the EU PV manufacturing industry' funding opportunity (grant agreement No. 857775), the European Commission has awarded €10.6m to the project HIPERION (HybrId Photovoltaics for Efficiency Record using Integrated Optical techNology) to ultimately strengthen the competitiveness of the European Union's solar power industry in the high-performance segment.

Running from September for 48 months, the project's 16-member consortium comprises: R&D center CSEM and startup Insolight SA (both of Switzerland); European PV research centers Universidad Politécnica de Madrid (Spain), Fraunhofer Institute for Solar Energy Systems (Germany) and Lodz University of Technology (Poland); industry partners Mondragon Assembly (Spain), X-Celeprint (Ireland), Argotech a.s. (Czech Republic), IQE plc (UK), Sonceboz (Switzerland), 3S Solar Plus (Switzerland) and ENGIE Laborelec (Belgium); solar installers Muon Electric (Portugal) and Milieu Studio (France); and Compaz – Communication through art and science (Switzerland) and L-UP SAS (France). The project is coordinated by R&D senior engineer Jacques Levrat of CSEM (Centre Suisse d'Electronique et de Microtechnique, or the Swiss Center for Electronics & Micro-technology).

The grant will aid in establishing a pilot assembly line to bring breakthrough photovoltaic technology, designed by startup Insolight SA (based at the EPFL Innovation Park in Lausanne, Switzerland), closer to market. Supported by private investors and several EU programs, Insolight is developing next-generation solar PV panels based on a patented optical technology.



Using an optical micro-tracking process that concentrates sunlight, Insolight's technology reaches 29% efficiency in the pre-production phase.

Tested under concentrator standard test conditions (CSTC) in the pre-production phase, Insolight's technology achieves solar energy conversion efficiency of 29% in a standard flat module. This is well above the efficiency levels of standard photovoltaic (PV) panels, which typically reach 18–20%.

The firm's system uses a planar optical micro-tracking process that concentrates sunlight on multi-junction solar cells mounted on top of a conventional silicon back plane. Insolight's solar panels are highly efficient under direct sunlight and can harvest energy under cloudy conditions as well, which is not the case for standard concentration systems.

Insolight has proven the effectiveness of its technology through extensive outdoor trials and at pilot installations. Its panels can be installed on standard rooftop or ground-mounted racks, or as an overlay on other solar panels.

Production scale-up

The primary aim of HIPERION is to scale up the production of Insolight's technology by showing solar panel manufacturers how they can adapt their existing production lines. "In addition to developing a pilot assembly line, we will also further demonstrate the performance and reliability of our innovation through qualification tests and several commercial pilot sites across Europe," says CEO Laurent Coulot.

"Our consortium has the expertise needed to bring this promising technology one step closer to mass production by further testing its economic potential and developing an assembly process that can be integrated into existing PV module production lines," says Christophe Ballif, vice president of CSEM and head of photovoltaics research. "Consortium members include several solar project developers that will assess the technology from the perspective of the rooftop and utility market segments."

Insolight's innovative design is said to sharply reduce solar power generation costs by significantly boosting efficiency, as it collects 50% more energy per square meter than traditional products. It is expected that combining this technology with the back-end manufacturing solutions that will be developed under the HIPERION project will give European PV manufacturers an edge over their mainstream competitors, putting them in a position to increase their share of the growing PV market.

www.insolight.ch

First Solar outsourcing US EPC to third-party providers

Scaling, developing and selling Series 6 module technology becomes top priority

Cadmium telluride (CdTe) thin-film photovoltaic module manufacturer First Solar Inc of Tempe, AZ, USA is transitioning away from its internal engineering, procurement & construction (EPC) execution model in the USA, and moving towards leveraging the capabilities of trusted EPC partners.

The transition to leveraging third-party EPC services will occur through the rest of 2019 and will not impact any projects under construction and slated for delivery this year.

First Solar is expanding its manufacturing capacity to meet the demand for Series 6 modules, with its second facility in the USA — representing nearly $1bn in cumulative investment — expected to start production in early-2020. Once operational, the new facility in Perrysburg, Ohio, will boost aggregate Series 6 manufacturing capacity to 5.4GW per year, making First Solar the USA's largest solar manufacturer.

"This transition, which mirrors the technology shift to the large-format Series 6 module, marks the natural evolution of our long-term growth strategy," says CEO Mark Widmar. "While self-performed EPC was necessary to optimize our earlier-generation modules, the seamless compatibility of Series 6 with industry systems and processes now allows us to leverage a much broader external ecosystem of knowledge and expertise," Widmar adds.

"This shift will allow us to concentrate on our core business of scaling, developing and selling our world-class module technology while executing on our project development pipeline with the same level of service that our customers have come to expect," Widmar concludes.

The transition will impact about 100 associates at various stages of the process, who will be provided with compensatory and outplacement support.

www.firstsolar.com

First Solar sets 25GW milestone for thin-film solar as it celebrates 20th anniversary

Cadmium telluride (CdTe) thin-film photovoltaic (PV) module maker First Solar is celebrating two decades since its founding in 1999 and 25GW$_{DC}$ of PV modules shipped (the only American solar manufacturer to achieve this milestone).

"Today, First Solar powers communities, infrastructure, and decarbonization ambitions with the world's cleanest PV solar technology; technology that forms the backbone of utility-scale solar fleets in some of the largest markets around the globe," says CEO Mark Widmar.

First Solar's technological roots are in Perrysburg, Ohio, where the firm achieved commercial production of its proprietary thin-film module technology in 2002. Since then, it has celebrated milestones including the establishment of the industry's first PV module recycling program in 2005, and becoming the first solar module maker to break the $1 per watt barrier, while also producing 1GW of modules in 2009.

More recently, First Solar has transitioned to its new large-format Series 6 module, which was designed and developed at its R&D centers in California and Ohio. The module leverages First Solar's proprietary thin-film technology, retaining the proven performance and reliability advantages of earlier-generation modules. Produced in just 3.5 hours using fully integrated manufacturing processes at factories in the USA, Malaysia and Vietnam, the Series 6 module has a carbon footprint that is said to be up to six times lower than crystalline silicon PV panels manufactured using conventional, energy-intensive production methods.

First Solar says it is on track to become the largest solar module maker in the Western Hemisphere when its second Series 6 factory in the USA – representing nearly $1bn in cumulative investment – becomes operational in early 2020. The new facility in Perrysburg, Ohio, will take First Solar's aggregate Series 6 manufacturing capacity to 5.4GW per year.

"From 1.5MW of annual production less than two decades ago to multiple gigawatts today, our journey has seen us successfully overcome challenges and make the most of opportunities," says Widmar. "Our ability to not just survive but to thrive in challenging environments that have claimed a number of our competitors is due to the relentless energy and the sense of purpose that drives us as a company."

Meanwhile, operations and maintenance (O&M) provider First Solar Energy Services is also celebrating its tenth year and 10GW of assets under management. Recognized as the global industry leader in operating and maintaining utility-scale solar plants by Wood Mackenzie and IHS, First Solar Energy Services' technology-agnostic experience spans several PV, tracker and inverter manufacturers.

www.firstsolar.com

Solliance and MiaSolé set record 23% efficiency for flexible solar cells

Top semi-transparent perovskite cell combined with bottom CIGS cell in tandem solar cell stack

Nine months after presenting the first record-breaking flexible solar cell, copper indium gallium diselenide (CIGS) thin-film photovoltaic solar cell and panel maker MiaSolé Hi-Tech Corp of Santa Clara, CA, USA (a subsidiary of Beijing-based renewable energy firm Hanergy) and Solliance Solar Research — a cross-border (Dutch-Flemish-German) public-private thin-film photovoltaic (TFPV) solar energy R&D consortium in the Eindhoven-Leuven-Aachen (ELAT) region — have set a new record power conversion efficiency of 23% on a flexible solar cell.

The solar cell combines two thin-film solar cell technologies into a tandem solar cell stack: a top flexible semi-transparent perovskite solar cell together with a bottom flexible CIGS cell.

Combing best of both worlds

Such a tandem solar cell has the potential for conversion efficiency exceeding single-junction solar cell performance due to tunable and complementary bandgaps of these individual thin-film solar cells.

To realize maximum conversion efficiencies, the absorption properties of the top perovskite cell and of the bottom CIGS cell can be tuned to complement each other. The perovskite solar cell was deposited on a transparent and flexible substrate, employed transparent conductive electrodes, and was optimized for maximum visible light conversion efficiency and infrared light transparency to allow the majority of infrared light to reach the bottom CIGS cell.

Cost efficient and high potential

CIGS technology has a proven track record as a high-efficiency and stable solar technology and has entered high-volume manufacturing in multi-Gigawatt scale around the world. CIGS technology has been used to produce high-efficiency flexible and lightweight cells and modules, addressing markets where heavy and rigid panels cannot be used.

Perovskite solar cells, despite being a relatively young technology, have already achieved high efficiencies, and promise low-cost solar technology based on abundant materials. Combining both technologies in a flexible and lightweight package expands the horizon of high-performance, flexible and customizable solar technology.

Collaboration

Developed by MiaSolé Hi-Tech, the CIGS bottom cell used in this tandem architecture is based on a commercially available high-efficiency flexible solar cell technology fabricated on lightweight stainless-steel foil using a proprietary high-throughput roll-to-cell sputtering process. Recently, MiaSolé reported a flexible large-area certified module efficiency of 17.44% with an active area of 1.08m^2.

"A highly efficient flexible hybrid solar cell is an outlook on how perovskite solar cell technology can innovate the established solar technology, leading to a different application area with improved performance," says Sjoerd Veenstra, program manager for perovskite-based solar cells at Solliance.

"This significant tandem cell performance gain was achieved through process improvements in the bottom CIGS cell," says Dmitry Poplavskyy, MiaSolé's director of technology. "These process changes, implemented by MiaSolé, enable high-efficiency CIGS cells with the spectral response better matched to the top perovskite cell," he adds. "Further improvements in spectral matching, as well as overall higher CIGS cell efficiency, are expected to push the tandem architecture well beyond 23%".

www.solliance.eu
www.MiaSole.com

Midsummer enters agreement with Rusnano

Russia to promote CIGS PV production and end-user product development across Eurasian Union

Midsummer AB of Järfälla, near Stockholm, Sweden — a provider of turnkey production lines as well as flexible, lightweight copper indium gallium diselenide (CIGS) thin-film solar panels for building-integrated photovoltaics (BIPV) — has entered into a frame agreement with the Moscow-based Russian government-owned technology firm Rusnano Group and its Fund for Infrastructure and Educational Programs (FIEP) to develop the non-silicon flexible photovoltaics market in Russia and the Eurasian Union.

Rusnano seeks to use Midsummer's technology to promote and develop the manufacturing of lightweight flexible CIGS PV cells and modules to set up production and end-user product development in Russia and in other countries of the Eurasian Economic Union (Russia, Armenia, Belarus, Kazakhstan and Kyrgyzstan). Midsummer will also source panels for worldwide distribution of panels manufactured in Russia and the region.

"This could open up a whole new market for our advanced manufacturing equipment for light, flexible, robust and energy-efficient thin-film solar cells," believes Midsummer's CEO Sven Lindström. "Our DUO system has taken the position as the most widespread manufacturing tool for thin-film flexible CIGS solar cells in the world," he claims. "We are especially impressed with Rusnano's focus on the building-integrated possibilities of thin-film technology, a vision that we share."

Rusnano is a government-owned joint-stock company established in 2011 as a $5bn private equity and venture capital evergreen fund by the government of Russia and aimed at commercializing developments in nanotechnology. Other Nordic energy companies cooperating with Rusnano are Vestas of Denmark and Fortum of Finland.

"The market for flexible solar panels designed to be installed on buildings which are still under construction and on existing structures is currently one of the fastest-growing markets in the energy industry," notes Ruslan Titov, deputy CEO of FIEP, which promotes Russia's economy development in nanotechnology and related high-tech sectors. "Several research groups and companies in Europe and the USA have made breakthroughs in photovoltaic technology in recent years, breakthroughs which have made it possible to install solar panels in places where we had not been able to before – on unexploited roofs, facades, and windows," he adds. "We are systematically developing non-silicon flexible photovoltaics in Russia, the only way feasible — first we transfer and localize technologies, then we upgrade the technology and increase the scale of production in order to meet the demands of the growing market, including export to Midsummer."

www.midsummer.se
https://en.rusnano.com/about/fiep

Midsummer increases size of CIGS PV solar cells and hence power of modules

Midsummer has increased the radius of its rounded solar cells from 90mm to 100mm, reducing the unused area of the module from 8% to just 2% and hence boosting the power per surface area by 6% without raising production costs.

"Six percent higher power per area for the same production cost is a big improvement in our industry," says CEO Sven Lindström. "In addition to an increased effect per area, we now have the opportunity to offer a visually more attractive product [in the form of the new R100 module]," he adds.

"We are investing heavily in future research with our new laboratory in Järfälla, Sweden that will open in October," Lindström notes.

III-nitride superluminescent diodes on silicon for displays and communications

Opportunities for compact on-chip light sources for speckle-free images and visible light data transfer.

Indium gallium nitride superluminescent diodes (SLDs) have been monolithically integrated on silicon substrates [Jianxun Liu et al, ACS Photonics, 2019, 6, 8, p2104]. The team from Suzhou Institute of Nano-Tech and Nano-Bionics (SINANO), University of Science and Technology Beijing and University of Science and Technology of China sees opportunities for compact on-chip light sources for speckle-free displays and visible light communications (VLC).

The researchers used metal-organic chemical vapor deposition (MOCVD) on (111) silicon substrates to create the III–nitride structure (Figure 1) for the SLD (Figure 2). The index-guided SLD featured a 4μm-wide ridge, which was J-shaped to suppress optical feedback oscillation in the 800μm-long cavity. Optical feedback runs the risk of laser action, which is not desired in SLDs. The J-bend of 6º occurred halfway down the cavity. The bend resulted in a facet that was not perpendicular to the cavity direction, allowing light to escape more easily.

Contact	p^+-GaN	30nm
Cladding (p-type)	132x($Al_{0.2}Ga_{0.8}N$/GaN)	132x(1.5nm/3nm)
Electron blocking	p-$Al_{0.2}Ga_{0.8}N$	20nm
Waveguide	30x($In_{0.02}Ga_{0.98}N$/GaN)	30x(1nm/1nm)
Quantum wells	3x($In_{0.12}Ga_{0.88}N$/$In_{0.02}Ga_{0.98}N$)	3x(2.7nm/12nm)
Waveguide	40x($In_{0.02}Ga_{0.98}N$/GaN)	40x(1nm/1nm)
Cladding (n-type)	14x($Al_{0.085}Ga_{0.915}N$/GaN)	14x(75nm/10nm)
Contact	n-GaN	1.3μm
Buffer	GaN	1.4μm
Buffer	$Al_{0.17}Ga_{0.83}N$	450nm
Buffer	$Al_{0.35}Ga_{0.65}N$	340nm
Nucleation	AlN	300nm
Substrate	(111) Si	

Figure 1. III–nitride epitaxial structure of SLD, using combinations of aluminium indium gallium nitride (AlInGaN) alloys.

The ridge waveguide and device mesa were formed with plasma etch. The p- and n-electrodes consisted, respectively, of palladium/platinum/gold and titanium/platinum/gold. After thinning, lapping and chemical mechanical planarization (CMP), the wafer was cleaved into bars containing 24 devices each. Comparison laser diodes were produced with straight waveguides. The devices were tested without packaging or facet coating.

The superluminescence of the device was demonstrated from the reduction in linewidth as the current injection increased from 400mA to 800mA, giving a reduction in full-width at half-maximum (FWHM) from 13.8nm (102meV) to 3.6nm (26meV), respectively (Figure 3). The main part of the reduction in FWHM occurred around 500mA when the value was 8.5nm (67meV), indicating the main onset of amplified spontaneous emission (ASE). In laser diodes, the reduction in FWHM is sharper, and generally results in linewidths narrower than 1nm — the fabricated comparison laser diodes had FWHMs of ~0.5nm (3.7meV) above threshold.

As the current through the SLD increased, there was at first a red-shift and then a blue-shift of the electro-luminescence (EL) peak wavelength. The researchers comment: "The observed red-shift under a low injection current can be attributed to the bandgap narrowing resulting from many-body effects. While the blue-shift of the EL peak under a high injection current can be explained by combined effects of the band-filling effect and the carrier-induced screening of the quantum-confined Stark effect." The quantum-confined Stark effect refers to the electric field that arises in III–nitride semiconductor heterostructures due to the charge-polarization of the chemical bonds. The effect tends to shift electron energy levels and to negatively impact electron-hole recombination into photons.

The transition from spontaneous emission to ASE was also reflected in optical polarization measurements. Even below threshold, the emissions were dominated by the transverse electric (TE) modes of the waveguide structure. The degree of polarization, as expressed by the difference in TE and transverse magnetic (TM) emission relative to the total emission, increased from

84% to 97.6% between 400mA and 600mA injection. The 97.6% value is said to correspond to 20dB polarization extinction ratio (I make it 19dB, but I may have worked from a different definition).

Comparing SLD and comparison laser diode threshold currents, the former occurred around 550mA and the latter around 230mA, less than half the value of the SLD.

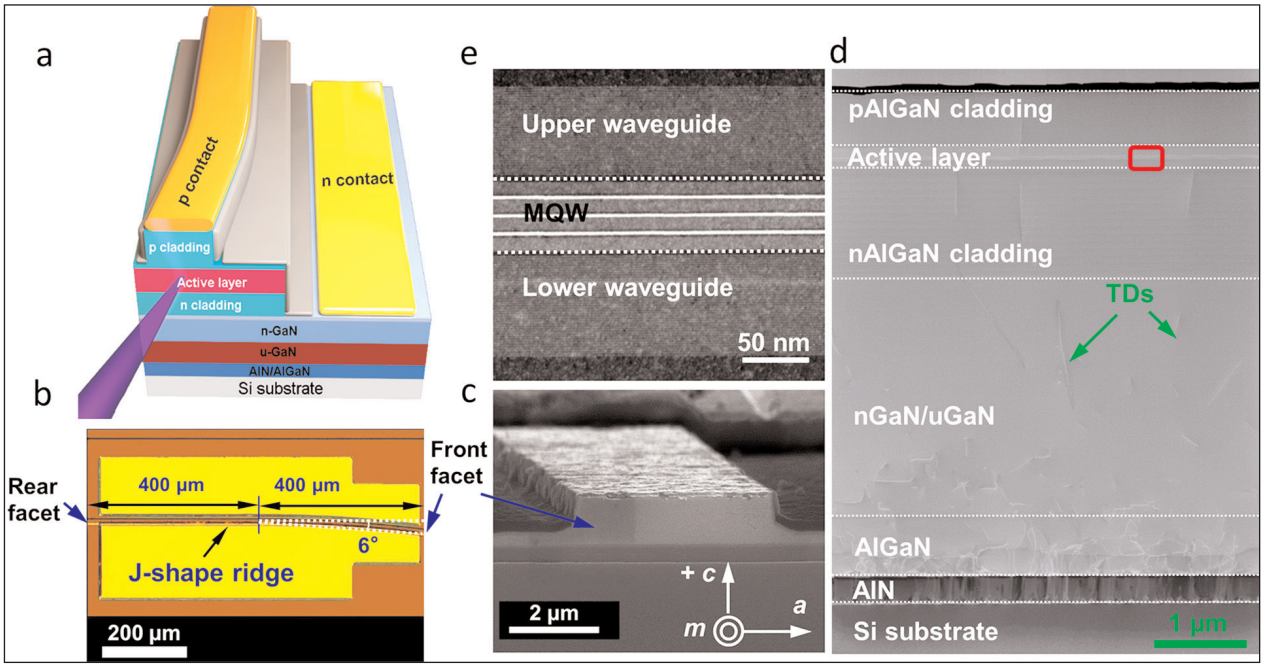


Figure 2. (a) Three-dimensional illustration of InGaN-based SLDs grown on silicon with J-shaped ridge waveguide. (b) Top-view optical microscopy image of bar of InGaN-based SLDs after facet cleavage. (c) Scanning electron microscope image of cleavage facet. (d) Cross-sectional scanning transmission electron microscope (STEM) image. Total thickness of epitaxial layer was 5.8μm. (e) Enlarged STEM image of marked zone in (d).

The SLD light output power began to saturate at 1100mA injection, and rolled off at 1400mA when about 2.5mW. Although the power was measured under pulsed injection, the saturation and roll-off was attributed to heating effects. "A significant improvement in optical output power is expected for the SLDs by applying anti-reflection coating to the cavity facets and adopting proper packaging with good heat dissipation," the team writes.

Current–voltage and capacitance–voltage measurements were used to assess the devices' resistance–capacitance (RC) bandwidth. The series resistance was estimated at 2.8Ω for the SLD, on the basis of the linear section of the current–voltage plot between 150mA and 400mA injection. A similar estimate for the laser diode gave 2.6Ω series resistance. A 1MHz modulated signal with the diode biased between –8V and +2V gave a capacitance estimate of 32.5pF at –4V bias, representing deep depletion in the diode (34.4pF for the laser diode). The RC time constant for the SLD was 90ps, representing a frequency of 1.77GHz. This opens up VLC opportunities. ■

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Author: Mike Cooke

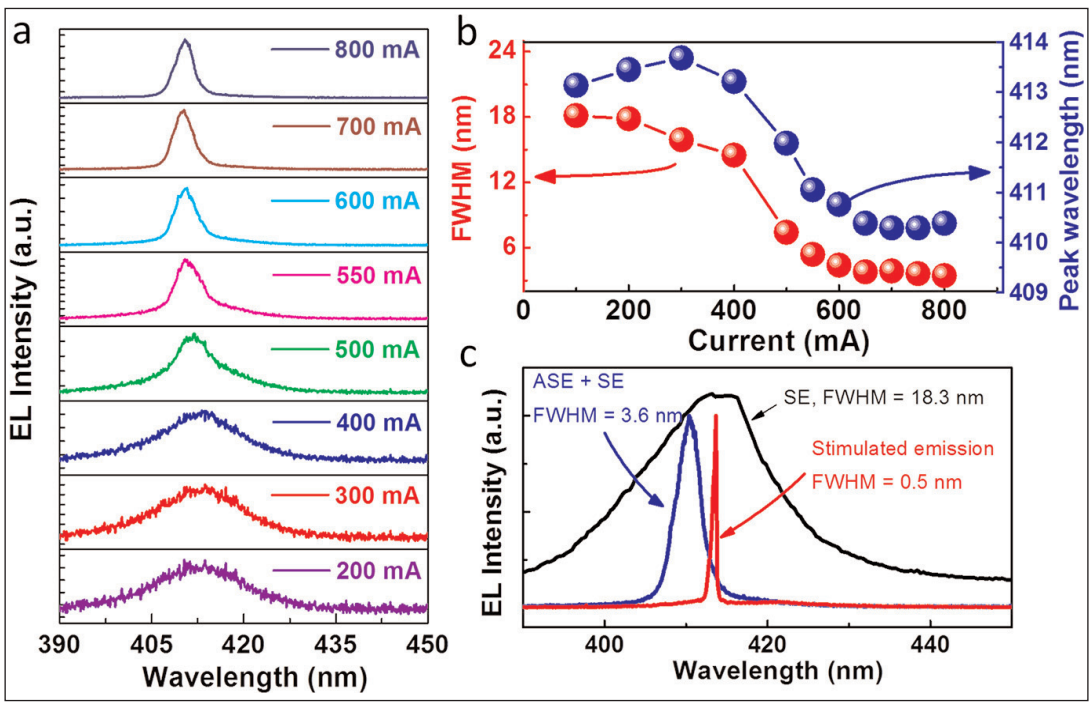

Figure 3. (a) EL spectra of SLD under various pulsed injection current at room temperature. (b) Peak wavelength and FWHM as function of injection current. (c) EL spectra for SLD below threshold (100mA), above threshold (800mA), and stimulated emission from LD (250mA) with identical epitaxial design.

Metal nanoparticle plasmon push for III-nitride light-emitting diodes

Red- and white-emitting devices benefit from resonance between free-electron states and semiconductor active regions and phosphors, Mike Cooke reports.

Present-day reality is far from theoretical limits when it comes to the performance of light-emitting diodes (LEDs) based on indium gallium nitride (InGaN) compound semiconductors. Ways to edge towards the physical boundary come slowly and many concepts are brought into play.

Two recent works have used localized surface plasmons (LSPs) on metal nanoparticles (NPs) to step up red and white LED performance. Plasmons describe oscillations of free-electron density in metals. Confining plasmons in NPs create resonant LSPs, dependent on the particle composition and size.

Here, we look at this recent work.

Red boost

Japan's Osaka University has combined silver (Ag) nanoparticles with europium-doped gallium nitride (GaN:Eu) LEDs to boost red electroluminescence by a factor of two [Jun Tatebayashi et al Appl. Phys. Express, vol12, p095003, 2019]. The output power enhancement is attributed to coupling between localized surface plasmons on the Ag NPs and the electron transitions in the Eu ions that produce red photons.

The GaN:Eu LEDs operate through ~620nm-wavelength transitions in the electronic state of the Eu^{3+} ions, rather than the band-to-band transitions of InGaN devices, for which ~520nm green wavelengths are a struggle to obtain efficiently.

The research team points out that stable, narrow-wavelength GaN:Eu red LEDs "have recently reached output-powers respectable for commercialization." They suggest that further performance enhancements could lead to applications such as in micro-LED displays with red, green and blue emitters on a common GaN platform.

The GaN layers were applied using metal-organic vapor phase epitaxy (MOVPE) on sapphire via trimethyl-gallium and ammonia precursors (Figure 1). The GaN:Eu layer, co-doped with oxygen (O), used in addition bis(n-propyl-tetramethyl-cyclopenta-dienyl)europium ($EuCp^{pm}_2$) and argon-diluted O_2 sources. The n- and p-type silicon and magnesium doping was achieved by adding monomethylsilane and bis(cyclopentadienyl)-magnesium (Cp_2Mg), respectively.

The growth sequence was: 530ºC GaN buffer, 1.5μm 1200ºC undoped GaN, 2.4μm n-GaN contact, 100nm 960ºC GaN:Eu,O active layer, and 1050ºC p-GaN contact.

Further processing consisted of 10-minute 800ºC annealing in nitrogen to activate the p-GaN doping, formation of self-assembled Ag nanoparticles, 150nm indium tin oxide (ITO) sputtered p-contact, and chromium/gold (Cr/Au) metal contact electron-beam deposition.

Inductively coupled plasma etch was used to expose the n-GaN layer for the metal contact deposition. The final devices were 1mmx1mm in lateral dimensions.

The nanoparticle formation consisted of electron-beam deposition of a silver film, followed by annealing at 200ºC for 30 minutes in nitrogen.

Photoluminescence (PL) experiments on the epitaxial material with Ag nanoparticles showed a 622.4nm peak at room temperature. The peak shifted to 621.8nm at 10K. The emission was attributed to $^5D_0$–$^7F_2$ transitions in the Eu. At 10K, there are also

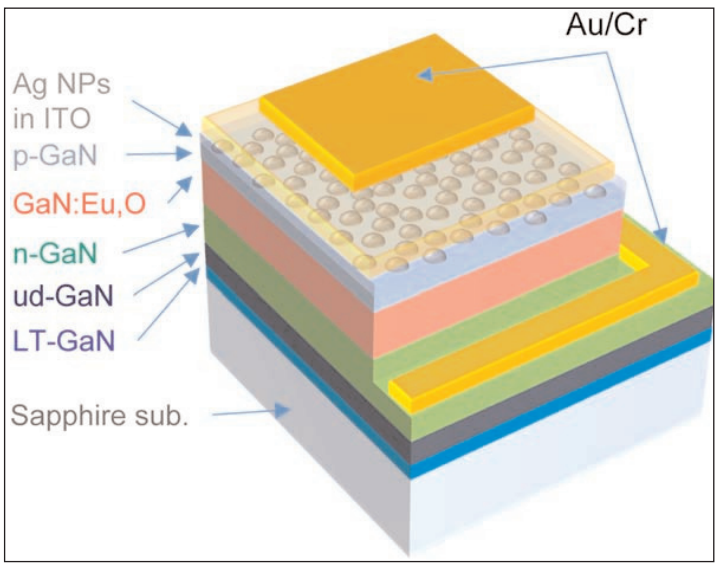

Figure 1. Schematic of fabricated LEDs.

"several" lesser peaks either side of the main one. [I see two (with a broad ~10nm hump on the short-wavelength side) in the image in the paper, but maybe these break up into "several" at higher resolution.] These peaks become less clearly defined at room temperature. The different peaks are attributed to variations in the electromagnetic environment of the Eu^{3+} ions in the GaN crystal structure.

"This is a result of the existence of defects such as Ga and N vacancies, as well as carbon, oxygen and hydrogen, yielding various 'Eu incorporation sites', and also modifies the transition probabilities of each Eu site," the team explains.

The intensity of the emissions generally increased with the thickness of the Ag film used to create the nanoparticles — at 20nm the intensity was 3.4x that for the bare material at room temperature (6.65x at 10K). There was a slight intensity dip initially with 5nm Ag, before enhancements set in with thicker Ag films.

The researchers comment: "The observed enhancement of the luminescence intensity is predominantly a result of coupling of the Eu^{3+} luminescence to the localized surface plasmon modes of Ag nanoparticles, although a small increase due to reflection at the GaN/Ag nanoparticles interface might be expected after the formation of Ag nanoparticles."

The PL studies did not show near-band-edge emissions from the GaN material (in the near ultraviolet) or 'yellow luminescence' associated with crystal defects. The team writes: "This indicates that electron-hole pairs generated in the GaN host can be efficiently captured to the trap level responsible for energy transfer from the host material to the Eu^{3+} ion."

Time-resolved PL analysis at 10K found that the decay time with 20nm Ag nanoparticles was shorter than that for bare material — 204μs, compared with 263μs. The 1.3 increased decay probability was taken as deriving from the coupling between the Eu ions and the localized surface plasmons of the Ag nanoparticles. In fact, the decay time was minimized at 194μs with nanoparticles created with 15nm Ag films. The researchers tentatively attribute the increase with 20nm Ag to "the irregular shape and large size variation" of the nanoparticles reducing the coupling with the Eu ions.

The LSP-ion coupling is seen as being rather small, compared with conventional InGaN quantum well and surface plasmon structures reported in the scientific literature. The researchers suggest that this is due to the much thicker GaN:Eu,O layer, compared with quantum wells — 100nm versus 1–3nm, typically. Resonance effects tend to drop off rapidly with distance.

Electroluminescence performance was assessed for radiation extracted out of the sapphire back-side of the device (Figure 2). The onset of light emission came at around 10mA current injection. The researchers say

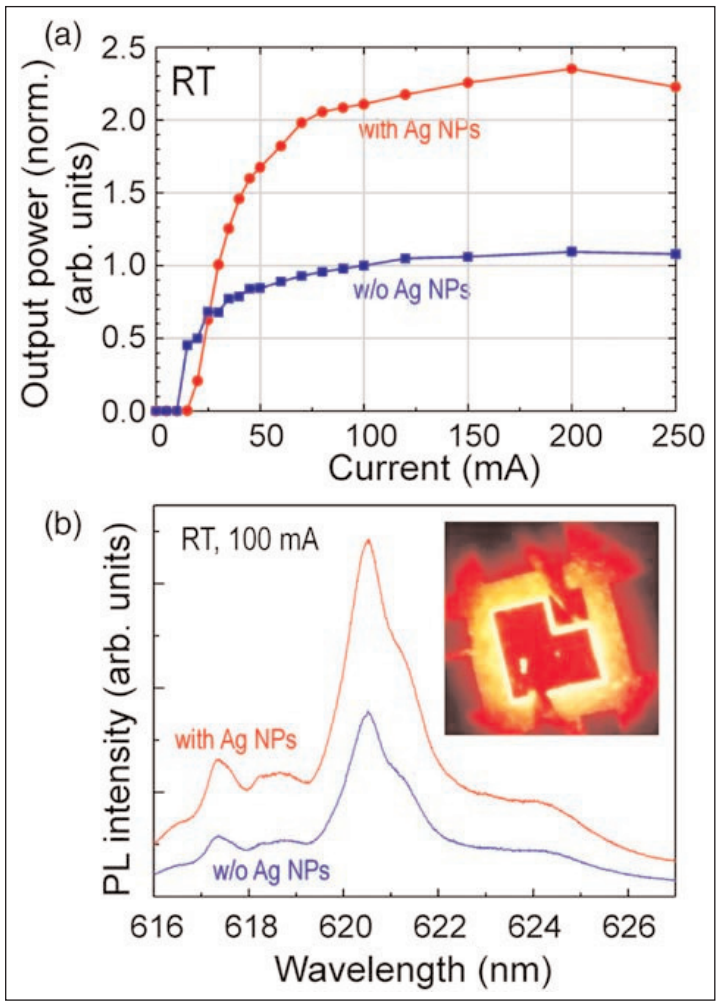

Figure 2. (a) Output-power versus injection current of fabricated GaN-Eu-based LEDs with and without Ag nanoparticles. (b) EL spectra of GaN:Eu-based LEDs under 100mA injection current. Inset: microscopic image of red LEDs.

that optimization of the thickness and doping density of the p-GaN layer is required to reduce current leakage while maintaining coupling efficiency between the localized surface plasmons and GaN:Eu layers. The light output saturated around 100mA. The device with Ag nanoparticles had 2.1x the output without the particles at 100mA.

While it is tempting to increase the emission by increasing the Eu concentration, this runs the risk of reducing crystal quality and thus the light emission performance.

White luminous efficiency and color rendering

Researchers based in China have combined phosphors, quantum dots, and metal nanoparticles to create blue-to-white light converters for InGaN LEDs with simultaneously improved luminous efficiency (LE) and color rendering [Rongqiao Wan et al, Optics Letters, vol44, p4155, 201]. Often improved color rendering comes at the cost of reduced LE.

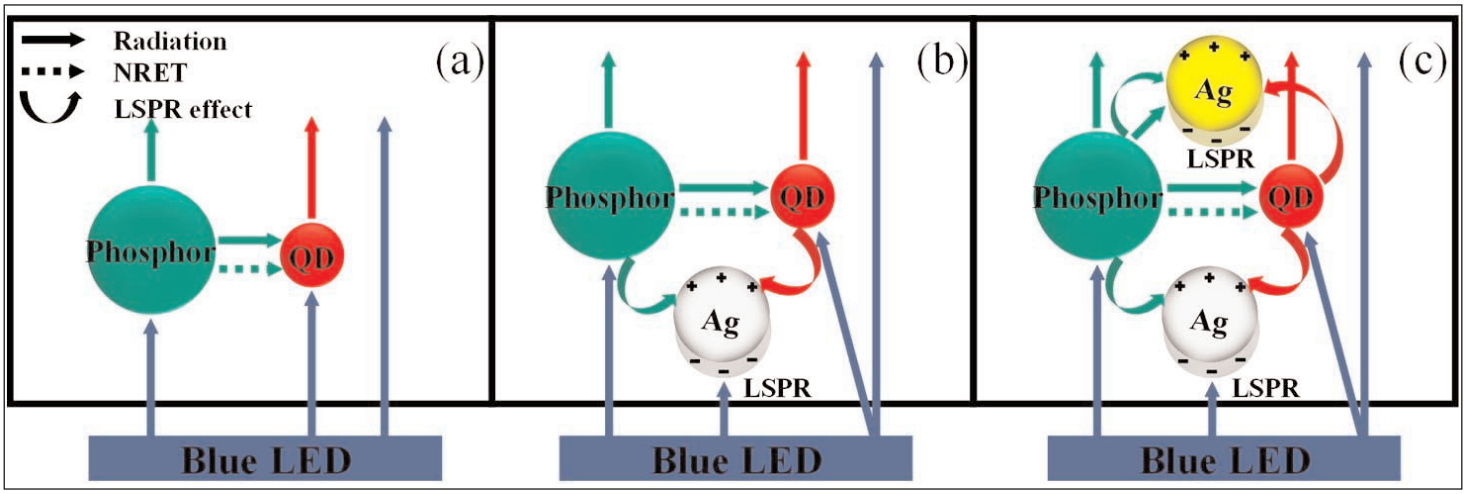

Figure 3. Schematic mechanisms and energy transfer paths for (a) wo-WLEDs; (b) Ag-WLEDs; (c) AgAu-WLEDs.

The approach adopted by Central South University, Semiconductor Lighting Technology Research and Development Center, and University of Chinese Academy of Sciences, enables a broader spectrum of light over the visible range, filling in the red end of the spectrum, compared with the low-cost white LEDs using yellow phosphors that are presently in mass production.

The researchers combined green- and red-emitting phosphors with silver (Ag) and gold (Au) nanoparticles. The broadband green emitter consisted of cerium-doped lutetium aluminium garnet (LuAG:Ce, $Al_5Lu_3O_{12}$). Core/shell cadmium selenide/zinc sulfide (CdSe/ZnS) quantum dots (QDs) in toluene solvent provided a narrowband blue-to-red converter. The Ag nanoparticles, on average, were 15nm diameter, and the Au nanoparticles 70nm diameter. The nanoparticles were dispersed in toluene.

The materials were mixed into silicone gel, and the mixture was placed in vacuum for 90 minutes to remove the toluene. The gel was then dropped onto 10milx23mil 451nm blue LED chips in a lead frame. The blue electroluminescence of the LEDs had a full-width at half maximum (FWHM) of 17nm. Thermal curing at 130ºC lasted 15 minutes. All the samples contained the green phosphor and red QDs, but some also contained silver (Ag-WLEDs) or silver and gold (AgAu-WLEDs) nanoparticles to give white LEDs. The samples without nanoparticles were designated wo-WLEDs.

Table 1. CRI, CCT and LE of Ag-WLEDs with varied nanoparticle concentrations.

Ag NPs (ppm)	Current density (A/cm^2)	CRI	CCT (K)	LE (lm/W)
0	4	89	5800	81
0	40	90.8	6000	61
1	4	90	5500	82
1	40	92	5700	61
3	4	93	5100	87
3	40	91	5200	66
5	4	93.6	5230	86
5	40	92.6	5450	64

Table 2. CRI, CCT and LE of AgAu-LED with varied Au nanoparticle concentrations and constant 3ppm Ag nanoparticles.

Ag NPs (ppm)	Current density (A/cm^2)	CRI	CCT (K)	LE (lm/W)
0	4	93	5100	87
0	40	91	5200	66
0.5	4	92	4750	89
0.5	40	89	4880	67
1	4	93.2	5070	92
1	40	92	5200	68
1.5	4	86	4950	92.5
1.5	40	84.3	5010	69.5

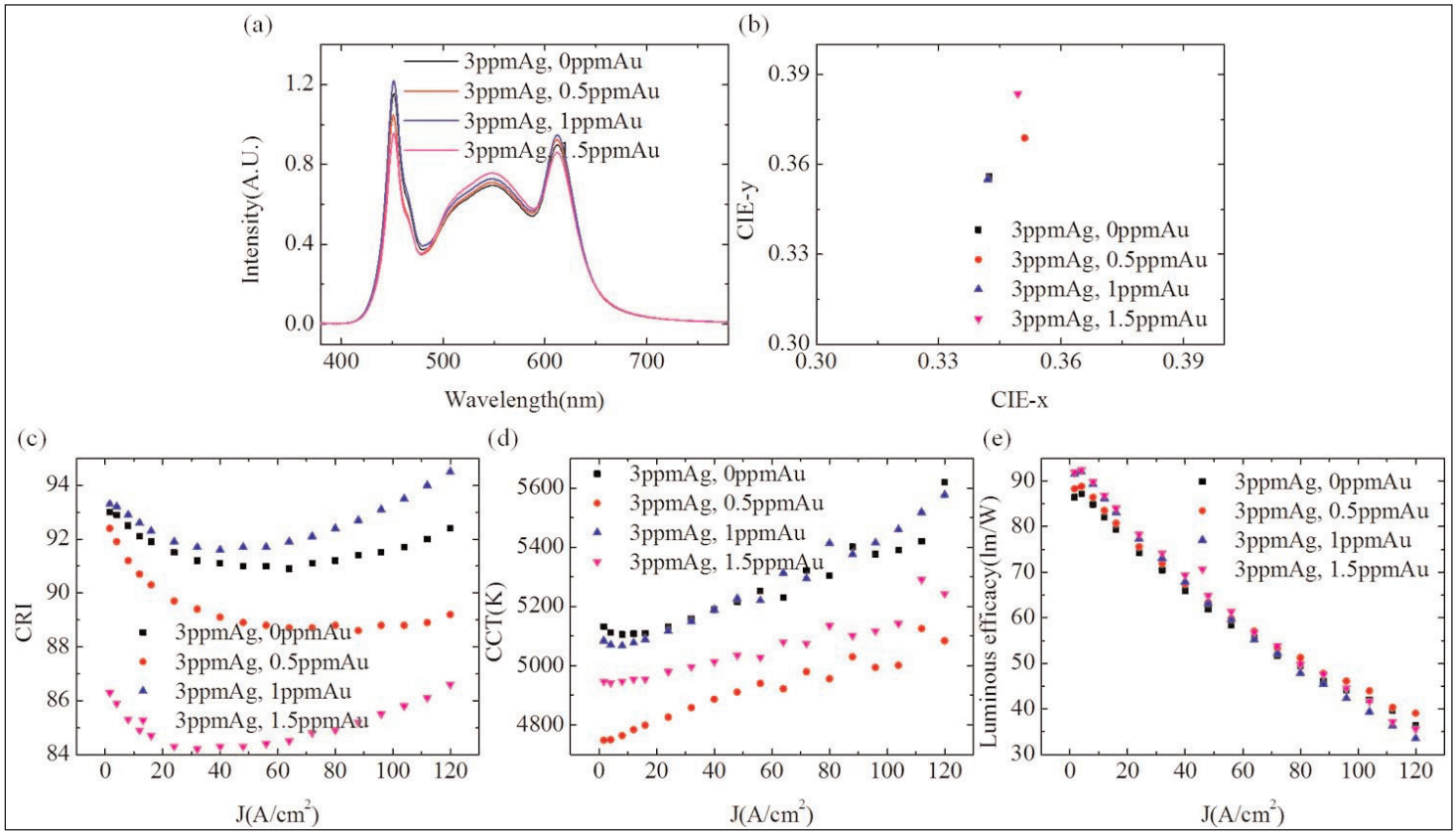

Figure 4. (a) Electroluminescence spectra of Ag-WLEDs and AgAu-WLEDs with varied concentration of Au nanoparticles and constant 3ppm Ag concentration under 20mA (16A/cm^2) injection current. (b) CIE-1931 chromaticity coordinates of AgAu-WLED, (c) CRI, (d) CCT, and (e) LE of Ag-WLEDs and AgAu-WLEDs versus current density.

The blue-to-white conversion layer was designed to take advantage of a variety of physical processes (Figure 3). The green (544nm wavelength under photoluminescence, 106nm FWHM) and red (613nm, 30nm FWHM) phosphors/QDs operated through Stokes processes of absorption of blue photons and emission of the longer-wavelength, lower-energy green and red light. Since green light has higher photon energy than red, some green-to-red conversion might also be expected. The use of QDs was also expected to add non-radiative energy transfer (NRET) channels between the green and red emitters.

The metal nanoparticles were also hoped to provide NRET enhancement. The Ag nanoparticles also absorbed the main blue light (454nm absorption peak) from the LED active region through localized surface plasmon resonance (LSPR). The team comments: "Due to the resonant light scattering effect, the absorption cross section of LuAG:Ce and CdSe/ZnS QDs for blue light increases, thus enhancing color conversion efficiency."

The Au nanoparticles were designed to have LSPR with the green emissions (531nm peak). The researchers also suggest that the resonance may provide an environment that gives Purcell-effect enhancement of spontaneous emission of the phosphor and QDs.

The researchers first investigated the improvements achievable with varied concentrations of Ag nanoparticles (Table 1). The peak color rendering index (CRI) of 93.6 was achieved with 5 parts per million (ppm) nanoparticles, by weight, and 4A/cm^2 current injection. Higher LE of 87 lumens per watt (lm/W) was found with 3ppm nanoparticles at 4A/cm^2. The 3ppm Ag-WLEDs also demonstrated the lowest correlated color temperature (CCT) of 5100K at 4A/cm^2. A low CCT indicates higher red and green content in the 'white' light, which is associated with 'warmer' illumination compared with regular white light.

The Ag-WLEDs were further enhanced with Au nanoparticles (Table 2). The Ag nanoparticles concentration was fixed at 3ppm. The incorporation of 1ppm Au nanoparticles enabled an increase in LE to 92lm/W at 4A/cm^2, while the CRI and CCT were 93.2 and 5070K, respectively. Increasing the injection current to 120A/cm^2 enhanced the CRI to 94.5 (Figure 4). With 1.5ppm Au nanoparticles the LE increased to 92.5lm/W at 4A/cm^2, but at the cost of reduced 86 CRI.

The team expects further enhancements from "package and energy transfer structure optimization" to reduce energy losses. ■

The author Mike Cooke has worked as a semiconductor and advanced technology journalist since 1997.

Reduced contact resistance aluminium gallium nitride channel power devices

Researchers develop improved metal-organic chemical vapor deposition process.

Ohio State University and University of South Carolina in the USA have been developing ohmic contact structures for use with aluminium gallium nitride (AlGaN)-channel electronic devices [Towhidur Razzak et al, Appl. Phys. Lett., vol115, p043502, 2019]. AlGaN is an ultrawide-bandgap semiconductor alloy material that should be able to withstand very large electric fields, enabling high-power and high-voltage applications.

The AlGaN bandgap increases with aluminium content. Pure GaN has been developed for some time for high-power and high-voltage devices, based on its already

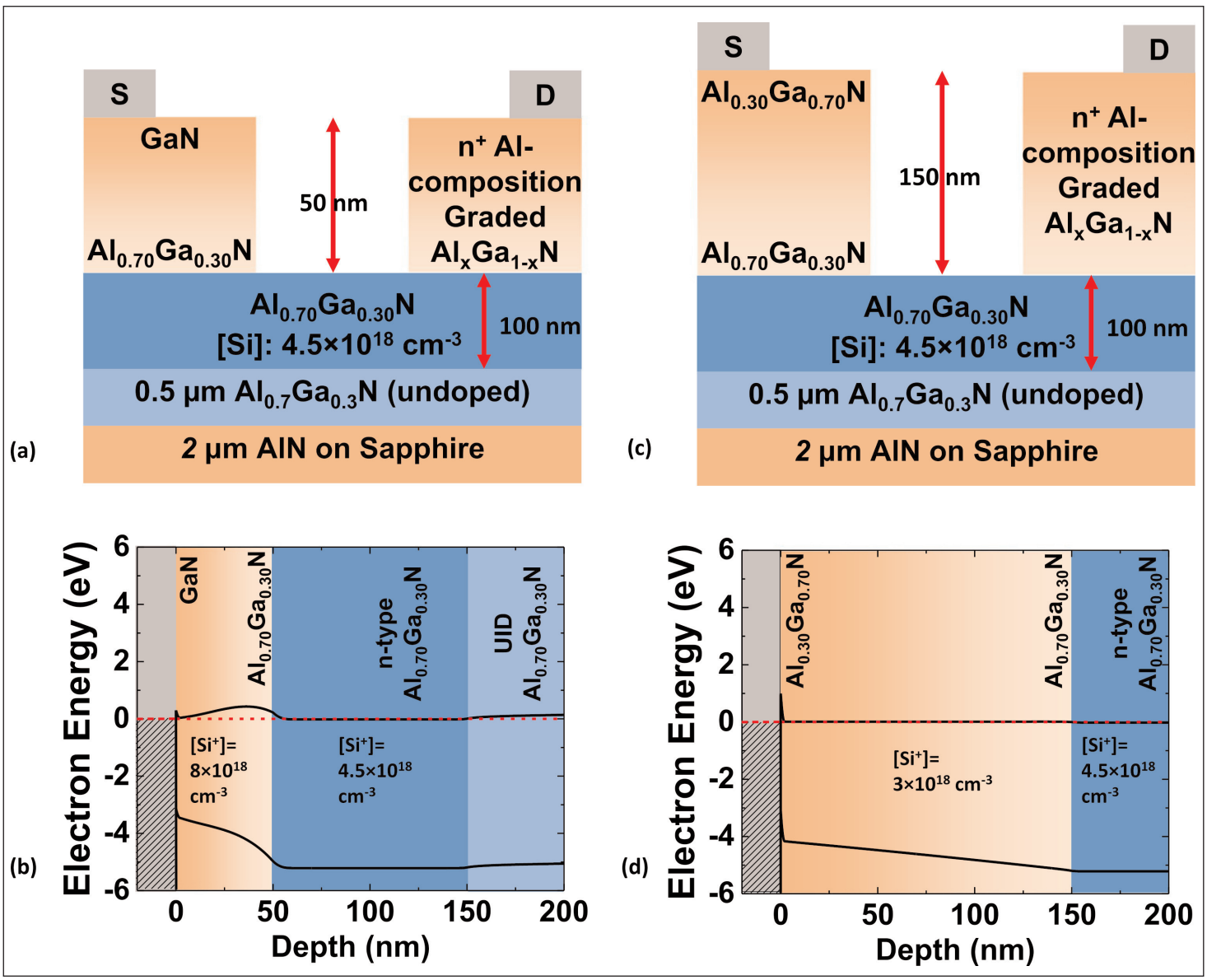

Figure 1. (a) Schematic and (b) energy-band diagram of the access region of sample A with silicon-doping concentration of 8×10^{18}/cm^3, and (c) schematic and (d) energy-band diagram of sample B with 3×10^{18}/cm^3 silicon concentration.

wide bandgap of ~3.4eV. For Al contents greater than 0.7, the AlGaN bandgap exceeds 5.1eV. Breakdown fields greater than 11MV/cm should thus be possible. However, low resistance to metal contacts is tricky to achieve in high-Al-content AlGaN.

Source–drain contact layers were grown over an $Al_{0.7}Ga_{0.3}N$ channel. Two samples were produced — one (A) where the aluminium content was graded down to zero (GaN=Al_0Ga_1N) over 50nm, and the other (B) where the grading was to $Al_{0.3}Ga_{0.7}N$ over 150nm (Figure 1). The sample B structure enabled a lower silicon doping to be used to compensate the polarization charge arising from the shallower Al content gradient. The trade-off is between a low metal–semiconductor contact resistance when the Al content at the surface is low (or zero), and high contact layer resistance arising from polarization charge effects.

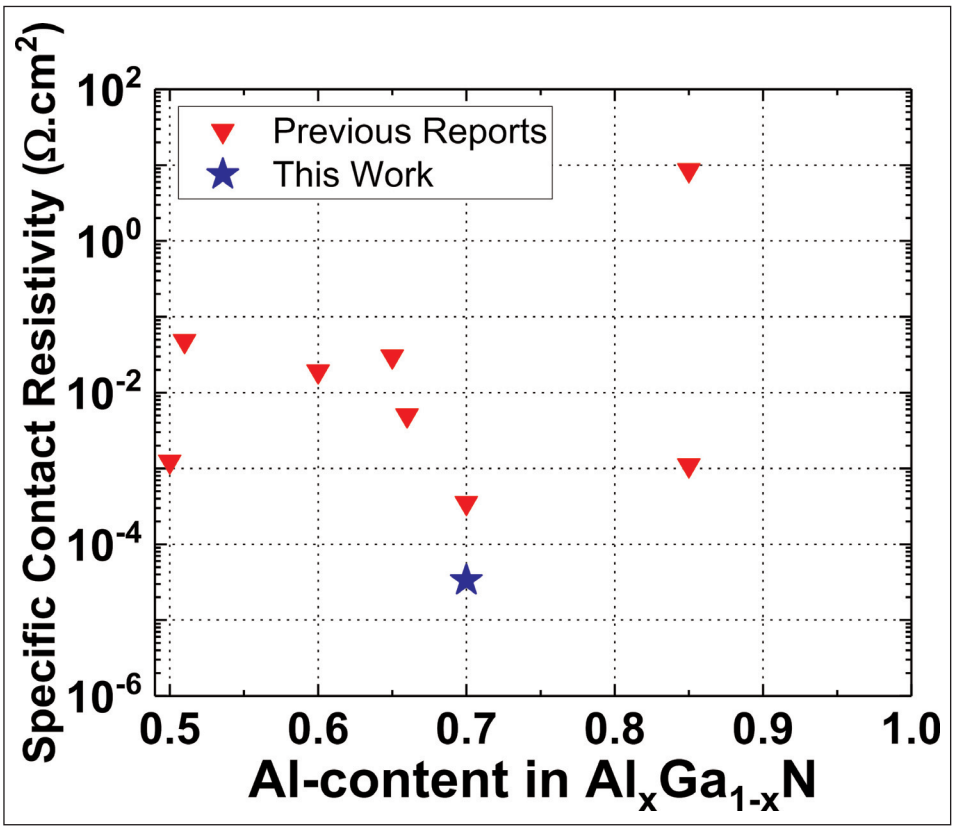

Figure 2. Comparison of specific contact resistivity versus Al-content for state-of-the-art MOCVD-grown $Al_xGa_{1-x}N$-channel transistors with x greater than 0.5.

The samples were grown using metal-organic chemical vapor deposition (MOCVD) on AlN-on-sapphire templates. The source–drain contacts consisted of alloyed titanium/aluminium/nickel/gold. Inductively coupled plasma etched out isolation mesas. Selective recessing 60nm into the channel layer defined the active areas of the devices. Hall measurements on sample B gave a channel sheet resistance of 5.6kΩ/square, based on $1.8x10^{13}/cm^2$ sheet carrier density and $56cm^2$/V-s mobility.

Sample A had non-linear current-voltage characteristics — indicating incomplete compensation of the negative polarization charge in the contact layer by the silicon doping. By contrast, sample B's characteristic was linear. Sample B's specific contact resistivity was $3.3x10^{-5}\Omega$-cm^2, according to transfer-length measurements.

The contact layer resistivity in sample B was estimated at $1x10^{-5}\Omega$-cm^2, somewhat higher than reported for layers grown by molecular beam epitaxy (MBE). The researchers suggest that this could be due to either non-uniform grading of the contact layer, leading to higher localized polarization charge, and/or non-uniform silicon incorporation.

Sample A was not subjected to Hall or transfer-length analysis due to the non-linear behavior.

The researchers comment (Figure 2) that "the specific contact resistivity obtained for sample B is the lowest observed for any MOCVD-grown $Al_xGa_{1-x}N$-channel devices to date for x > 0.5."

Sample B was used to create metal-semiconductor field-effect transistor (MESFET) structures with nickel/gold/nickel gates. The gate length was 0.6μm; the source–drain gap was 1.5μm. With 20V drain bias, the peak transconductance was 38mS/mm; pinch-off occurred at −16V gate potential. The maximum drain current was 635mA/mm with +2V gate. This value is claimed as "the highest current density achieved to date for $Al_xGa_{1-x}N$-channel devices with x > 0.5".

Three-terminal breakdown measurements with the gate at −20V showed no breakdown up to +220V gate–drain potential difference. Combining this with the 0.77μm gate-drain gap gives an average field of 2.86MV/cm — "almost 3x higher than that exhibited by lateral GaN channel devices with similar dimensions," the researchers say.

The team adds: "The breakdown is mainly limited by the gate leakage current which is the primary contributor to the drain current in the three-terminal breakdown measurement. Thus, the breakdown characteristics can be further improved by the addition of a gate dielectric such as [aluminium oxide,] Al_2O_3."

The researchers conclude: "This demonstration provides a technologically important approach to form low-resistance contacts to MOCVD-grown ultrawide-bandgap (UWBG) $Al_xGa_{1-x}N$-channel transistors." ■

https://doi.org/10.1063/1.5108529

Author: Mike Cooke

Ferroelectric gate stack for normally-off gallium nitride power transistors

Researchers claim the lowest reported specific on-resistance with breakdown voltages greater than 650V.

Taiwan's National Chiao Tung University and Universiti Kebangsaan Malaysia (UKM) have used ferroelectric materials to create normally-off tri-gate gallium nitride (GaN) metal–insulator–semiconductor high-electron-mobility transistors (MIS-HEMTs) [Chia-Hsun Wu et al, IEEE Transactions on Electron Devices, vol66, issue8 (August 2019), p3441]. The researchers claim the lowest reported specific on-resistance for normally-off GaN transistors with breakdown voltages greater than 650V.

A hafnium oxynitride (HfON) ferroelectric layer in the gate stack was designed to trap charge that shifted the threshold voltage of the transistor to positive values, giving normally-off behavior — i.e. a low current flow at 0V gate potential. Normally-off behavior is desired to reduce power consumption, and in power applications to provide fail-safe operation with simpler circuits. A key trade-off in such devices is between low on-resistance and high breakdown voltage.

The tri-gate structure improved electrostatic control of current flow in the channel by wrapping the gate stack around fins etched out of the channel material.

The III–nitride materials were applied to silicon substrates using metal-organic chemical vapor deposition (MOCVD) to give a 20nm aluminium gallium nitride ($Al_{0.3}Ga_{0.7}N$) top barrier, 300nm GaN channel and 3μm carbon-doped GaN buffer. Carbon doping of GaN has been found to make it highly resistive.

The fabricated devices (Figure 1) featured titanium/aluminium/nickel/gold ohmic source–drain contacts, nitrogen implant planar electrical isolation, inductively coupled plasma (ICP) etched 700nm-long fins/nanowires,

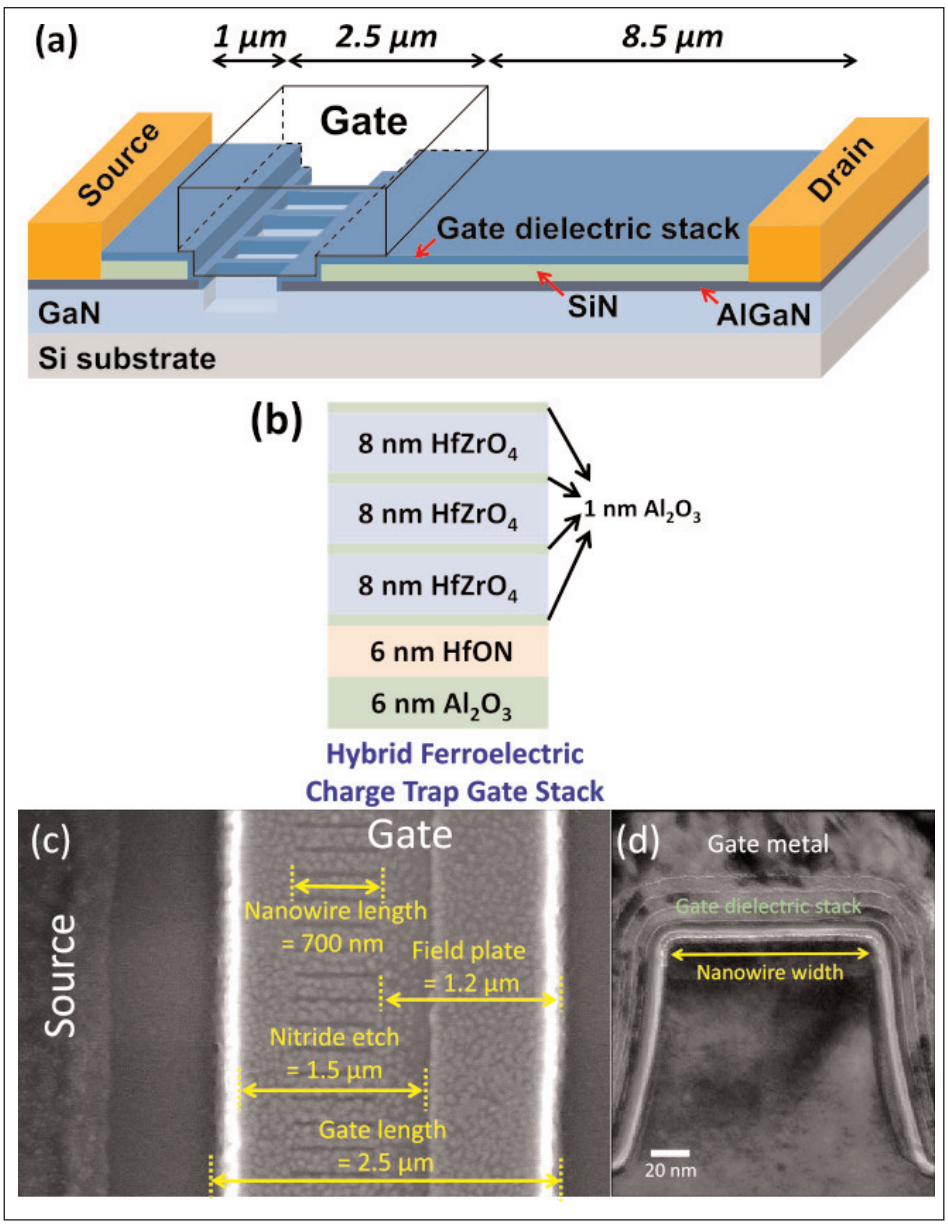

Figure 1. (a) Schematic cross section of GaN tri-gate device with hybrid ferroelectric charge trap gate stack. (b) Schematic cross section of gate dielectric stacks. (c) Top-view scanning electron microscope image of tri-gate device. (d) High-resolution transmission electron microscope image of single nanowire.

50nm plasma-enhanced CVD silicon nitride passivation, ICP etch of silicon nitride in the 1.5μm gate region, atomic layer deposition (ALD) of gate dielectric stack layers, 400°C annealing to crystallize the hafnium zirconium oxide ($HfZrO_4$) in the gate stack, and electron-beam evaporation of the nickel/gold tri-gate.

The gate structure was designed to allow charge trapping in the HfON layer with tunneling through the bottom 6nm Al_2O_3 layer. A comparison planar structure without nanowire/fin etching was also fabricated. The overhang of the gate metal on the drain side was designed as a field plate to increase the breakdown voltage. The nanowire region of the transistor consisted of 119 fins of 140nm height, 100nm width, and 110nm separation.

The transistors were initialized with 12V applied to the gate, charging up the HfON trapping layer of the gate stack. The fin structure enables the charges to be closer to the GaN channel, separated by 6nm tunneling oxide on the sidewalls. This contrasts with the planar structure, and the top of the nanowires, where there is in addition the 20nm AlGaN barrier, giving a 26nm total.

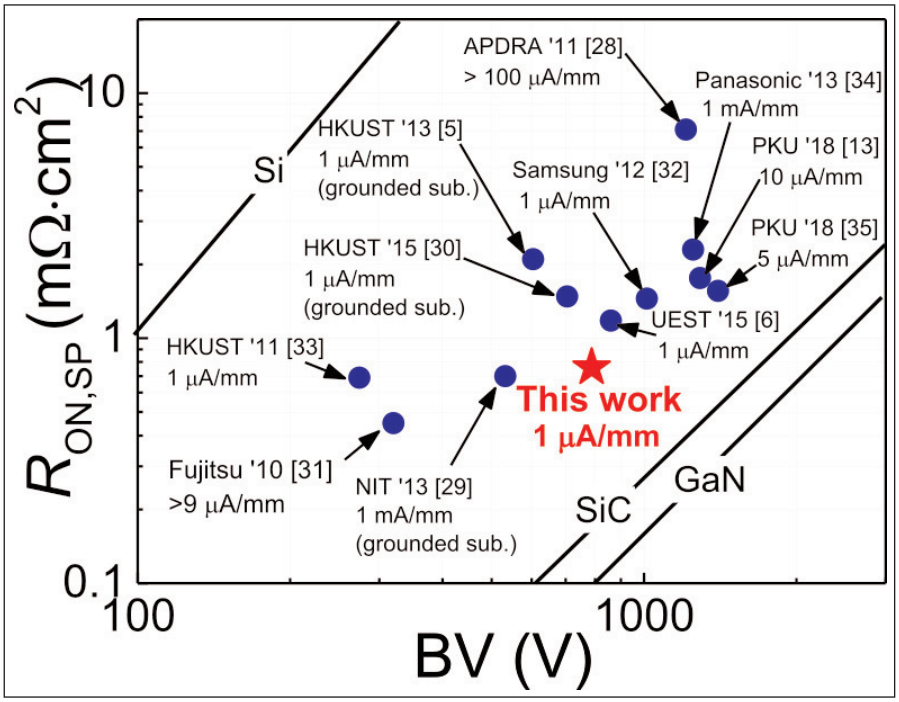

Figure 2. Benchmarking $R_{ON,SP}$ versus BV data of tri-gate device with state-of-the-art normally-off GaN devices.

The closer proximity of the sidewall charge trapping layer increases the threshold voltage of the transistor — +5.38V shift for the nanowire device, compared with a +3.80V shift for the planar gate with 5V drain bias. These shifts enabled a positive 'normally-off' threshold (V_{th}) for 1μA/mm drain current of +2.61V in the tri-gate device, compared with the negative 'normally-on' value of −5.28V for the planar transistor.

The team comments: "The tri-gate device demonstrated the highest V_{th} among the reported normally-off nanostructured GaN device results, this is due to a high density of negative charges stored in the hybrid ferroelectric charge trap gate stack."

The tri-gate finFET also demonstrated better gate control with 73mV/decade subthreshold swing, compared with 83mV/decade for the planar structure. The hysteresis was slightly higher for the tri-gate transistor at 0.19V, compared with 0.1V for the planar device. The researchers blamed etch damage, creating interface traps on the nanowire sidewalls.

The gate leakage of the tri-gate device was 0.4nA/mm with the gate at 12V. The peak transconductance of the tri-gate transistor, 177mS/mm, was lower than that of the planar device, 208mS/mm, due to a lower drain current resulting from removal of more than 50% of the channel width in the fin region.

The maximum drain currents for the planar and tri-gate transistors were 1330mA/mm and 896mA/mm, respectively. The corresponding gate potentials were 10V and 14V. The on-resistance at these gate potentials at 0.5V drain bias were, respectively, 4.3Ω-mm and 5.0Ω-mm. Again, the removal of channel width by the fin etch explains the lower drain current and higher on-resistance of the tri-gate transistor.

The breakdown voltage for a leakage current of 1μA/mm was 788V with 0V gate in the tri-gate transistor. To give an off-state in the planar device, the gate was set at −8V; the resulting breakdown voltages was 738V. The researchers write: "Higher BV for the tri-gate device is due to the field-plate design associated with the tri-gate structure."

The current collapse was investigated with the drain bias off-state stress up to 600V. The off-state time was 10ms. The dynamic on-resistance for 150μs pulses was 1.66x and 1.64x, compared with the DC value (0V drain stress), for the tri-gate/planar transistors, respectively. The on-state was measured with 12V on the gate and 1V drain bias.

In benchmarking breakdown voltage (BV) against specific on-resistance ($R_{ON,SP}$) in other reports (Figure 2), the researchers comment: "To the best of our knowledge, the proposed tri-gate device shows the lowest $R_{ON,SP}$ among reported normally-off GaN device results with BV >650V." The $R_{ON,SP}$ of the tri-gate transistor was as low as 0.76Ω-cm^2.

One worry for the device would be high-temperature performance at~150°C. The team points out that the thermal risk of charge detrapping would lead to V_{th} instability worries. Similar concerns are raised by long-term gate-bias stress. ■

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Author: Mike Cooke

Increasing on-current in III–V transistors on silicon

Researchers claim the highest reported value for 13nm-gate-length device.

IBM Research Zurich in Switzerland claims the highest reported on-current for ultra-scaled III–V field-effect transistors (FETs) on silicon [Clarissa Convertino et al, Jpn. J. Appl. Phys. vol58, p080901, 2019]. The gate length was 13nm and the on-current reached 300μA/μm at 0.5V operating voltage, with the off-current at 100nA/μm.

The device used source-drain spacers and doped extension regions to reduce the off-current and mitigate parasitic bipolar and floating-body effects in semiconductor-on-insulator structures. III-V compound semiconductor transistors integrated on silicon platforms are seen as a way to provide future space for the development of radio-frequency and low-power applications.

A 20nm InGaAs layer was transferred to silicon using direct wafer bonding. The 2-inch diameter InGaAs layer was sourced from a metal-organic chemical vapor deposition (MOCVD) process on indium phosphide.

The InGaAs layer wafer was bonded to the silicon substrate wafer through silicon dioxide layers deposited on both wafers. The silicon dioxide bond created a 25nm buried oxide (BOX) in the final structure. The indium phosphide was removed by wet etch down to an InGaAs/InAlAs heterostructure that served as an etch stop. A slower wet etch removed the stop layers.

Transistor fabrication began with dry etch of InGaAs fins. A dummy gate was formed by deposition of aluminium oxide liner and amorphous silicon. The amorphous silicon was then patterned and etched with inductively coupled plasma reactive ions (RIE) to give the dummy gate.

Silicon nitride (SiN_x) spacers were created using atomic layer deposition (ALD) and RIE. The SiN_x spacers were undercut with a hydrochloric acid digital etch process to create an overhang in which doped source/drain extensions are inserted. The tin-doped n^+-doped InGaAs raised source/drain (RSD) contacts were then regrown using MOCVD.

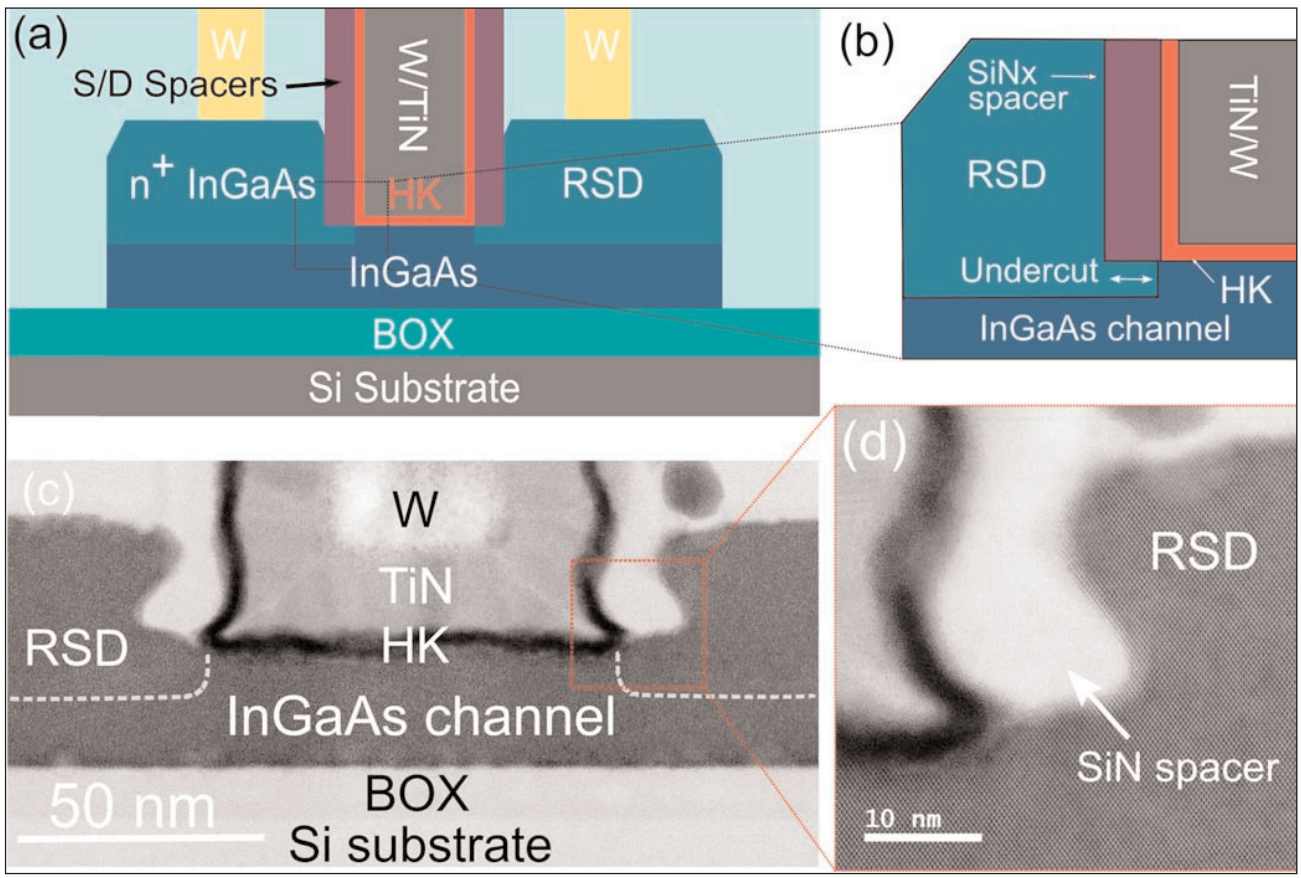

Figure 1. (a) Schematic cross-section of fabricated InGaAs-on-insulator FinFETs. (b) Zoom-in schematic on gate side. (c) Scanning transmission electron microscope (STEM) cross section of 60nm-gate-length device. Dashed line indicates interface between channel and RSD. (d) STEM image on gate side showing 10nm SiN spacers.

Further fabrication consisted of: deposition and chemical mechanical planarization (CMP) of interlayer dielectric; removal of the dummy gate by selective dry etch; plasma-enhanced atomic layer deposition (PE-ALD) of aluminium oxide/hafnium dioxide gate dielectric bilayer and titanium nitride gate metal; sputtering of tungsten (W); CMP; deposition of a second interlayer dielectric oxide; and finishing with a standard level-1 metalization (M1) with source–drain–gate contacts to the devices made through via holes.

A device with 20nm gate length and 15nm fin width (Figure 2) achieved 350μA/μm on-current (I_{ON}) and 100nA/μm off-current (I_{OFF}) at 0.5V drain bias (V_{DS}). The linear and saturation substhreshold swings were 74mV/decade and 78mV/decade, respectively. The researchers claim the on-current is "among the highest for silicon CMOS-compatible III–V FETs".

The team reports: "In comparison to our previous work, based on devices featuring no spacers, we lower the off-current by approximately three orders of magnitude, resulting in a subthreshold slope improvement near the off-current target and thus an overall increase in I_{ON}."

A 13nm gate length FET (25nm fin width) also achieved a high I_{ON} of 300μA/μm with I_{OFF} at 100nA/μm. "This value represents the highest reported on-current for ultra-scaled CMOS-compatible III–V MOSFETs integrated on silicon," the researchers write. ■

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Author: Mike Cooke

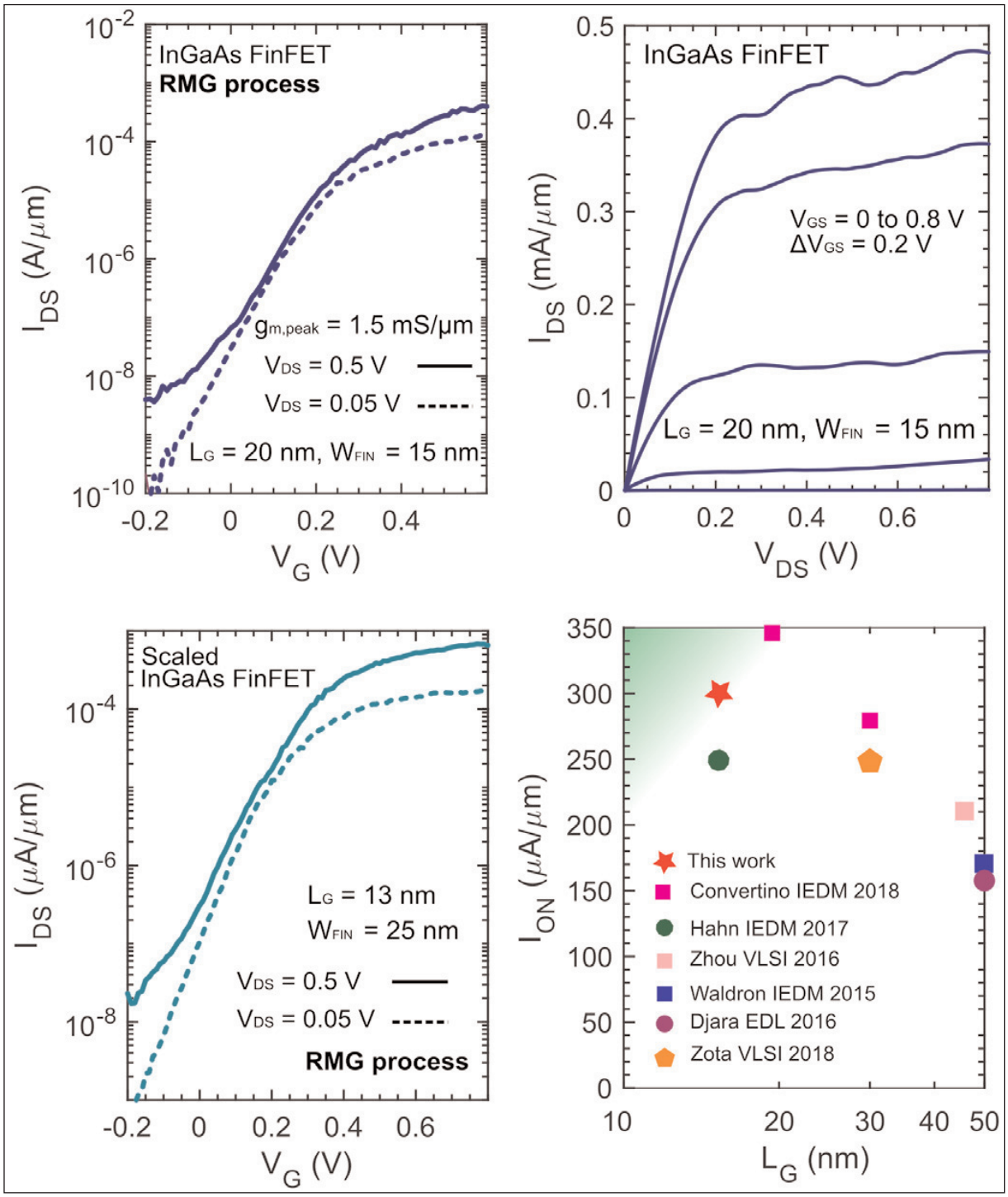

Figure 2. (a) Transfer and (b) output characteristics of InGaAs FinFET with 20nm gate length (L_G) and 15nm fin width (W_{FIN}). (c) Transfer characteristic of shortest 13nm-gate-length device. (d) Benchmarking plot showing I_{ON} (I_{OFF} at 100nA/μm, V_{DS} at 0.5V) versus L_G for different III–V-on-Si technologies. Green-shaded area highlights preferred operation region.

Thermal atomic layer etching of III-arsenide semiconductors

Process used to fabricate fin transistors with 2.5nm channel width.

Massachusetts Institute of Technology and University of Colorado in the USA have been exploring the potential of thermal atomic layer etching (ALE) of III-arsenide compound semiconductor materials with a view to the production of electronic devices such as fin field-effect transistors (finFETs) [Wenjie Lu et al, Nano Letters (2019), 19 (8), p5159].

Thermal ALE is like thermal atomic layer deposition (ALD) in reverse. The first report, in 2015, was for a process that etched aluminium oxide (Al_2O_3).

The researchers used a viscous-flow, hot-wall ALD reactor to perform the ALE. The process was developed on templates with 70nm indium gallium arsenide ($In_{0.53}Ga_{0.47A}s$) on a 300nm indium aluminium arsenide ($In_{0.52}Al_{0.48}As$) buffer. The substrate for the molecular beam epitaxy (MBE) of the templates was semi-insulating indium phosphide (InP).

The team studied three ALE recipes: hydrogen fluoride (HF) and trimethyl-aluminium ($Al(CH_3)_3$, TMA), with and without ozone; and hydrogen fluoride and dimethyl-aluminium chloride ($AlCl(CH_3)_2$, DMAC). The HF provided the fluorination reactant, while the organic aluminium molecules provided the reactive reagent for ligand exchange. The HF/TMA combination has been successfully used for Al_2O_3 and hafnium dioxide thermal ALE.

The team thought that the methyl components (CH_3) of TMA might combine with In and Ga to give volatile trimethyl metal-organic species. It was found that this did not happen. Adding ozone to oxidize the In/Ga metal atoms didn't help to increase the fluorination in preparation for the ligand-exchange.

The researchers comment: "These experiments indicate that TMA is not an efficient metal reactant for InGaAs thermal ALE. TMA can only provide CH_3 ligands during the ligand-exchange reaction. Alternative ligands may be needed for InGaAs thermal ALE."

By contrast, HF/DMAC achieved a 250°C thermal ALE reduction in film thickness of 19Å after 200 cycles and a further 22Å after 400 cycles, according to x-ray reflectivity (XRR) measurements. With an ozone oxidation step, the HF/DMAC process reduced the total film thickness by 50Å after 200 cycles. The latter process left a 23Å oxide layer.

A variety of etch products from the ligand-exchange step are suggested, but the researchers say that these need to be confirmed by mass spectroscopy analysis (Figure 1).

The researchers applied the HF/DMAC ALE to InGaAs/InAlAs vertical nanowire (VNW) structures that were previously etched by a reactive-ion process involving boron trichloride, silane and argon. Before ALE the VNWs were 185nm high and 28nm diameter.

A 300-cycle 250°C ALE reduced the diameter of the InGaAs section to 24nm diameter, while the InAlAs was 18nm. The InGaAs section remained constant under 300 more cycles of ALE, but the InAlAs section reduced further to 10nm.

Increasing the ALE temperature to 300°C enabled thinning of 34nm-diameter VNWs to 24nm and 4nm for the InGaAs and InAlAs sections, respectively, after 250 cycles. The etch rates for InGaAs and InAlAs were 0.24Å/cycle and 0.62Å/cycle, respectively.

The team comments that the delicate structure with a 4nm-diameter stem is possible "because thermal ALE is a gas-phase process without a wet etchant". The researchers add: "In contrast, conventional solution-based self-limiting etching techniques, such as the digital etch, can be destructive to fragile nanostructures."

X-ray photoelectron spectroscopy (XPS) studies suggested that a gallium layer builds up on the etch front of the lower temperature ALE, which inhibits the process. The researchers point out that Gibbs free energy considerations make InAs fluorination more favorable than that for GaAs.

The ALE process was incorporated into a finFET fabri-

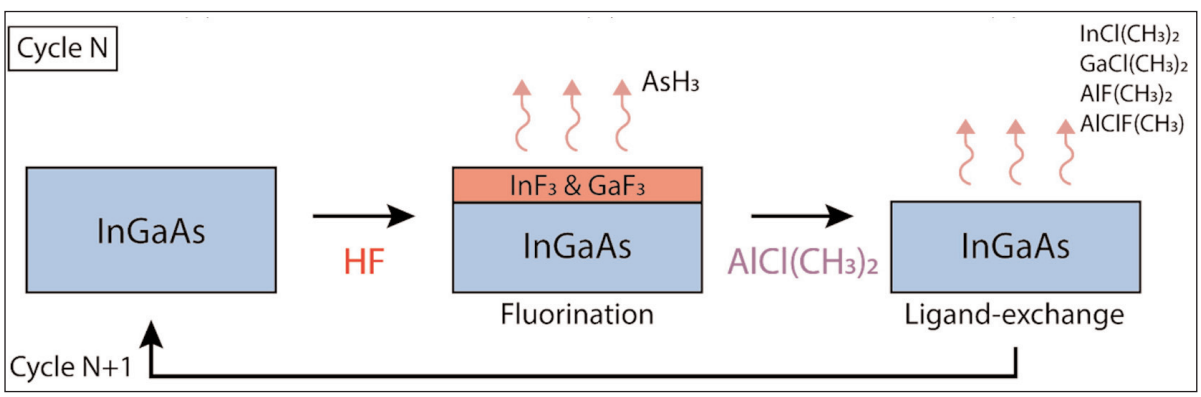

Figure 1. Proposed reaction mechanism of InGaAs thermal ALE.

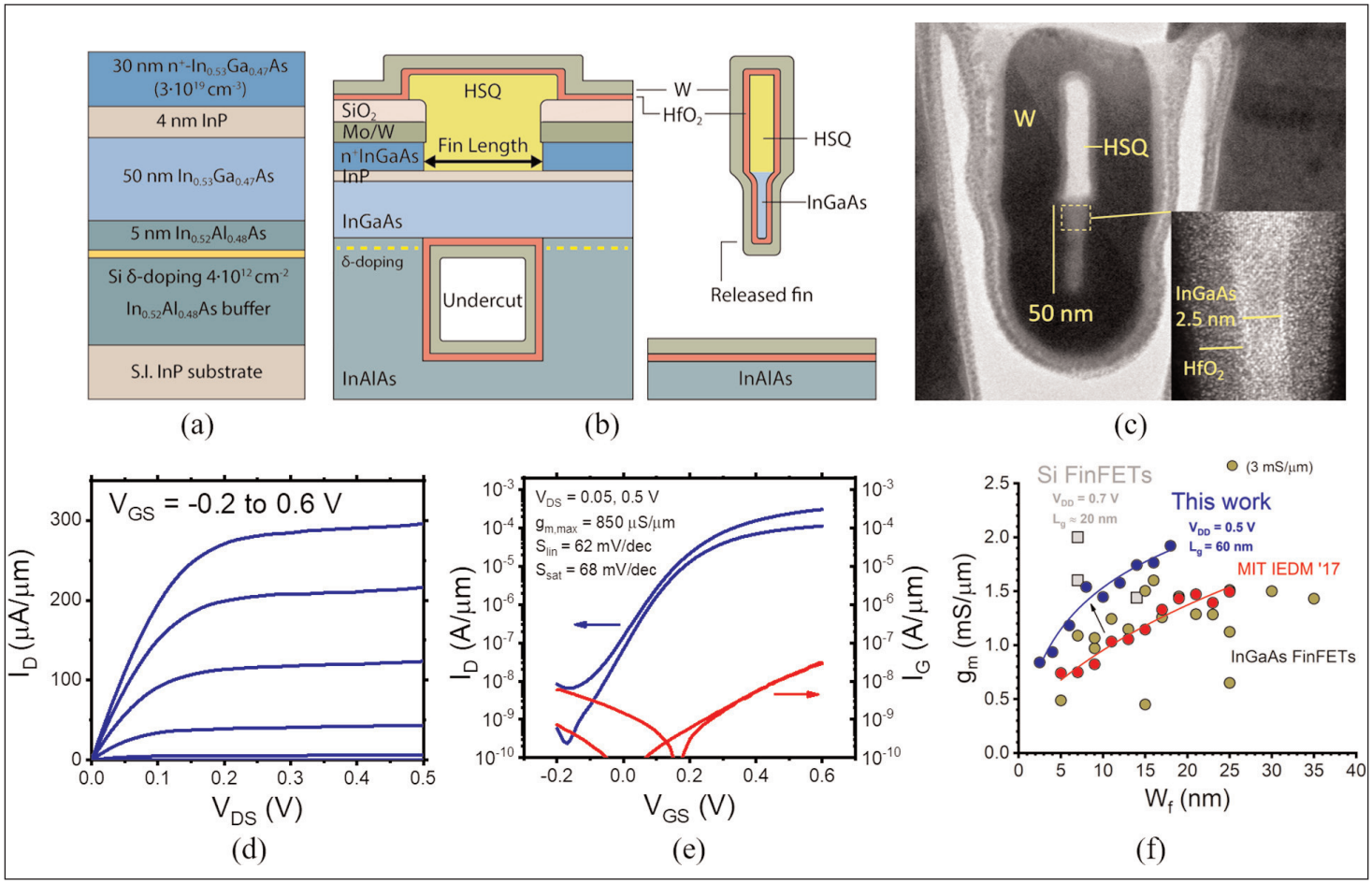

Figure 2. (a) Starting heterostructure for InGaAs n-channel FinFETs grown by MBE. (b) Cross-sectional schematics of FinFET along source-drain direction and across fin. (c) Cross-sectional transmission electron microscope image of finished FinFET with 2.5nm fin width. Inset: close-up of InGaAs channel. (d,e) Output and subthreshold characteristics of 2.5nm-width fin device. (f) Benchmark of maximum transconductance (g_m) as function of fin width (W_f) for InGaAs FinFETs and state-of-the-art Si FinFETs. Blue data from latest work; red data from earlier heterostructure without in-situ thermal ALE and ALD.

cation flow. Dry etch was used to create 24nm-wide fins. An alcohol-based digital reduced the fin width by 1nm/cycle for eight cycles, before loading into the ALD tool for in situ ALE and ALD processing. A 300°C HF/DMAC ALE was run for 250 cycles. This cut through the InAlAs, leaving InGaAs fins suspended in space.

ALD was used to deposit 4.7nm Al_2O_3 and 20nm tungsten all-around gate stacks. Since the etch processes were crystal orientation-dependent, the fin sidewalls were chosen to be along the {011} direction.

The resulting finFETs were found to have fin widths as low as 3nm in the upper section and 4nm in the middle. The researchers comment that the ALE/ALD process results in much sharper metal-oxide-semiconductor interfaces, compared with a similar process without ALE. The team attributes this to the prevention of surface oxidation before the gate-stack deposition.

Complete finFETs were fabricated in an ohmic contact-first, gate-last, self-aligned flow, using the in-situ ALE/ALD process (Figure 2). The hydrogen silsesquioxane (HSQ) hard mask used for patterned etching was not removed from the top of the fins. This means the gate was not strictly 'all-around' but rather formed an inverted trigate wrapping around the bottom of the fin.

The ohmic contacts were formed from molybdenum/tungsten (Mo/W). The gate stack used 3nm ALD hafnium dioxide (HfO_2) as the dielectric — the equivalent oxide thickness was 0.8nm. The ALD W gate metal thickness was 30nm. The preceding ALE fin thinning was 162 cycles HF/DMAC at 300°C. Fin widths ranged from 180nm down to 2.5nm. The gate length was 60nm.

The 2.5nm fin width device demonstrated near-ideal linear (50mV drain) and saturation (0.5V) subthreshold swings of 62mV/decade and 68mV/decade, respectively. The ideal at 300K (room temperature) would be 60mV/decade — many InGaAs devices report around double or even more of that value. The drain-induced barrier lowering (DIBL) was found to be 40mV/V. The peak transconductance was 850μS/μm at 0.5V drain bias. The device was previously reported at the last 2018 IEEE International Electron Device Meeting in December. ■

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Author: Mike Cooke

Wafer-level backside processing of high-frequency indium phosphide chips

Researchers use thinning and through-substrate vias to reduce ground-bounce and resonance instability.

Japan's Nippon Telegraph and Telephone Corp has been working to reduce substrate resonance and ground-bounce effects in indium phosphide (InP)-based chips through wafer-level backside processing [Takuya Tsutsumi et al, IEEE Transactions on Electron Devices, vol66, issue 9 (September 2019), p3771]. The aim is to ensure stable operation of the chips at frequencies needed for sub-millimeter-wavelength electromagnetic radiation and high-speed applications.

The high frequencies of such devices are needed to support future mobile communications: smartphones, 5G, Internet of Things (IoT), autonomous motor vehicles, and so on. The 5G sector is looking to 10Gbits per second data rates using V- and E-band radio frequencies (RFs) of 40–75GHz and 71–76GHz/81–86GHz, respectively. Beyond 5G at 100Gbps data rates, even higher carrier wave frequencies of ~300GHz will be needed.

Also, InP-based integrated circuits (ICs) with high-speed heterojunction bipolar transistors (HBTs) and high-electron-mobility transistors (HEMTs) can be combined with optical emitters and detectors, creating the link between optical fiber and RF networks. The HBT side covers drive circuits for optical transmitters and limiting amplifiers for optical receivers. HEMTs are applied in RF power and low-noise amplifiers.

The 'ground bounce' problem refers to instability at high frequency in the ground potential due to feedback through parasitic capacitors and inductors in the body of the device. Ground bounce generates peaks and dips in small-signal response and increases group delay fluctuation. Ground stability can be improved by connecting the IC ground plane to the module ground potential with through-substrate vias or bonding wires.

Substrate resonance is caused by the RF wavelength being of the order of the size of the IC dimensions — millimeter waves can resonate in millimeter chip cavities. The researchers used wafer thinning and dense via structures to reduce these resonance effects.

The process consisted of a number of steps (Figure 1). First the InP wafer was mounted substrate-side up on a glass substrate, using an epoxy-based UV-cured adhesive. The glass mount also included a sacrificial layer to be used later in the demounting step. The InP wafer was thinned through grinding. The final thickness was either 100μm or 50μm — the smaller value was used for higher-frequency performance.

Vias were formed using hydrogen iodide (HI) inductively coupled plasma reactive ion etch (HI ICP-RIE). The mask material was polybenzoxazole (PBO). The etch process had an InP etch selectivity ratio of 16, relative to PBO. The temperature was carefully controlled to avoid adhesive degradation. At the same time, the temperature needed to be above 150°C for efficient sublimation of halogenated InP in the material removal process. The team reports that it used an interval cooling step during the etching to precisely and reproducibly control the substrate surface temperature, meeting the rigorous thermal constraints.

The researchers comment: "We obtained an InP etching rate of about 1.5μm/min with good reproducibility with good uniformity across the substrate. With the developed etching sequence, we successfully fabricated the vias without residue, and with good shape uniformity and size controllability."

Metallization began with the sputtering of a gold (Au) seed layer, followed by selective electroplating of 7μm of gold. Unwanted gold seed residue was removed with RIE. The team reports that the electroplated gold was conformal, void-free, and without defects. The gold on the bottom of the vias was 4μm thick, due to micro-loading effects, which also affected the material on the side-walls. The electrical connection between the backside gold and the IC devices was made through the vias.

The researchers achieved 2.5 aspect-ratio (AR) vias in thinner 50μm-thick InP wafers, compared with just 2 AR for 100μm-thick chips. The via diameter could also be reduced to 20μm, compared with 40μm for the 100μm thick chips.

The via diameter was actually tapered, being wider on the backside – in the case of 50μm-diameter vias, the backside diameter was 64μm. The topside diameter (bottom of the via in the etch) was a little less than 50μm in both cases.

According to simulations, vias spaced at 50μm were sufficient to suppress substrate resonance effects.

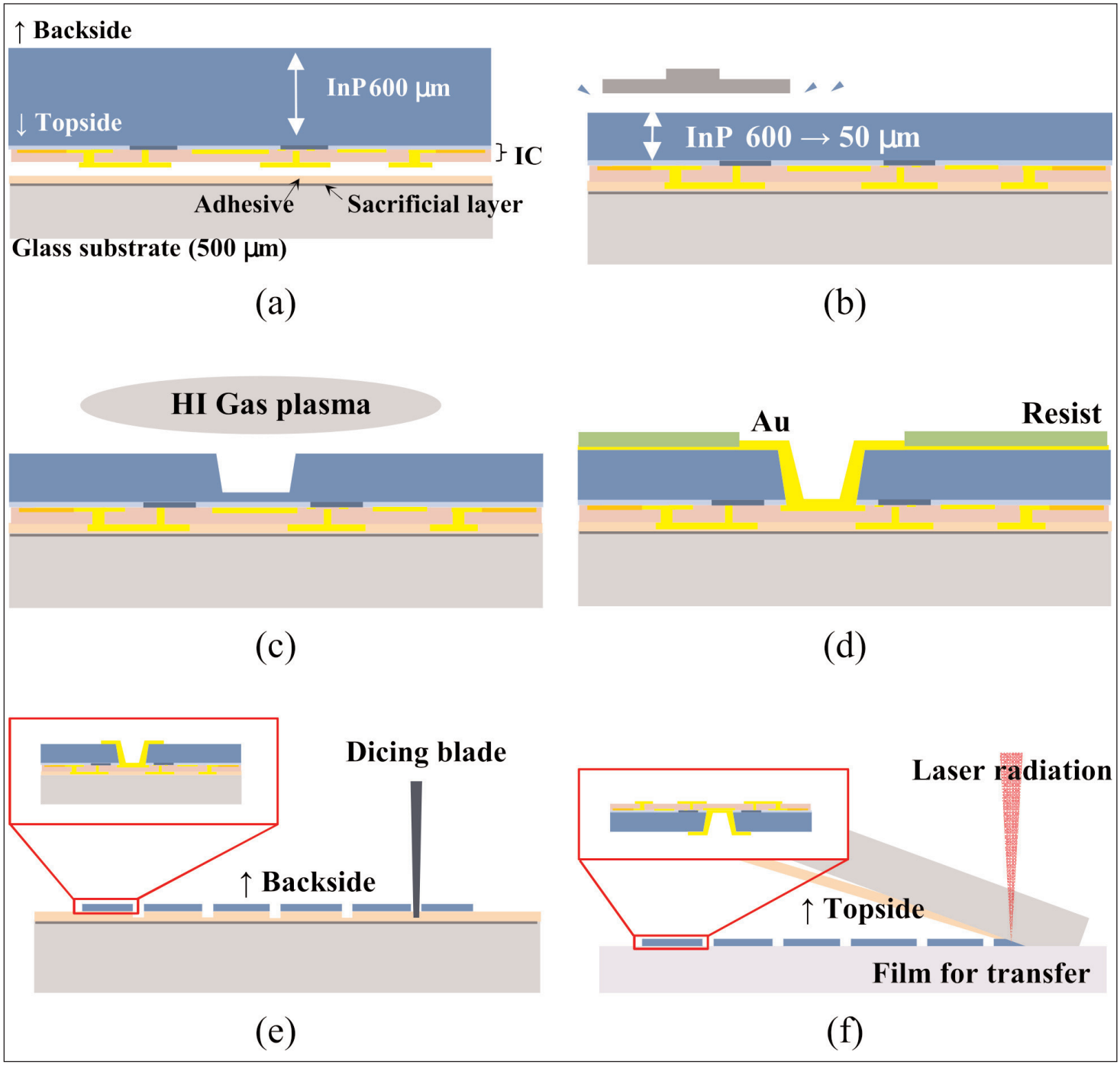

Figure 1. Overview of backside process flow for InP-ICs: (a) mounting on glass substrate; (b) wafer thinning; (c) forming vias by HI-based ICP-RIE; (d) electroplating; (e) backside dicing; and (f) demounting.

The chips were diced by sawing through the InP wafer and part of the adhesive layer. The chips were demounted using 1.06μm infrared yttrium aluminium garnet (YAG) laser radiation, which was transmitted through the glass substrate and absorbed by the sacrificial layer.

The team reports: "The adhesive layer and glass substrate can be easily removed because the sacrificial layer is carbonated by the laser irradiation. Since the InP wafer is already diced, ICs are not broken when partial mechanical stress is relieved by removing the adhesive and glass substrate. Thus, we can successfully obtain crack-free InP-IC chips."

Some negative effects from the laser demounting process were found on InP HBT performance. With the laser power density at 0.31μW/μm^2 (just above the minimum needed), the performance was not degraded between that before and after demounting. By contrast, 0.91μW/μm^2 irradiation increased base–collector leakage current by more than four orders of magnitude.

InP HEMTs seemed rather more robust to the demounting laser power — with no degradation up to 0.78μW/μm^2. At 0.91μW/μm^2, there was a slight increase in the maximum drain current with 1.0V bias.

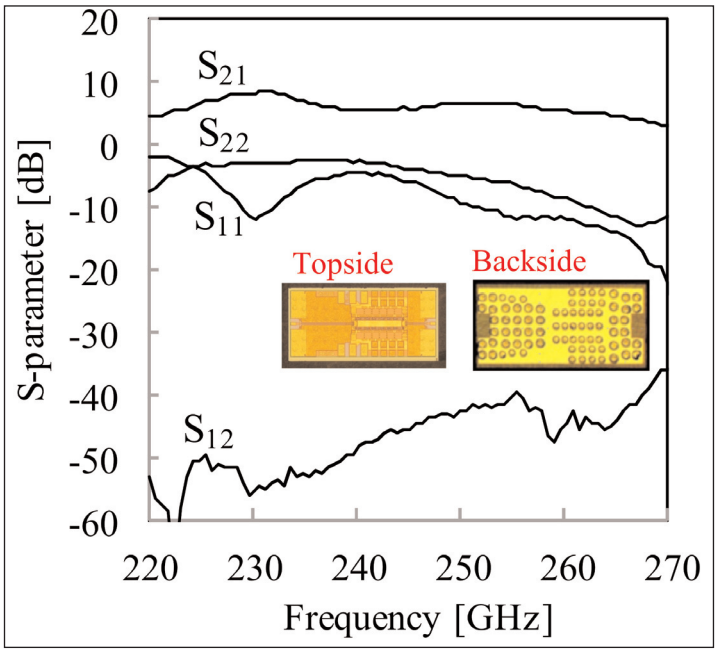

Figure 2. S-parameters of fabricated InP-HEMT-based power amplifier. Inset: topside and backside optical microscope images of InP-HEMT-based power amplifier.

The researchers applied the process to an InP-based HBT limiting amplifier. Such devices could be used in optical receivers for 50Gbps-class NRZ (non-return-to zero) IMDD (intensity modulation direct detection) communication systems.

A 100μm-thick substrate was used since ground-bounce effects were expected to be more important that resonance. Without the backside process, there were dips in the gain-frequency profile of the order 2dB; with the process, the dips were removed giving a smooth curve. The backside process also gave a more consistent group delay with 4ps variation, compared with 14ps for chips without backside processing.

The team comments: "The flatness of the group delay characteristics contributes to improving the waveform quality of RF signals. These experimental results clearly show that thinning the wafer and forming ground vias are effective for achieving stable operation of InP-HBT-based limiting amplifiers with good ground stability."

The 50μm process was applied to 250GHz InP-HEMT-based sub-millimeter-wave monolithic ICs (SMMICs). The higher frequency was expected to make resonance effects more problematic. These effects were dealt with by incorporating a dense array of vias. The researchers report: "This SMMIC is used as a power amplifier in the transmitter of a wireless communications system. Unlike the case for suppressing ground bounce, the vias are densely formed over the whole surface to cut off the substrate resonance."

The suppression of resonance enabled a device that showed no dips in its S21 power gain parameter as a function of frequency (Figure 2). Signal isolation (S12) was below –40dB at 250GHz, "thanks to cutting off signals propagating between the input and output ports by vias," according to the team. Stable amplification was seen between 220GHz and 260GHz with no sign of substrate resonance.

The researchers suggest, based on simulations, that the 50μm process with dense vias could enable frequencies up to 700GHz, beyond the Y-band (325–500GHz) range. ■

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Tel: +33 (0)1 69 31 61 30
Fax: +33 (0)1 69 31 61 79
www.picogiga.com

5 Deposition materials

Akzo Nobel High Purity Metalorganics
www.akzonobel.com/hpmo
Asia Pacific:
Akzo Nobel (Asia) Co Ltd,
Shanghai,
China
Tel. +86 21 2216 3600
Fax: +86 21 3360 7739
metalorganicsAP@akzonobel.com
Americas:
AkzoNobel Functional Chemicals,
Chicago,
USA
Tel. +31 800 828 7929 (US only)
Tel: +1 312 544 7000
Fax: +1 312 544 7188
metalorganicsNA@akzonobel.com
Europe, Middle East and Africa:
AkzoNobel Functional Chemicals,
Amersfoort,
The Netherlands
Tel. +31 33 467 6656
Fax: +31 33 467 6101
metalorganicsEU@akzonobel.com

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

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

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

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

Praxair Electronics
542 Route 303, Orangeburg,
NY 10962,
USA
Tel: +1 845 398 8242
Fax: +1 845 398 8304
www.praxair.com/electronics

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

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

6 Deposition equipment

AIXTRON SE
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52134 Herzogenrath,
Germany
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www.aixtron.com

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CH-9477 Trübbach, Switzerland
Tel: +41 81 403 8000
Fax: +41 81 403 8001
www.evatecnet.com

Ferrotec-Temescal
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Livermore,
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USA
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www.temescal.net

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www.plasmatherm.com

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95873 Bezons Cedex,
France
Tel: +33 (0) 1 39 96 65 00
Fax: +33 (0) 1 39 47 45 62
www.riber.com

SVT Associates Inc
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Eden Prairie, MN 55344,
USA
Tel: +1 952 934 2100
Fax: +1 952 934 2737
www.svta.com

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

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

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

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

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

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

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

9 Materials & metals

Goodfellow Cambridge Ltd
Ermine Business Park,
Huntingdon,
Cambridgeshire PE29 6WR,
UK
Tel: +44 (0) 1480 424800
Fax: +44 (0) 1480 424900
www.goodfellow.com

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

10 Gas and liquid handling equipment

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

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

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

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

11 Process monitoring and control

Conax Technologies
2300 Walden Avenue,
Buffalo, NY 14225,
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Tel: +1 800 223 2389
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E-mail: conax@conaxtechnologies.com

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Conax Technologies is a designer and manufacturer of standard and custom-engineered temperature sensors, compression seal fittings and feedthroughs, probes, wires, electrodes and fiber-optic cables. The company is headquartered in Buffalo, New York, with locations on the US West Coast, Canada, Europe and Asia.

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Tel: +1 734 426 7977
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KLA-Tencor
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USA
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Fax: +1 408 875 4144
www.kla-tencor.com

LayTec AG
Seesener Str. 10–13,
10709 Berlin,
Germany
Tel: +49 30 89 00 55 0
Fax: +49 30 89 00 180
www.laytec.de
LayTec develops and manufactures optical in-situ and in-line metrology systems for thin-film processes with particular focus on compound semiconductor and photovoltaic applications. Its know-how is based on optical techniques: reflectometry, emissivity corrected pyrometry, curvature measurements and reflectance anisotropy spectroscopy.

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

12 Inspection equipment

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

13 Characterization equipment

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

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

14 Chip test equipment

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

15 Assembly/packaging materials

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

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

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

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

16 Assembly/packaging equipment

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

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

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

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

17 Assembly/packaging foundry

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

18 Chip foundry

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

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

19 Facility equipment

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

20 Facility consumables

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

21 Computer hardware & software

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

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

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

22 Used equipment

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

23 Services

Henry Butcher International
Brownlow House, 50–51
High Holborn, London WC1V 6EG,
UK

Tel: +44 (0)20 7405 8411
Fax: +44 (0)20 7405 9772
www.henrybutcher.com

M+W Zander Holding AG
Lotterbergstrasse 30,
Stuttgart, Germany
Tel: +49 711 8804 1141
Fax: +49 711 8804 1950
www.mw-zander.com

24 Consulting

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

25 Resources

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

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

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

event calendar

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

29 September – 3 October 2019
Eleventh Annual Energy Conversion Congress and Exposition (ECCE 2019)
Baltimore, MD, USA
E-mail: ecce@courtesyassoc.com
www.ieee-ecce.org/2019

29 September – 4 October 2019
International Conference on Silicon Carbide and Related Materials (ICSCRM 2019)
Kyoto International Conference Center, Japan
E-mail: icscrm2019-regist@or.knt.co.jp
www.icscrm2019.org

29 September – 4 October 2019
22nd European Microwave Week (EuMW 2019) including:
49th European Microwave Conference (EuMC 2019)
14th European Microwave Integrated Circuits Conference (EuMIC 2019)
Paris Expo Porte de Versailles, Paris, France
E-mail: eumwreg@itnint.com
www.eumweek.com

30 September – 3 October 2019
SCTE-ISBE Cable-Tec Expo 2019
Ernest N Morial Convention Center, New Orleans, LA, USA
E-mail: expo@scte.org
https://expo.scte.org

6–11 October 2019
22nd European Microwave Week (EuMW 2019)
Paris Expo Porte de Versailles, Paris, France
E-mail: eumwreg@itnint.com
www.eumweek.com

7–10 October 2019
38th International Congress on Applications of Lasers & Electro-Optics (ICALEO)
Rosen Centre Hotel, Orlando, FL, USA
E-mail: MARKETING@LIA.ORG
www.icaleo.org

17–18 October 2019
EPIC Meeting on VCSELs Technology and Applications at Sony
Sony Europe BV, Zweigniederlassung Deutschland, Stuttgart Technology Center, Germany
E-mail: neringa.norbutaite@epic-assoc.com
www.epic-assoc.com/epic-meeting-on-vcsels-technology-and-applications-at-sony

17–19 October 2019
LASER World of PHOTONICS INDIA 2019
Bombay Exhibition Centre (BEC), India
E-mail: info@world-of-photonics-india.com
www.world-of-photonics-india.com

20–22 October 2019
9th Annual World Congress of Nano Science & Technology 2019 (Nano S&T-2019) – Small World, Big Thinking, Big Pattern, and Great Development
Suzhou, China
E-mail: selina@bitconferences.com
www.bitcongress.com/nano2019

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29–31 October 2019
7th IEEE Workshop on Wide Bandgap Power Devices & Applications (WiPDA 2019)
Marriott Stateview Hotel,
North Carolina State University (NCSU) campus,
Raleigh, NC, USA
E-mail: rodriguesrostan@ieee.org
www.wipda.org

3–6 November 2019
2019 IEEE BiCMOS and Compound Semiconductor Integrated Circuits and Technology Symposium (BCICTS)
Loew's Vanderbilt Hotel,
Nashville, TN, USA
E-mail: bruce.green@nxp.com
www.bcicts.org

5–8 November 2019
5th International Conference on Advanced Electromaterials (ICAE 2019) — Symposium 8, 'Materials and Devices for Power Electronics'
Ramada Plaza Jeju Hotel,
Jeju Korea
E-mail: secretary@icae.kr
www.icae.kr

7 November 2019
Interlligent UK's 2019 RF & Microwave Design Seminar
Møller Centre, Cambridge, UK
E-mail: info@interlligent.co.uk
www.eventbrite.co.uk/e/interlligent-uks-2019-rf-microwave-design-seminar-tickets-59049393325

12–15 November 2019
SEMICON Europa 2019, co-located with productronica
Munich, Germany
E-mail: SEMICONEuropa@semi.org
www.semiconeuropa.org

9–11 December 2019
65th IEEE International Electron Devices Meeting (IEDM 2019)
San Francisco, CA USA
E-mail: info@ieee-iedm.org
www.ieee-iedm.org

2–6 February 2020
IEEE International Solid- State Circuits Conference (ISSCC 2020)
San Francisco, CA, USA
E-mail: Issccinfo@yesevents.com
www.isscc.org

12–14 March 2020
International Conference on Nano Research and Development (ICNRD-2020) – Breakthrough and Innovation in Nano Science and Technology
Grand Copthorne Waterfront Hotel,
Singapore
E-mail: laura@icnrd.com
www.istci.org/ICNRD2020/Program.asp

15–19 March 2020
IEEE Applied Power Electronics Conference and Exposition (APEC 2020)
Ernest N. Morial Convention Center,
New Orleans, LA, USA
E-mail: apec@apec-conf.org
www.apec-conf.org

21–23 April 2020
24th Annual Components for Military & Space Electronics Conference & Exhibition (CMSE 2020)
Four Points by Sheraton (LAX),
Los Angeles, CA, USA
E-mail: info@tjgreenllc.com
www.tjgreenllc.com/cmse

26–29 April 2020
2nd International Conference on UV LED Technologies & Applications (ICULTA 2020)
MELIÃ Hotel, Berlin, Germany
Abstract deadline: 30 November 2019
E-mail: contact@iculta.com
www.ICULTA.com

10–15 May 2020
2020 Conference on Lasers & Electro-Optics (CLEO)
San Jose Convention Center, San Jose, CA, USA
E-mail: CLEO@compusystems.com
www.cleoconference.org

22–25 July 2020
International Congress on Advanced Materials Sciences & Engineering (AMSE-2020)
Vienna, Austria
E-mail: eve@istci.org
www.istci.org/amse2020

7–11 September 2020
22nd European Conference on Power Electronics and Applications (EPE 2020 ECCE Europe)
Lyon, France
www.epe2020.com

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