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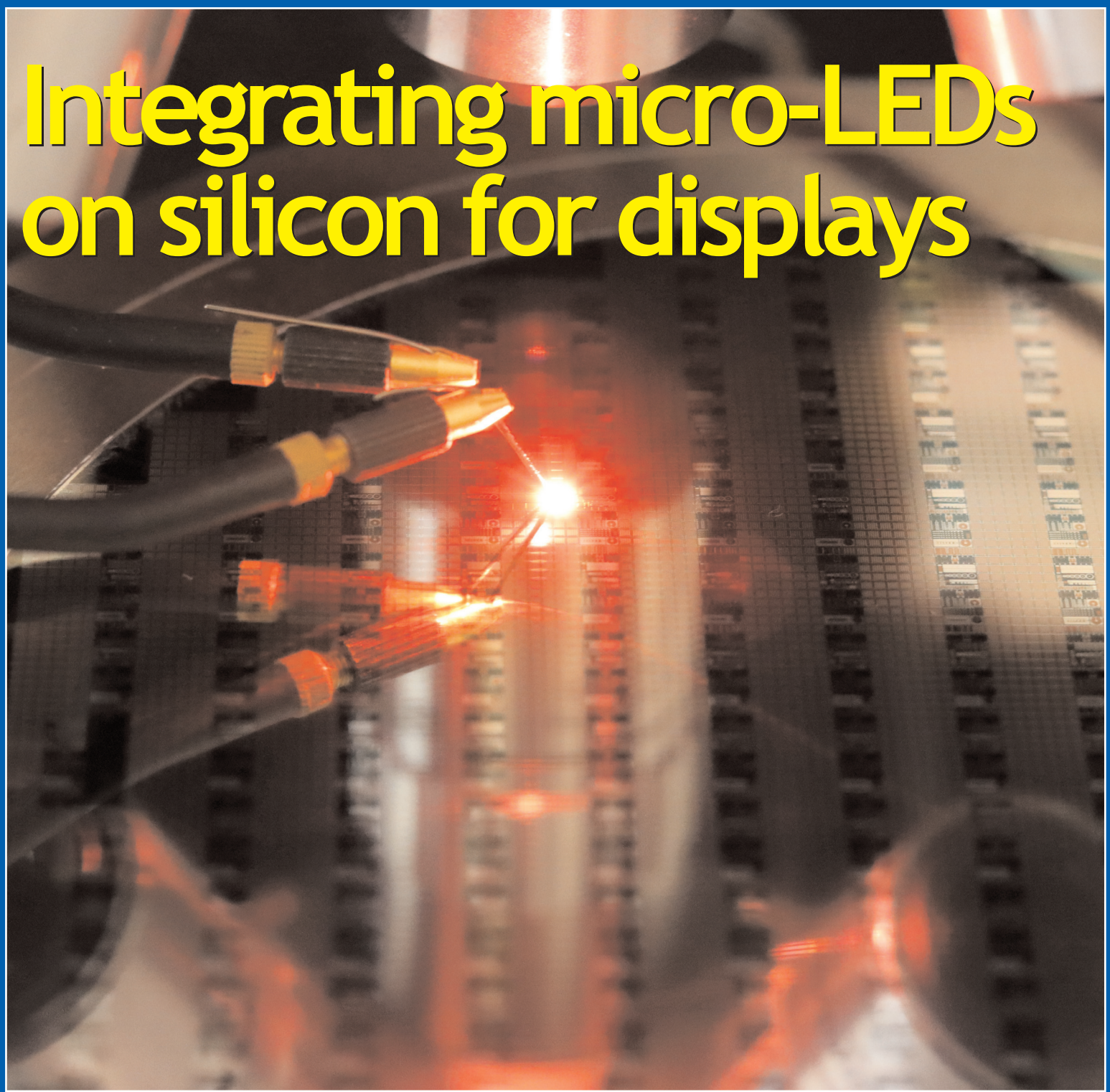

Integrating micro-LEDs on silicon for displays

SiC wafer supply deals flourish • GaN power chargers at CES
Qromis license for Shin-Etsu • TDK invests in SLD Laser

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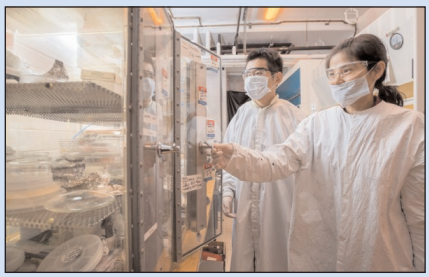
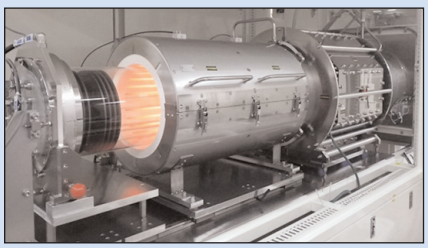
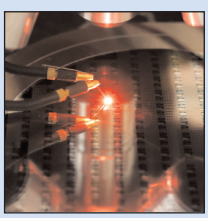


p19 Professor Yuping Zeng (right) and graduate student Peng Cui of the University of Delaware, which has used using a $In_{0.17}Al_{0.83}N$ barrier layer for a record-performance GaN HEMT on Si.

p28 A Cardiff-based consortium gained £5.2m funding for a SMARTExpertise RF-GaN project.



p31 The Japan Science and Technology Agency's 'Newly extended Technology transfer Program' has developed bulk GaN growth equipment based on tri-halide vapor phase epitaxy.



Cover: Plessey has developed what it claims is the first GaN-on-silicon-based red LED, offering lower manufacturing costs, scalability to larger 200 or 300mm-diameter wafers and better hot/cold factor over incumbent AlInGaP-based red LEDs, and enabling integrated RGB micro-LED displays. **p42**

editorial

Wide-bandgap adoption proliferating

Continuing on from the last few months' announcements on developments in silicon carbide (SiC) materials and device production — driven especially by demand for power semiconductors in automotive applications — Germany-based wafer maker SiCrystal (owned by Japanese power semiconductor manufacturer ROHM) has signed a multi-year agreement to supply over $120m of 150mm-diameter SiC wafers to Switzerland's STMicroelectronics to "meet the strong demand ramp-up from customers for automotive and industrial programs" (see page 14).

Such a trend is emphasized by Arizona-based equipment maker Amtech Systems selling its Netherlands-based solar business Tempress Systems — which supplies diffusion and PECVD furnaces — in order to focus on "power semiconductor and silicon carbide growth opportunities", citing electric vehicles as a driver (see page 16).

As well as SiCrystal, fellow wafer maker II-VI Inc has also signed a multi-year deal to supply over $100m of silicon carbide substrates, for gallium nitride RF power amplifiers deployed in 5G wireless base stations (page 15). "GaN-on-SiC RF power amplifiers have superior performance compared with devices based on GaN-on-silicon over a wide spectrum of 5G operating frequencies," II-VI notes. "The accelerating rollout of 5G wireless services is driving deeper strategic relationships in the 5G wireless supply-chain ecosystem to meet the market windows," adds the firm, which recently launched what it claims is the first semi-insulating 200mm SiC that will "enable customers to scale production far into the future".

As a vertically integrated manufacturer, II-VI is also establishing its own 150mm GaN-on-SiC HEMT device manufacturing platform. Likewise, Japan's Sumitomo Electric is expanding its GaN-on-SiC RF HEMT production from 4" to 150mm substrates (after ordering an Aixtron AIX G5+ MOCVD system in 8x6"-wafer configuration), targeting radar, SatCom and 5G base-station applications (page 18).

In addition to wireless RF applications, GaN is also rapidly being adopted for more efficient, smaller/lighter and faster power chargers — ranging up to 300W, as seen at January's Consumer Electronics Show (CES) in Las Vegas, made by the likes of AUKEY, HYPER by Sanho, and Griffin Technology — using GaN-on-silicon HEMTs and power ICs from suppliers including Navitas and GaN Systems (pages 23–27).

Meanwhile, Japanese silicon wafer maker Shin-Etsu is aiming to develop large-diameter (6-12") GaN-on-Si substrates by licensing the GaN substrate technology of Santa Clara-based Qromis (page 33).

While GaN devices are currently used in relatively low-power applications compared with SiC devices in power electronics for automotive applications, the prospect of using GaN for multiple applications in an electric vehicle (traction inverter, DC–DC converter, and on-board charger, as well as the LED lighting) has been demonstrated around Tokyo by the 'All GaN Vehicle' (developed by Toyota Advanced Power Electronics Research Division and Nagoya University Institute for Future Materials and Systems). Toyota has correspondingly shown its commitment to gallium nitride as a member of the 'Mirai Creation Fund II' of SPARX Group that has just invested in Canada's GaN Systems, which develops GaN-based power switching semiconductors for power conversion and control applications (page 22). "GaN has emerged as a critical building block for power in automotive applications," notes SPARX.

Mark Telford, Editor

mark@semiconductor-today.com

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

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

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

Original design Paul Johnson
www.higgs-boson.com

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

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

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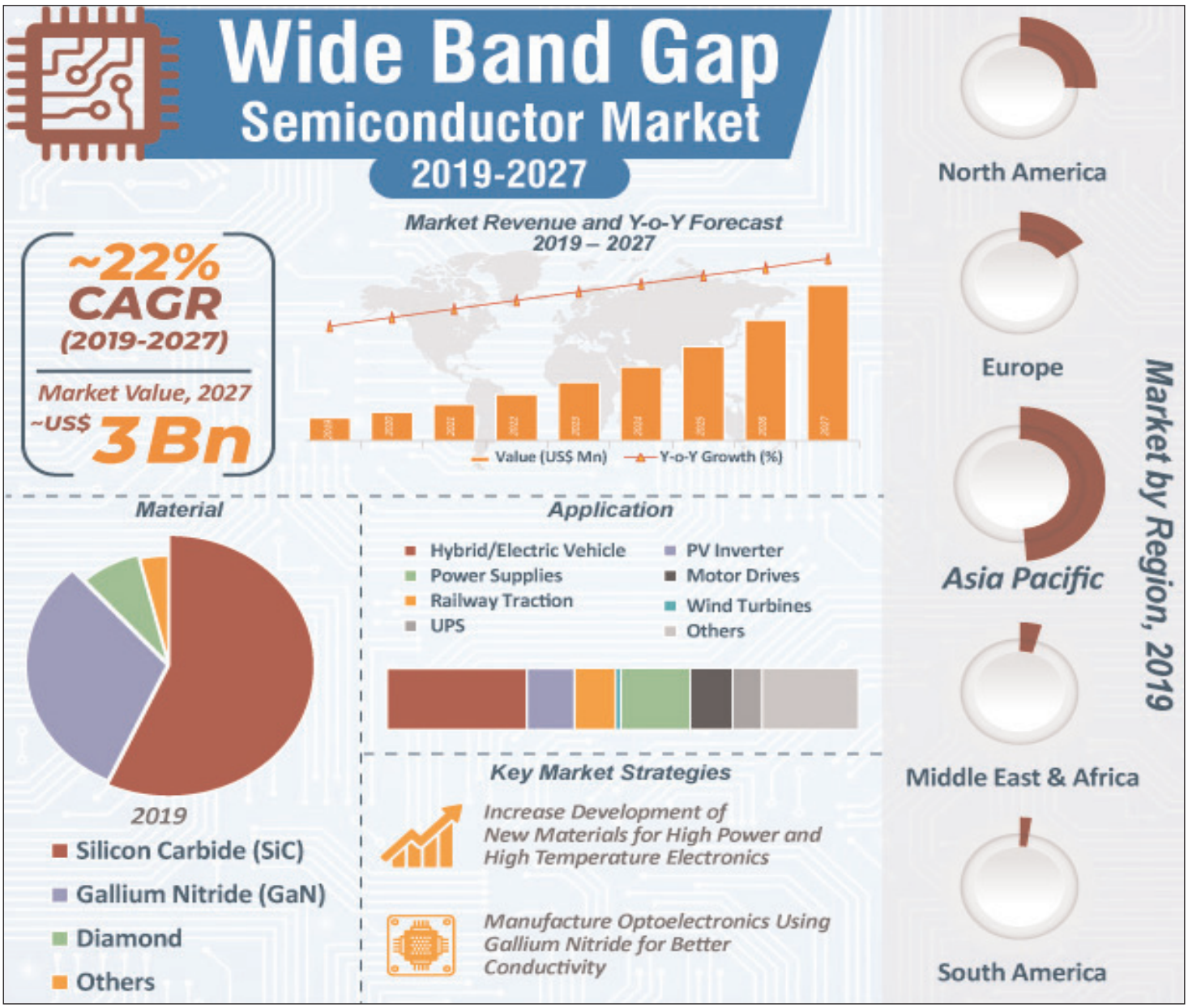
Wide-bandgap semiconductor market to grow at 22% CAGR to $3bn by 2027

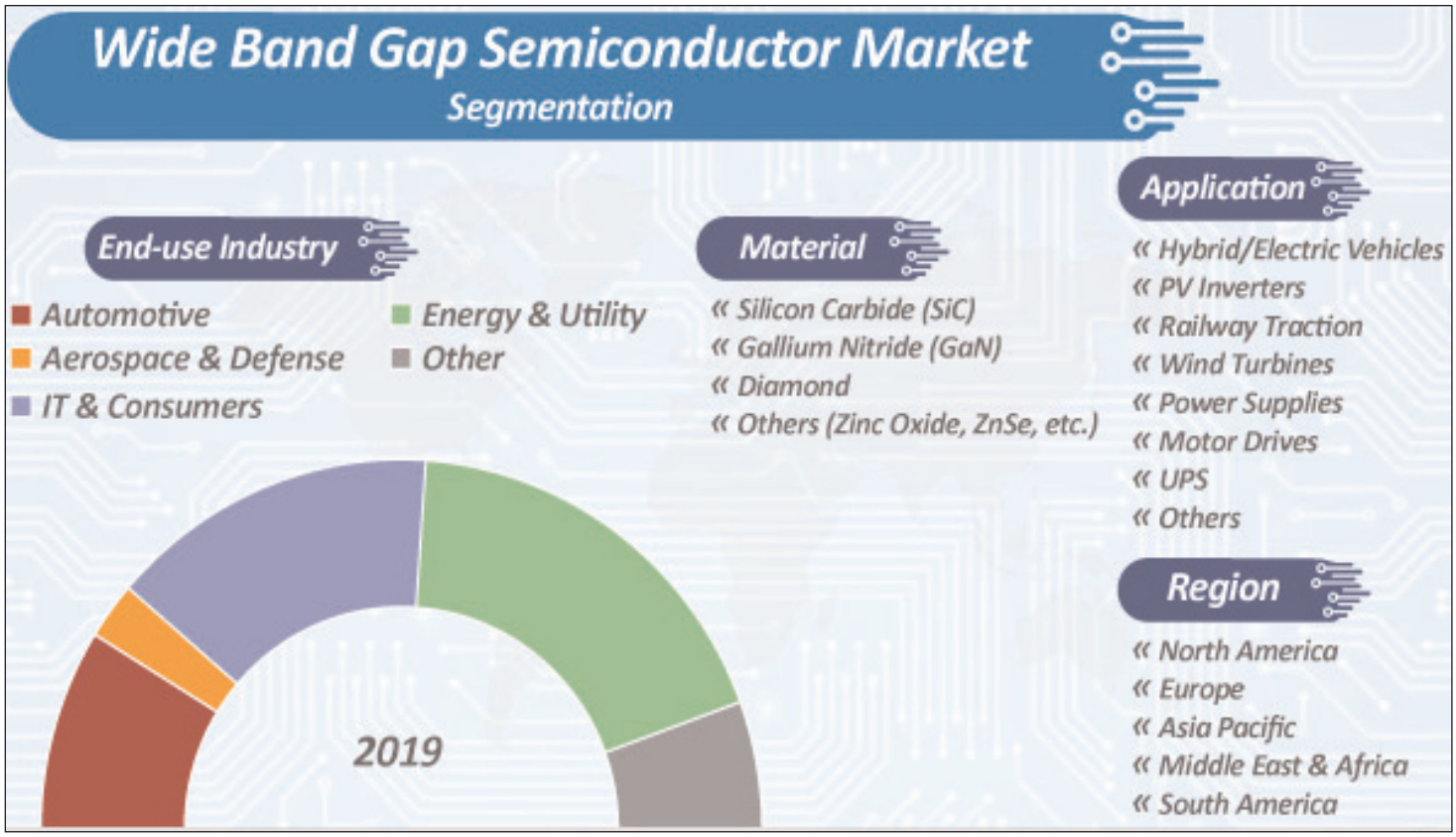
According to a report from Transparency Market Research, the global wide-bandgap (WBG) semiconductor market will rise at a compound annual growth rate (CAGR) of about 22% to $3bn by 2027 — including $1.5bn and $1.2bn for silicon carbide (SiC)- and gallium nitride (GaN)-based semiconductors, respectively — as it continues to be influenced by a range of macroeconomic and market-specific factors.

Rise in demand for power semiconductor devices to drive wide-bandgap market

The use of wide-bandgap semiconductors makes power semiconductor devices smaller, quicker and more reliable and efficient than other available semiconductor materials such as their silicon-based counterparts. Advantages such as light weight, a longer life-cycle and larger energy bandgap offered by wide-bandgap materials make their use preferable in different types of power semiconductor devices.

Wide commercial availability, the decline in the prices of WBG power devices, and increasing demand for SiC and GaN power devices for applications such as telecom equipment, computers, military devices, electric vehicles (EVs) and photovoltaic inverters are expected to drive the global wide-bandgap semiconductor market in the near future.





The increasing investment in wide-bandgap semiconductor materials and their adoption by the power semiconductor industry are expected to boost the global wide-bandgap semiconductor market.

Energy & utility applications to account for leading share

Among materials, silicon carbide accounted for the leading share of the global wide-bandgap semiconductor market in 2018, and is expected to maintain its dominance during the forecast period.

The hybrid/electrical vehicles (HEV) application segment is expected to lead the global wide band gap semiconductor market and expand at a high CAGR during the forecast period.

Energy & utility is a highly attractive end-use industry segment of the wide-bandgap semiconductor market, since it is the largest segment in terms of market size and is expected to grow rapidly during the forecast period. Additionally, a rise in the procurement of wide-bandgap materials by different power semiconductor manufacturers is expected to drive growth of the global wide-bandgap semiconductor market.

Asia-Pacific a highly lucrative wide-bandgap market

The Asia-Pacific region is expected to hold the biggest share of the global wide-bandgap semiconductor market during the forecast period due to the early adoption of wide-bandgap semiconductors in the region. Asia–Pacific and North America account for a considerable market share, and are projected to provide lucrative market opportunities during the forecast period.

China dominated the wide-bandgap semiconductor market in the Asia-Pacific in 2018, and it is expected to grow at a significant CAGR during 2019–2027. Various government organizations across the Asia-Pacific are increasing their spending on research & development for advanced power semiconductor devices. This, in turn, is expected to boost the wide-bandgap semiconductor market in the region. Moreover, a rise in demand for electric vehicles and great interest for 5G-supported devices are some of the major drivers that are likely to propel the wide-bandgap semiconductor market during the forecast period.

Investment in new products development to fuel WBG market

Leading players in the global wide-bandgap semiconductor market are cited as Cree Inc, GeneSiC Semiconductor Inc, Infineon Technologies AG, Panasonic Corp, ST Microelectronics N.V., ON Semiconductor, ROHM Semiconductor, Osram Opto Semiconductors GmbH, TT Electronics, Qorvo Inc, and Broadcom Inc.

As a leading maker of wide-bandgap semiconductor materials (both SiC and GaN), ROHM Semiconductor began mass production of SiC power components such as SiC Schottky diodes and SiC planar MOSFETs in 2010. In February, it announced plans to upgrade its existing production facility for WBG semiconductors with the help of advanced equipment. This should be completed by the end of 2020.

In August, ON Semiconductor added a SiC MOSFET to its product line. The firm expects the new product to see high demand in the near future, due to the rise in the use of WBG semiconductor devices in applications such as automotive electric systems and electric vehicles.

www.transparencymarketresearch.com

Qorvo raises $200m in additional offering of senior notes

Qorvo Inc of Greensboro, NC, USA (which provides core technologies and RF solutions for mobile, infrastructure and defense applications) has completed its offering of an additional $200m worth of its senior notes (maturing in 2029). The offering had been upsized from the $100m initially announced. Paying interest semi-annually at a rate of 4.375% per annum, the additional notes will mature on 15 October 2029, unless earlier redeemed in accordance with their terms.

The additional notes were issued to qualified institutional buyers (pursuant to Rule 144A under the Securities Act of 1933, as amended) and to certain non-US persons (in accordance with Regulation S under the Securities Act).

Qorvo completed the offering of the initial $350m worth of notes on 30 September. The additional offering brings the total amount of the notes offered to $550m.

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

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

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

Qorvo expands cellular Internet of Things portfolio

Cellular IoT partnership with Nordic enables always-on global connectivity for battery-powered devices

Qorvo Inc of Greensboro, NC, USA (which provides core technologies and RF solutions for mobile, infrastructure and defense applications) is expanding its Internet of Things (IoT) portfolio with two RF front-end (RFFE) modules that support the NB-IoT and LTE-M cellular standards.

Featuring what is claimed to be the smallest integrated dual-band module, Qorvo says that its expanded portfolio accelerates global connectivity by helping manufacturers add cellular IoT capability to a range of new devices.

The firm has partnered with fabless semiconductor company Nordic Semiconductor of Trondheim, Norway to develop cellular IoT solutions using Qorvo's RFFE modules. "We are very impressed by the features and performance of Qorvo's new modules," comments Nordic's chief technology officer Svein-Egil Nielsen. "With their high integration level, extensive band coverage and support for both NB-IoT and LTE-M, they enable truly global products — while providing industry-leading power consumption and robust design margins," he adds.

"The NB-IoT and LTE-M standards usher in a new era of always-on global connectivity for a massive number of devices, including applications that weren't previously feasible," notes Eric Creviston, president of Qorvo Mobile Products. "Minimizing RF solution size and power consumption are critical for this new wave of battery-powered devices, many of which will be expected to provide years of unattended and maintenance-free operation."

NB-IoT and LTE-M networks are quickly expanding worldwide. The Ericsson Mobility report estimates that the number of NB-IoT and LTE-M connections tripled during 2019 and will account for more than half of the almost 5 billion cellular IoT connections by 2025. Operators have already launched more than 120 NB-IoT and LTE-M networks

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Qorvo says that leading manufacturers of IoT devices, including wearables, are designing products using its newest modules, which comprise the 4mm x 4mm QM55003 integrated multi-band NB-IoT/LTE-M module (with low-band and mid-band PAs, Tx/Rx filters and switch supporting multiple transmit/receive paths) and the 4mm x 5mm QM55001 multi-band NB-IoT/LTE-M module (with low-band and mid-band PAs and switch, providing flexibility to add filters as required). In addition to compact size, both modules offer what is claimed to be the industry's lowest minimum operating voltage, allowing extended battery life in IoT devices.

www.qorvo.com/applications/internet-of-things

Qorvo supports Wi-Fi Alliance expansion into 6GHz spectrum with Wi-Fi 6E

Qorvo Inc of Greensboro, NC, USA has announced its support for Wi-Fi Alliance efforts to advance the discussion and implementation of Wi-Fi 6E — the extension of Wi-Fi 6 into the 6GHz spectrum and the next step in meeting the growing global demand for high-performance indoor connectivity. Qorvo says it will continue to develop technologies that help to realize all the benefits of this spectrum expansion.

As a member of the Wi-Fi Alliance, Qorvo says that it has long been committed to solving Wi-Fi RF challenges with unique power, filter and front-end products that feature the highest levels of integration, power and efficiency in a small form factor. The firm also designs products that ensure coexistence among multiple industry protocols to promote broader and faster adoption of Wi-Fi systems. These solutions optimize wireless network performance, range and capacity in home environments as well as offices, stadiums and convention centers.

"Qorvo fully stands behind the Alliance and all it is doing to help simplify and enable the 6GHz spectrum," says Cees Links, general manager of Qorvo's Wireless Connectivity business and a founding member of the Wi-Fi Alliance. "We will help pioneer this next generation of Wi-Fi with products that support the entire wireless connectivity ecosystem — enabling faster bandwidth, additional high-capacity channels and new use cases for dedicated, high-capacity backhaul," he adds,

Qorvo's Wireless Connectivity (WCON) business develops wireless semiconductor system solutions for connected devices that support Wi-Fi, Zigbee, Thread and Bluetooth Low Energy. WCON offers integrated Wi-Fi front ends and a portfolio of RF chips and software for the Internet of Things.

www.qorvo.com/applications/internet-of-things

SIA elects ON Semi's CEO Keith Jackson as chair and Qorvo's CEO Bob Bruggeworth as vice chair for 2020

The board of directors of the Washington-based Semiconductor Industry Association (SIA) has elected Keith Jackson, president, CEO & director of ON Semiconductor, as its 2020 chair and Robert Bruggeworth, president, CEO & director of Qorvo, as its 2020 vice chair.

SIA represents US leadership in semiconductor manufacturing, design, and research, with members accounting for about 95% of US semiconductor sales.

"Keith is an accomplished and well-respected industry mainstay with a strong background in semiconductor technology. Bob is a dedicated industry leader and a superb advocate for semiconductor priorities," comments SIA's president & CEO John Neuffer. "Together, their skills and experience will be a tremendous asset to SIA as we move the ball forward on policy priorities of great significance to our industry."

Jackson has more than 30 years of semiconductor industry experience and began serving as president, CEO & director of ON Semiconductor in November 2002. Previously, he was with Fairchild as executive VP & general manager, Analog, Mixed Signal and Configurable Products Groups, and was head of its Integrated Circuits Group. Before that, Jackson served as president and a member of the board of directors of Tritech Microelectronics in Singapore and worked for National Semiconductor Corporation, most recently as VP & general manager of the Analog and Mixed Signal division. He also held various positions at Texas Instruments Inc, including engineering and management positions, from 1973 to 1986. Jackson earned his bachelor's and master's degrees from Southern Methodist University.

"Amid mounting global trade unrest and rising overseas competition, smart government policies are needed now more than ever to ensure continued US leadership in semiconductor technology," said Jackson. "Our industry speaks with one voice through SIA to promote our interests in Washington and capitals around the world, and I look forward to helping guide that effort as 2020 SIA Chair."

Bruggeworth served as president & CEO of RFMD from January 2003 to December 2014, prior to the merger of RFMD and TriQuint to form Qorvo. He was previously president of RFMD from June 2002 until January 2003. Before that, he was also VP and then president of RFMD's wireless products group. Prior to joining RFMD in September 1999, Bruggeworth held various leadership positions at AMP Inc (a supplier of electrical and electronic connection devices) serving most recently as VP of global computer and consumer electronics. He is a graduate of Wilkes University, Wilkes-Barre, Pennsylvania.

"Semiconductor technology is critical to America's economy, national security, and global technology leadership," commented Bruggeworth. "I look forward to working alongside my colleagues at SIA to advance policies that strengthen the semiconductor industry and our country."

www.semiconductors.org
www.qorvo.com

Skyworks powering 5G Massive IoT applications

Skyworks Solutions Inc of Woburn, MA, USA says that its family of connectivity modules are powering the rapidly emerging 5G Massive Internet of Things (Massive IoT) market. Specifically, its turnkey engines provide the critical wireless functionality that is becoming essential for the billions of devices, objects and machines across an increasingly connected world.

IoT manufacturers are embracing cellular connectivity, given its ability to deliver a secure, real-time device-to-cloud connection needed for remote monitoring, control or management. LPWAN (low-power, wide-area network) capability is suitable for widely adopted consumer products such as smartwatches, wearables and asset trackers, as well as industrial and infrastructure applications such as gas, water and electric metering, machine monitoring, factory automation, supply chain and logistics oversight.

"With the emergence of 5G, IoT devices utilizing Skyworks' carrier-certified solutions will go to market faster and be more cost-effective than implementing discrete architectures," says John O'Neill, VP of marketing. "Skyworks has established itself as a leader in developing breakthrough 5G platforms for mobile and has now combined this expertise with market-leading modem technology to provide extremely power-efficient and unmatched integration for IoT innovations globally."

According to a recent 5G Americas white paper, in parallel to the 5G rollout, cellular IoT (i.e. Massive IoT) is becoming the technology of choice for wide-area IoT applications. In a 2019 Mobility Report from Ericsson, cellular-connected IoT devices are predicted to grow from 1 billion units in 2018 to 4.1 billion units by 2024, representing a compounded annual growth rate (CAGR) of 27%. As a subset, LTE-M/NB-IoT (Massive IoT) is expected to represent 45% of this figure, or about 2 billion connections (up from under 10 million in 2018).

Skyworks' claims that the flagship SKY66430-11 is the smallest, fully certified all-in-one device and incorporates a multi-band, multi-chip system-in-package (SiP) enabling cellular LTE-M/NB-IoT (half-duplex FDD) architectures. Integrating Sequans' MONARCH SQN3330 chip provides an entire RF front-end (RFFE), transceiver, power management, memory and baseband modem for an LTE multiband radio operating at 700–2200MHz.

Skyworks says that its SiP has been certified by leading worldwide carriers including KDDI, NTT Docomo, SoftBank and Verizon. Early adopters of Skyworks' Massive IoT portfolio include Pebblebee, Daatrics and GeoTraq.

Other products in the Massive IoT portfolio include the SKY68020-11, SKY68001-31, SKY68001-41, SKY68018-11 and SKY77368-11 multi-band RFFE modules supporting up to Power Class 3 (+23dBm) half-duplex transceiver platforms. These solutions are designed for global 5G Massive IoT network deployments in low- and mid-band frequencies in addition to providing 2G backward compatibility, either natively or through auxiliary ports. These 5G-ready devices work in tandem with all major LTE-M/NB-IoT modems and are currently available.

www.skyworksinc.com/system-solutions/cellular-iot

pSemi's former CEO Jim Cable retires as chairman & CTO

After over 20 years with the firm, Jim Cable is retiring as chairman & chief technology officer of pSemi Corp (formerly Peregrine Semiconductor Corp) of San Diego, CA, USA — a fabless provider of radio-frequency integrated circuits (RFICs) based on silicon-on-insulator (SOI) — and as global semiconductor R&D director for parent firm Murata Manufacturing.

Cable joined the firm in 1996 and was chief operating officer and VP of technology and engineering before becoming CEO in 2002. From 2002 to 2017, he was CEO during a period of high growth, funding rounds, an IPO and Murata's acquisition in 2014.

"Jim has been instrumental to our semiconductor growth strategy at Murata," comments Norio Nakajima, senior executive VP, Module business unit and board member at Murata. "It has now been five years since the closing of the pSemi acquisition, and it has proven to be hugely successful — in large part due to Jim's leadership, his passion for this industry and his dedication to his team."

An early pioneer of SOI technology, Cable believed SOI would ultimately replace gallium arsenide (GaAs) and other technologies in the RF front end, and he encouraged his team to innovate in silicon-on-sapphire (SOS) and SOI. Under his engineering leadership, pSemi pioneered stacked CMOS RF switch integration, solved circuit linearity problems and ultimately manufactured high-performance, multi-throw-count CMOS RF switches that already support more than 40 communications bands and will become even more mission-critical in 5G. Cable is a co-inventor on more than 70 semiconductor and technology patents, including breakthroughs that are now used by most modern cellphones.

In September, Cable was recognized by the SOI Industry Consortium for his role in the advancement of RF SOI globally, where he received an award for the contribution he made to the development of RF switches and SOI technology.

"For the last two decades, Jim has embodied and shaped the pSemi entrepreneurial and innovative culture," says CEO Sumit Tomar. "Every department of our business has greatly benefited from Jim's technical expertise, tenacity and leadership."

www.psemi.com

Sanan IC appoints Plextek RFI as GaAs MMIC design services partner for 5G

Plextek RFI demos 5G mm-wave PA reference design on Sanan IC P15EP1 GaAs technology

Sanan Integrated Circuit Co Ltd (Sanan IC) of Xiamen City, Fujian province (China's first 6-inch pure-play compound semiconductor wafer foundry) has recognized Plextek RFI Ltd of Cambridge, UK (which designs RFICs, MMICs and microwave/millimeter-wave modules) as an authorized resource for gallium arsenide (GaAs) monolithic microwave integrated circuit (MMIC) design services in the emerging 5G market.

The effectiveness of the collaboration has been demonstrated by the recent design by Plextek RFI of a single-chip surface-mount-packaged 4-channel 5G millimeter-wave power amplifier (PA) for the 28GHz spectrum using Sanan IC's P15EP1 0.15µm 6" GaAs E/D pseudomorphic high-electron-mobility transistor (pHEMT) process technology. The reference design was presented by Plextek RFI at the Automated RF and Microwave Measurement Society (ARMMS) conference in Bedfordshire, UK (18–19 November).

"As the 5G infrastructure market expands from sub-6GHz into the millimeter-wave spectrum, RF front-end design activities for the associated telecoms equipment are naturally increasing," says Sanan IC's CEO Raymond Cai. "We are pleased to have Plextek RFI as an authorized design services partner, to assist our customers worldwide in augmenting their GaAs IC design and development resources with RF engineering expertise. We anticipate that our newly launched P15EP1 E/D pHEMT GaAs process will be widely adopted in high-performance millimeter-wave applications, particularly in the 5G space," he adds.

"The roll-out of 5G infrastructure has generated demand for a variety of millimeter-wave RF front-end architectures and topologies that require high-performance GaAs IC designs," notes Plextek RFI's CEO Liam Devlin. "We are delighted to provide our clients innovative solutions and design options to address these requirements, as demonstrated by our compact, multi-channel power amplifier reference design on Sanan IC GaAs technology. We expect to build on this success by leveraging other Sanan IC GaAs processes and exploiting its future roadmap for high-performance, high-integration and high-quality RF designs."

Sanan IC's P15EP1 process is a high-performance 6" GaAs pHEMT technology, integrated with E-mode 0.15µm gate-length transistors with a current-gain cut-off frequency (f_T) of 85GHz and maximum oscillation frequency (f_{max}) of 155GHz. The process is suitable for millimeter-wave power amplifier and low-noise amplifier (LNA) designs, offering excellent gain, low noise figure and wide bandwidth, it is claimed, and can be combined with 0.5µm E-mode/D-mode devices for single-die logic implementation. This technology platform provides up to 3 metal interconnect layers, with 12 mask layers with and a back lapping thickness of 75µm.

The P15EP1 process is part of the P15 family of GaAs technologies, which can provide other options such as D-mode transistors, PIN diodes for switches and limiters, and which will be augmented later next year with a lower process node for higher-frequency support.

www.plextekrfi.com
www.sanan-ic.com

Fujitsu honored with IEEE Milestone for HEMT

The high-electron-mobility transistor (HEMT), developed by Fujitsu Laboratories, has been certified by the Institute of Electrical and Electronics Engineers as an IEEE Milestone. The firm was awarded the IEEE Milestone plaque at a ceremony in Tokyo, Japan.

The IEEE Milestone has recognized historic achievements in fields such as electricity, electronics, information and telecommunications that have contributed to the development of local communities and industries over the past 25 years.

The technology was developed by Fujitsu in 1979 and was recognized for its innovative achievements in improving the performance of radio telescopes and satellite broadcasting receivers.

The HEMT operates at high speed by creating a two-layer structure that spatially separates the source and travel regions of electrons within the transistor. This enables the transistor to receive weak, high-frequency signals with high sensitivity. In 1985, Fujitsu commercialized the HEMT as a microwave device with the world's lowest noise level and it was adopted for the radio telescope at the Nobeyama Radio Observatory (NRO) in Nagano, Japan. A year later, in 1986, the telescope discovered an unknown interstellar molecule.

Also, after being installed in satellite broadcasting receivers around the world, the transistors have become an essential part of various microwave and millimeter-wave devices, such as mobile devices, base stations, GPS receivers and millimeter-wave radar that prevents collisions between automobiles.

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

Lancaster University shows how InAs/AlSb resonant-tunnelling non-volatile memory consumes 100 times less switching energy than DRAM

Work targets manufacturability of working memory chips, including arrays, readout logic, scaling and implementation on silicon

Researchers in the Department of Physics of Lancaster University in the UK have demonstrated how their invention of a new type of memory device could transform the way computers, smartphones and other gadgets work (Dominic Lane and Manus Hayne, 'Simulations of Ultralow-Power Nonvolatile Cells for Random-Access Memory', IEEE Transactions on Electron Devices (2020) January issue; DOI: 10.1109/TED.2019.2957037).

In 'universal memory', data is very robustly stored, but can also easily be changed; something that had widely been considered to be unachievable.

Currently, the two main types of memory — dynamic random-access memory (DRAM) and flash — have complementary characteristics and roles. DRAM is fast and is hence used for active (working) memory, but it is volatile so information is lost when power is removed. DRAM continually 'forgets' and needs to be constantly refreshed. Flash is non-volatile, allowing use in mobile devices but is very slow, so it is well-suited for data storage but can't be used for active memory.

The paper shows how individual memory cells can be connected together in arrays to make RAM, and predicts that such chips would at least match the speed performance of DRAM, but do so 100 times more efficiently, and with the additional advantage of non-volatility.

The new non-volatile RAM (NVRAM), named 'ULTRARAM' (a compound semiconductor charge-storage memory that exploits quantum phenomena for its operational advantages), would be a working implementation of so-called 'universal memory', combining all the advantages of DRAM and flash but with none of the drawbacks, it is claimed. "The work published in this new paper represents a significant advance, providing a clear blueprint for the implementation of ULTRARAM memory," reckons professor Manus Hayne, who is leading the research.

The Lancaster team says that it has solved the paradox of universal memory by exploiting the quantum mechanical effect of resonant tunnelling, which allows a barrier to switch from opaque to transparent by applying a small voltage.

The new work describes simulations of this process. These show that the new NVRAM device consumes very little power, with 100 times lower switching energy per unit area than DRAM, but with similar operating speeds.

Nonvolatility is achieved due to the extraordinary band offsets of indium arsenide (InAs) and aluminium antimonide (AlSb), providing a large energy barrier (2.1eV), which prevents the escape of electrons. Based on the simulation results, an NVRAM architecture is proposed for which extremely low disturb-rates are predicted as a result of the quantum-mechanical resonant-tunneling mechanism used to write and erase.

The work also proposes a readout mechanism for the memory cells that should improve the contrast between logic states by many orders of magnitude, allowing cells to be connected in large arrays. It also shows that the sharp transition between opacity and transparency of the resonant-tunnelling barrier facilitates a highly compact architecture with a high bit density.

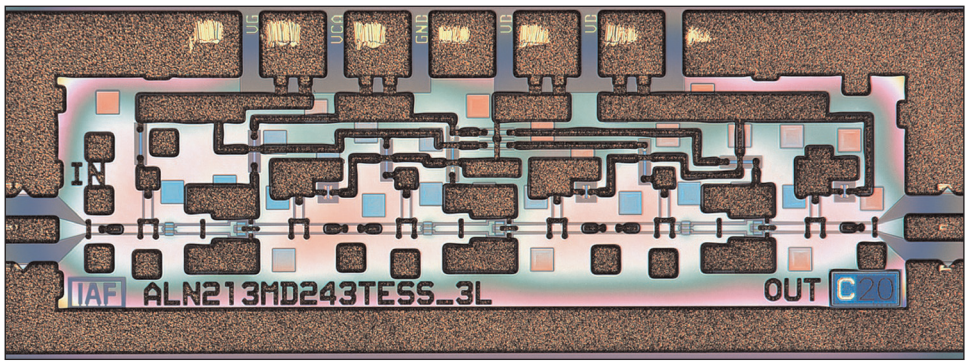
On-going work is targeted at the manufacturability of working memory chips, including the fabrication of arrays of devices, the development of readout logic, the scaling of devices, and implementation on silicon.

https://ieeexplore.ieee.org/document/8948343
www.research.lancs.ac.uk/portal/en/people/manus-hayne

Fraunhofer IAF reports record 640GHz InGaAs MOSHEMT transistors

Replacing InAlAs barrier with Al_2O_3 and HfO_2 isolating layers reduces gate leakage current more than 1000-fold

The Fraunhofer Institute for Applied Solid State Physics (IAF) in Freiburg, Germany has developed a metal-oxide-semiconductor high-electron-mobility transistor (MOS-HEMT) — replacing the Schottky barrier of a conventional indium gallium arsenide (InGaAs)-channel HEMT with an isolating oxide layer (enabling smaller and more powerful devices) — that achieves a record cut-off frequency of 640GHz.



MOSHEMT-based amplifier circuit, operating at 243GHz.

In recent years, the high-frequency characteristics of HEMTs have been steadily improved, becoming faster by downscaling the gate length to 20nm. However, at such small structure sizes, HEMTs encounter problems: the thinner the indium aluminum arsenide (InAlAs) barrier material becomes, the more electrons leak from the current-carrying channel through the gate. These unwanted gate leakage currents have a negative impact on the efficiency and durability of the transistor, which renders further downscaling attempts impossible. The existing transistor geometry of a conventional HEMT has reached its scaling limit. Silicon metal-oxide-semiconductor field-effect transistors (MOSFETs) are no stranger to this problem either. However, they have an oxide layer that can prevent unwanted leakage currents for longer than is the case with HEMTs.

Combining advantages of both transistor technologies

Combining the advantages of III–V semiconductors and silicon MOSFETs by replacing the Schottky barrier of a HEMT with an isolating oxide layer yields a "device which has the potential to exceed the efficiency of current HEMTs by far," says Dr Arnulf Leuther, a researcher in high-frequency electronics at Fraunhofer IAF. "The MOSHEMT allows us to downscale it even further, thus making it faster and more efficient," he adds. With the MOSHEMT technology, Leuther and his team have succeeded in achieving a record maximum oscillation frequency of 640GHz. "This surpasses the global state of the art for any MOSFET technology, including silicon MOSFETs," says Leuther.

Combining the advantages of III–V semiconductors and silicon MOSFETs by replacing the Schottky barrier of a HEMT with an isolating oxide layer yields a "device which has the potential to exceed the efficiency of current HEMTs by far," says Dr Arnulf Leuther. "The MOSHEMT allows us to downscale it even further, thus making it faster and more efficient

High barrier to overcome leakage currents

To overcome the gate leakage currents, the researchers had to use a material with a significantly higher barrier than the conventional Schottky barrier. They therefore replaced the semiconductor barrier material with a combination of isolating layers consisting of aluminum oxide (Al_2O_3) and hafnium oxide (HfO_2). "This enables us to reduce the gate leakage current by a factor of more than 1000," says Fraunhofer IAF researcher Dr Axel Tessmann. "Our first MOSHEMTs show a very high development potential, while current field-effect transistor technologies have already reached their limit."

First IC with MOSHEMTs

The extremely fast MOSHEMT is designed for the frequency range above 100GHz and is therefore especially promising for novel communication, radar and sensor applications. In the future, high-power devices should ensure faster data transmission between radio towers and enable imaging radar systems for autonomous driving as well as higher resolution and precision of sensor systems. Fraunhofer IAF says that, while it will take some years until the MOSHEMT finds its way into commercial application, it has already succeeded in realizing what it claims is the first monolithic microwave integrated circuit (MMIC) amplifier based on InGaAs MOSHEMTs for the frequency range 200–300GHz.

www.iaf.fraunhofer.de

ROHM's SiCrystal wins $120m multi-year deal to supply 150mm silicon carbide wafers to ST

Agreement aims to support commercial expansion of SiC products in automotive and industrial applications

Single-crystal silicon carbide (SiC) wafer maker SiCrystal AG of Erlangen, Germany (a company of power semiconductor manufacturer ROHM group of Kyoto, Japan) has signed a multi-year agreement to supply more than $120m of 150mm SiC wafers to STMicroelectronics of Geneva, Switzerland during what is described as this current period of demand ramp-up for silicon carbide power devices.

"This additional long-term SiC substrate supply agreement comes on top of the external capacity we have already secured and the internal capacity we are ramping," says STMicroelectronics' president & CEO Jean-Marc Chery. "It will enable ST to increase the volume and balance of the wafers we will need to meet the strong demand ramp-up from customers for automotive and industrial programs over the next years," he adds.

"SiCrystal is a group company of ROHM, a leading company of SiC, and has been manufacturing SiC wafers for many years," says SiCrystal's president & CEO Dr Robert Eckstein. "We are very pleased to enter into this supply agreement with our long-standing customer ST. We will continue to support our partner to expand silicon carbide business by ramping up wafer quantities continuously."

The adoption of silicon carbide devices in power electronics is accelerating in both the automotive and industrial markets, say the firms. With this agreement, the two companies aim to contribute to the increasingly widespread use of SiC in these markets.

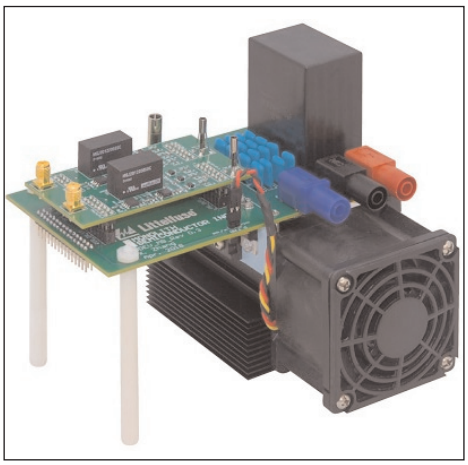
www.st.com
www.sicrystal.de
www.rohm.com/eu

Littelfuse launches Gate Drive Evaluation Platform to speed design cycle for SiC-based power converters

Littelfuse Inc of Chicago, IL, USA, which provides circuit protection technologies (including fuses, semiconductors, polymers, ceramics, relays and sensors), has launched the Gate Drive Evaluation Platform (GDEV) for evaluating silicon carbide (SiC) MOSFETs, SiC Schottky diodes and other peripheral components like gate driver circuitry, so that designers can better understand how silicon carbide technologies will behave in converter applications under continuous operating conditions.

The GDEV offers quick connect header pin terminals that allow for rapid and consistent comparison of different gate drive circuits, unlike most other SiC evaluation platforms, it is claimed. The GDEV supports an 800V DC link input voltage and up to 200kHz switching frequency.

Typical markets and applications for the GDEV include: automotive EV/HEV charging stations; industrial power supplies; data-center servers; telecom base stations; and solar/wind power inverters.



"The Gate Drive Evaluation Platform (GDEV) is a critical addition to our SiC technology portfolio because SiC is still relatively new and there are some unknowns surrounding the operating characteristics under various conditions," says Corey Deyalsingh, director, Power Control, at Littelfuse. "The GDEV helps engineers understand the operating characteristics of SiC devices," he adds. "By utilizing this evaluation platform, designers will be better informed about the incredibly energy-efficient opportunities that SiC technologies present. Equipped with that knowledge, we anticipate that designers will be more likely to incorporate SiC into their future designs."

Littelfuse says that the Gate Drive Evaluation Platform enables users to:

- evaluate continuous operation of SiC power MOSFETs and diodes under rated voltage and rated current, delivering real power to the load;
- analyze system-level impacts associated with SiC-based designs, including efficiency improvements, EMI emissions and passive components (size, weight, cost);
- compare the performance of different gate driver solutions under well-defined and optimized test conditions.; and
- test gate driving circuits under continuous working conditions to evaluate gate driver thermal performance and EMI immunity.

Requests for Gate Drive Evaluation Platform LF-SIC-EVB-GDEV1 can be placed through authorized Littelfuse distributors worldwide.

www.littelfuse.com

II–VI signs multi-year agreement of over $100m to supply silicon carbide substrates

Wafers to be used for GaN-on-SiC RF power amplifiers in 5G wireless base stations

Engineered materials and optoelectronic component maker II–VI Inc of Saxonburg, PA, USA has signed a multi-year agreement of over $100m (the firm's largest ever) to supply silicon carbide (SiC) substrates for gallium nitride (GaN) RF power amplifiers deployed in 5G wireless base stations.

The accelerating rollout of 5G wireless services is driving deeper strategic relationships in the 5G wireless supply-chain ecosystem to meet the market windows, notes II–VI. The new agreement builds on the firm's experience as a global supplier of SiC substrates for the 4G and 5G markets.

"GaN-on-SiC RF power amplifiers have superior performance compared with devices based on GaN-on-silicon over a wide spectrum of 5G operating frequencies, from the low gigahertz range to millimeter-wave bands," claims Dr Gary Ruland, VP, Wide Bandgap Semiconductors business unit. "Customers forge strategic partnerships with II–VI because of our long track record of pushing the technology forward with larger substrate diameters and industry-leading crystal quality," he adds. "II–VI's recently announced semi-insulating 200mm silicon carbide substrates, the first in the world, will enable our customers to scale production far into the future."

Leveraging an intellectual property portfolio of 30 active patents, II–VI is developing SiC substrates using proprietary technologies including crystal growth, substrate fabrication, and polishing.

The firm is also expanding its ability to drive the 5G RF roadmap by establishing a vertically integrated, 150mm GaN-on-SiC HEMT device manufacturing platform.

In addition to SiC substrates, II–VI provides an array of wavelength-management solutions and transceivers for the wireless optical access infrastructure.

Altogether, II–VI says that it offers a broad range of materials, devices, components and subsystems to enable the coming large-scale 5G rollout.

www.ii-vi.com

II–VI wins Best Strategic Partner Award from Dynax for supplying SiC substrates for wireless RF devices

II-VI Inc has won the Best Strategic Partner Award from China-based Dynax Semiconductor Inc as its supplier of silicon carbide (SiC) substrates for wireless RF devices.

Dynax's founder & CEO Dr Naiqian Zhang presented II-VI with the award for its outstanding supplier performance in quality, delivery and service. II-VI supplies Dynax with semi-insulating SiC substrates that enable GaN-on-SiC (gallium nitride-on-silicon carbide) RF power amplifiers deployed in 4G and 5G wireless base stations.

"Demand for GaN-on-SiC power amplifiers is increasing rapidly," notes Dr Gary Ruland, VP for II-VI's Wide Bandgap Semiconductors business unit. "II-VI continues to receive prestigious supplier and industry awards in China, demonstrating our strategic relationship with our customers in that region."

Semi-insulating SiC substrates enable RF power amplifiers for next-generation wireless networks operating over a wide frequency spectrum in the gigahertz range, including in the millimeter-wave bands. II-VI is a leading supplier of SiC substrates, with a strong technology portfolio of 30 active patents and with highly differentiated and proprietary manufacturing platforms and technologies including crystal growth, substrate fabrication, and polishing.

www.dynax-semi.com

Amtech completing sale of solar business in January

Equipment maker refocusing on power semiconductor and silicon carbide markets

Amtech Systems, Inc of Tempe, AZ, USA, a manufacturer of capital equipment (including for thermal processing and wafer handling and polishing) and related consumables for fabricating semiconductor devices such as silicon carbide (SiC) and silicon power chips, electronic assemblies and light-emitting diodes (LEDs), says that, due primarily to the year-end back-log of European notaries, the closing date on the sale of the remainder of its solar business Tempress Systems BV of Vaassen, The Netherlands, which supplies high-throughput diffusion and plasma-enhanced chemical vapor deposition (PECVD) furnaces, was delayed to January.

"In line with our strategic plan, we are completing the final steps necessary for the solar divestiture project and are moving forward with our full attention on our power semiconductor and silicon carbide growth opportunities," says executive chairman & CEO J.S. Whang. "The sale of R2D Automation [of Montpellier, France, which designs and makes wafer automation and handling equipment for the solar and semiconductor industries] to key members of their management team closed on 13 December 2019, and we are pleased that the Tempress divestiture will be completed in January," he adds. "With the solar divestitures, we are well positioned to realize profitable growth and enhance value for all stakeholders," he believes.

In July, Amtech said that its subsidiary PR Hoffman Machine Products Inc of Carlisle, PA, USA (which manufactures double-sided lapping and polishing machines, and complementary products including carriers, wafer polishing templates and machine parts) was moving to a larger manufacturing facility (to be operational in January) and had hired a business development manager.

"Our current manufacturing operations are at capacity," noted chief operating officer Michael Whang. "We are near doubling our manufacturing footprint and positioning our business to meet the expected longer-term increase in demand for our distinctive SiC, optics and silicon substrate solutions. The larger floor space plus the planned additional manufacturing equipment will improve manufacturing flow, add greater efficiencies and, importantly, reduce lead times," he added. "With the addition of our business development manager, who is an industry veteran, we are positioning PR Hoffman to maximize growth opportunities, while maintaining their outstanding customer service."

"We are very excited about the expanding market for SiC, optics, and silicon that is supported by the continuously growing demand for power devices used in electric vehicles, automotive sensors, consumer and industrial IoT, 5G mobility, artificial intelligence, and big data," commented J.S. Whang. "As this market grows, our strategy is to ensure the highest level of responsiveness to increasing demand from current and future customers, to bring timely product innovations to the marketplace, and capitalize on select external opportunities to further enhance our growth. Our move to this larger facility is an important step in our overall plan to capitalize on the attractive opportunities in the semiconductor marketplace, profitably grow our business, and enhance the value of our company for all stakeholders."

Amtech also owns the subsidiaries Bruce Technologies Inc (BTI) (which makes automation systems for semiconductor diffusion furnaces) and BTU International Inc (which supplies thermal processing equipment for electronics manufacturing), both of Billerica MA, USA.

www.prhoffman.com
www.amtechsystems.com

Atom Power unveils 2nd-generation digital circuit breaker, incorporating SiC power modules

Atom Power of Charlotte, NC, USA, which invented what is claimed to be the first commercial digital solid-state circuit breaker, has unveiled its Generation 2 Atom Switch, which is now UL Listed to UL 489I — the standard for solid-state circuit breakers. In May, the Generation 1 Atom Switch was the first of its kind Listed to UL 489I.

The next generation of Atom Power's technology contains the firm's own proprietary silicon carbide (SiC) power modules, doubling the performance compared with the Generation 1 Atom Switch.

Atom Power is said to be the first company to use wide-bandgap (WBG) semiconductors in commercially available solid-state circuit breakers, and the only firm to manufacture SiC modules specifically for use in circuit protection. The models SWXFT100CPM and SWXFT50CPM SiC power modules are UL Recognized to UL 1557.

Innovations of the Generation 2 Atom Switch include: increased interrupting rating; additional firmware capability (including new internal self-diagnostic and enhanced maintenance functions); and significantly reduced manufacturing time (10-times faster to assemble than Generation 1).

"With the first-generation Atom Switch, we introduced the first ever circuit breaker on the market that completely controls the flow of power via software and solid-state semiconductors," says co-founder & chief technology officer Denis Kouroussis. "Now, by incorporating semiconductor power modules that we designed and manufactured ourselves, we have taken our technology to the next level," he adds. "With enhanced performance capabilities and faster assembly times, our Generation 2 circuit breaker is more accessible than ever and furthers our mission of revolutionizing power management."

"The vision is to completely transform power distribution to meet our modern energy needs, and to reach a future where energy is fast, safe and intelligently controlled for the first time," says CEO Ryan Kennedy. "The Generation 2 circuit breaker marks a new milestone in fulfilling that vision and making intelligent power more accessible and attainable to more people."

www.atompower.com

Filtronic expands hybrid microelectronics assembly & test facility with $1.3m equipment investment

Workforce also increased to meet demand for E-band transceiver modules and custom design & manufacturing services

Filtronic, which designs and manufactures antennas, filters and millimeter-wave (mmWave) products for the wireless telecoms and critical communications markets, has invested more than $1.3m in new equipment for its manufacturing facility in Sedgefield, UK. The expansion will enable Filtronic to significantly increase capacity to meet growing demand for both its highly integrated E-band transceiver modules for mobile telecoms backhaul infrastructure and its precision hybrid microelectronics assembly & test services, including mmWave device packaging and sub-assembly manufacturing.

The new equipment includes automated pick-and-place and wire-bonding machines to augment Filtronic's existing assembly and production lines.

"5G backhaul network deployments are now driving a significant increase in demand for our E-band transceiver modules and a growing demand for microelectronics assembly services, in particular at microwave and mmWave frequencies," says executive chairman Reg Gott. "In addition to being able to produce high volumes of our own mmWave transceiver modules and filter products, the quality of our microelectronics assembly line and test capability is attracting an increasing level of business for our custom design and manufacturing services," he adds. "As a result, we are also increasing our workforce to cope with this demand."

5G backhaul network deployments are now driving a significant increase in demand for our E-band transceiver modules and a growing demand for microelectronics assembly services, in particular at microwave and mmWave frequencies

Filtronic's hybrid microelectronics assembly & test services include: low-void die attach and precision component placement; fully automated wire bonding with deep-access multi-level capability; hermetic sealing; and automated test to 90GHz and above. Proprietary air-cavity packages can include mixed gallium arsenide (GaAs), gallium nitride (GaN) and silicon die within a single package, and are capable of performing at frequencies higher than 90GHz.

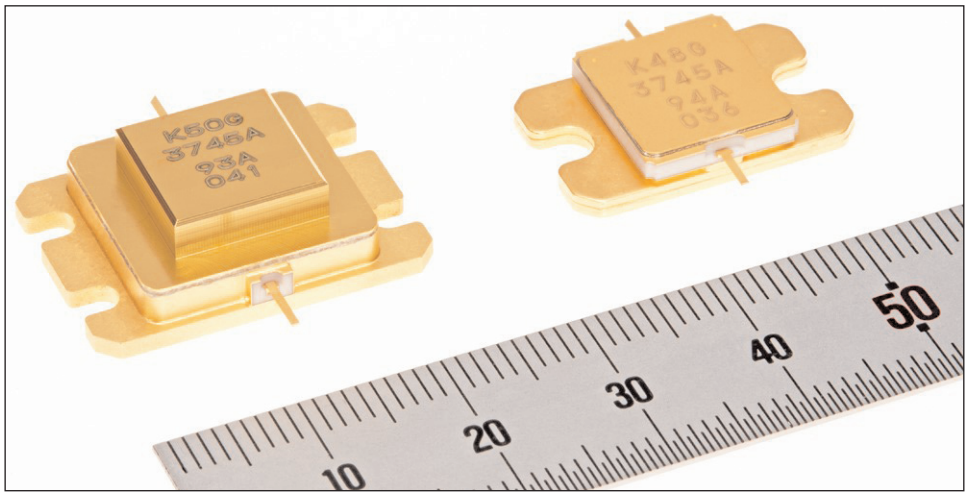
www.filtronic.com

Mitsubishi expanding lineup of Ku-band GaN HEMTs for SATCOM earth stations with 70W & 100W models

Tokyo-based Mitsubishi Electric Corp is expanding its lineup of gallium nitride high-electron-mobility transistors (GaN HEMTs) for satellite communications (SATCOM) earth stations with the addition of new Ku-band (12–18GHz) 70W and 100W GaN HEMTs (operating at frequencies of 13.75–14.5GHz) suitable for multi-carrier applications.

Demand for Ku-band satellite communications and satellite news-gathering (SNG) is growing rapidly to support communications during natural disasters and in rural areas where the installation of cable network equipment is difficult. In addition, increasingly large-capacity, high-speed communications have expanded needs for both multi-carrier and single-carrier satellite communications.

The new 70W (48.3dBm) MGFK48G3745A model GaN HEMT uses a new matching circuit to deliver what is claimed to be the industry's widest offset frequency of up to 400MHz (80 times higher than that of existing models) and a low third-order intermodulation distortion (IMD3), for large-capacity, high-speed satellite communications (including for multiple carriers).



GaN HEMTs for Ku-band SATCOM earth stations: the 100W MGFK50G3745A (left) and 70W MGFK48G3745A (right).

The new 100W (50.0dBm) MGFK50G3745A model GaN HEMT uses optimized transistor matching circuits to deliver a combination of what is said to be unmatched peak output power of 100W together with low IMD3 and an offset frequency of up to 200MHz, helping to downsize SATCOM earth stations by reducing on-board components.

Mitsubishi Electric begins shipping samples of both new models on 15 January. The firm expects its new GaN HEMTs to accelerate the realization of smaller earth stations as well as faster and larger-capacity communications for various needs.

www.MitsubishiElectric.com/semiconductors

Sumitomo Electric to begin 150mm GaN-on-SiC production after ordering Aixtron AIX G5+ system

Deposition equipment maker Aixtron SE of Herzogenrath, near Aachen, Germany says that Japan's Sumitomo Electric Device Innovations Inc (SEDI), a subsidiary of Sumitomo Electric Industries Ltd, has ordered an AIX G5+ metal-organic chemical vapor deposition (MOCVD) system with 8x6-inch wafer configuration (for delivery in 2019) in order to expand its production capacity of gallium nitride-on-silicon carbide (GaN-on-SiC) radio frequency (RF) devices for wireless applications such as radars, satellite communication and base stations for the rapidly expanding 5G mobile networks.

SEDI has already been relying on Aixtron's Showerhead technology for the production of 4-inch GaN high-electron-mobility transistor (HEMT) epitaxial wafers. The progressive deployment of 5G networks but also the introduction of new technologies like beamforming is expected to drive a rapid upturn in demand, steering the adoption of more efficient 6-inch substrates for RF applications on Aixtron's proven Planetary systems.

The new reactor is equipped with an EpiCurve TT metrology system as well as Auto-Feed Forward and P400 UV Pyrometer Close Loop temperature control. Aixtron adds that the system's wafer uniformity and precise process control is especially important for device production on cost-intensive silicon carbide wafers.

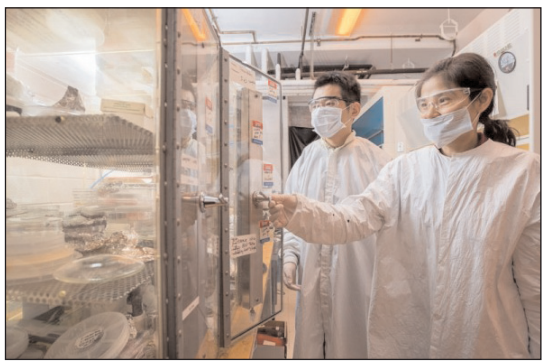
Sumitomo Electric Device Innovations Inc has an established portfolio of RF components, including a range of GaN HEMT devices for radar, mobile phone base stations, and general applications. The GaN-on-SiC HEMT devices enable high power amplification at operating frequencies of 28–40GHz and beyond, as required by new 5G communication standards.

www.aixtron.com
www.sedi.co.jp

University of Delaware reports record-setting InAlN/GaN HEMTs on silicon

Transistor achieves gate leakage current of $7.12x10^{-7}A.mm^{-1}$, on/off current ratio of $1.58x10^6$, current-gain cutoff frequency f_T of 200GHz, and $f_T x L_g$ of 16GHz.μm

Assistant professor Yuping Zeng and a team of researchers in the University of Delaware's Department of Electrical and Computer Engineering recently fabricated a 80nm gate-length gallium nitride (GaN) high-electron-mobility transistor (HEMT) on a silicon substrate using indium aluminium nitride ($In_{0.17}Al_{0.83}N$) as the barrier layer that demonstrates record performance (Peng Cui et al, 'High-performance InAlN/GaN HEMTs on silicon substrate with high $f_T x L_g$, 2019 Appl. Phys. Express 12 104001).



Professor Yuping Zeng (right) and graduate student Peng Cui. (Photo by Kathy F. Atkinson.)

Among devices of its type, the transistor is claimed to have record low gate leakage current (of $7.12x10^{-7}A.mm^{-1}$), record high on/off current ratio (of $1.58x10^6$) and (due to its DC performance) record high current-gain cutoff frequency (f_T of 200GHz). The product $f_T x L_g$ =16GHz.μm is also reckoned to be a new record for GaN HEMTs on silicon.

The researchers say that the transistor could be useful for higher-bandwidth wireless communication systems. For a given current, it can handle more voltage and would require less battery life than other devices of its type. "We want to expand the bandwidth of wireless communications, and this will give us more information for a certain limited time," says Zeng. "It can also be used for space applications because the gallium nitride transistor we used is radiation robust, and it is also wide-bandgap material, so it can tolerate a lot of power," he adds.

The transistors are made on a low-cost silicon substrate. "This process can also be compatible with silicon complementary metal–oxide–semiconductor (CMOS) technology," notes Zeng.

"We are trying to continue to break our own record, both for the low-power application as well as for the high-speed application," says Zeng. The team also plans to use the transistors to make power amplifiers that could be particularly useful for not only wireless communications but also Internet of Things (IoT) applications.

Several University of Delaware units helped Zeng's group set the new record. The group fabricated their device in the UD Nanofabrication Facility. Postdoctoral scholar Peng Cui, the Applied Physics Express paper's first author, has received funding through the Horn Entrepreneurship Postdoctoral Innovation Fellow program and the Air Force Office of Scientific Research.

https://iopscience.iop.org/article/10.7567/1882-0786/ab3e29
www.ece.udel.edu
www.udnf.udel.edu

Transphorm's GaN used in AES' power supplies for large passenger airplanes

Transphorm Inc of Goleta, near Santa Barbara, CA, USA — which designs and manufactures JEDEC- and AEC-Q101-qualified 650V gallium nitride (GaN) field-effect transistors (FETs) — says that its customer AES Aircraft Elektro/Elektronik System GmbH of Bremen, Germany has released its first 650V GaN-based power supplies.

Serving the aviation industry, AES provides products and services ranging from electrical engineering to certification and testing. Its latest switch-mode power supplies are used by large CS-25 airplane manufacturers (e.g. Airbus A318–A321, A330, A340, A380 and Boeing B767, B787 VIP aircraft) and use Transphorm's GaN FETs to increase overall system efficiency by more than 10% compared with competing silicon-based power supply units (PSUs).

The two GaN-based switch-mode power supplies are the PS250X 500W and PS6120 1200W systems (both currently shipping). Both support a 96–130V_{AC}/360–800Hz input voltage with a 28V_{DC} continuous power output at 15A for the 500W system and 42A for the 1200W system.

Further, AES certified the PS250X and PS6120 as DO-160 compliant — meeting the more than 25-point stringent standard of the Radio Technical Commission for Aeronautics (RTCA). This standard assesses system impact and performance under various external and internal conditions on aircraft — ranging from pressure and temperature to voltage spikes and RF emissions.

The flagship 500W PS250X is said to be the first passively cooled power supply at 420W and deploys Transphorm's GaN in a single-phase CCM boost power factor correction (PFC) topology. It offers more than 92% overall system efficiency at full load, which is claimed to be more than 10% greater than its competition. The system also yields a more than 0.98 power factor and 200mV_{pp} nominal at 115V_{AC}/400Hz input at full load, all within an end product that weighs just 1.4kg (3lbs).

The 1200W PS6120 deploys Transphorm's GaN in a fan-cooled, three-phase CCM boost PFC topology. It offers more than 91.5% overall system efficiency at full load, which is 11.5% greater than its competition. The PS6120 also yields the same power factor and nominal ripple voltage at 115V_{AC}/400Hz input at full load as the PS250X 500W PSU, all within an end product that weighs 4.0kg (~8.8lbs).

"The aviation industry is working toward reducing climate impact through any means possible," says Dr Andreas Hammer, head of Competence Center Power, AES. "We sought out Transphorm's GaN to replace previously used silicon MOSFETs so that we could provide a more efficient, lighter-weight power supply," he adds. "These supplies have the potential to make a notable impact when considering each aircraft deploys several such PSUs. After only a year of redesign, we were able to offer our customers a better power solution, while also raising the performance bar within our own industry."

Interested in the technology's inherent higher switching frequency, AES reviewed GaN power switch converters from several GaN device manufacturers. It ultimately selected Transphorm's 650V GaN technology due primarily to its ease of drivability and designability — specifically because Transphorm's GaN FETs do not require custom drivers. As a result, system design is simplified while engineers can drive the switches using technology they are already familiar with (i.e. drivers and packages). Other factors affecting AES' selection included Transphorm's proven reliability (underscored by its GaN platform earning both a JEDEC qualification and AEC-Q101 qualification at 175°C).

"Our two-switch normally-off GaN devices come in standard packages and require minimal supporting circuitry to drive them, which reduces the overall system size, increases reliability, and simplifies design," says Philip Zuk, VP of worldwide technical marketing & NA sales. "It's crucial to us that our customers can come to market quickly with a product they have confidence in," he adds.

www.transphormusa.com

Northrop Grumman awarded $189m extension to US Marines contract for full-rate production of GaN-based G/ATOR radar systems

Northrop Grumman Mission Systems of Linthicum, Maryland, has been awarded a $188,995,364 modification for the firm-fixed-price portion of a previous $958m contract (M67854-19-C-0043) awarded by the Marine Corps Systems Command of Quantico, Virginia.

The modification is for the purchase of six gallium nitride (GaN) full-rate-production Ground/Air Task-Oriented Radar (G/ATOR) systems and associated travel in support of Program Executive Officer Land Systems, Quantico, Virginia. Work will be performed in Linthicum and is expected to be complete by 4 April 2023.

www.northropgrumman.com
www.marcorsyscom.marines.mil

Advantech receives orders worth $2m for GaN-based Engage Class FlyAway military-grade SatCom terminals

Advantech Wireless Technologies Inc of Montreal, Canada (which manufactures satellite, RF equipment and microwave broadband communications systems) has received over $2m in orders of its satellite communication (SatCom) Engage Class 1.2m and 2.4m FlyAway SatCom Terminal from a NATO member country.

The flexible and transportable satellite terminal is a fully integrated tri-band system designed for strategic applications, easy deployment and operation under harsh environmental conditions. It is based on high-efficiency, ruggedized tri-band-ready 1.2m and 2.4m Flyaway Antennas that can cover the X-band, Ku-band or Ka-band by replacing the feed only. The antenna is fully motorized, with an integrated satellite finding controller. The RF section includes Advantech's gallium nitride (GaN)-based technology solid-state power amplifiers (SSPAs)/block-upconverters (BUCs), with power output in the X-band from 20W to 100W, Ku-band from 16W to 125W, and Ka-band from 10W to 40W. The entire SatCom terminal has been tested for the highest level of performance and compliance with military requirements.

An Engage Class 1.2m Flyaway Antenna.

"These advanced satellite terminals include state-of-the-art digital and RF technology," says Cristi Damian, VP business development at Advantech Wireless Technologies. "Within a completely modular and integrated solution, the terminals can uplink two independent carriers (up to 50Mbps each), allowing simultaneous communication with both upper and lower echelon," he adds. "These systems have been part of a complex modernization program for this active NATO member, and have already been deployed in the field since 2017."

www.advantechwireless.com

GaN Systems gets investment from SPARX Group

Mirai Creation Fund II investors including Toyota target GaN-based electric vehicles

GaN Systems Inc of Ottawa, Ontario, Canada (a fabless developer of gallium nitride-based power switching semiconductors for power conversion and control applications) says that it has received investment from SPARX Group 'Mirai Creation Fund II'.

Mirai fund provides capital to companies with the goal of accelerating innovation. One of the main targets is vehicle electrification. Mirai fund's LP investors include Toyota Motor Corporation.

At the 2019 Tokyo Motor Show in October, the All GaN Vehicle was revealed. Developed by Nagoya University Institute for Future Materials and Systems and Toyota Advanced Power Electronics Research Division, it features multiple applications of gallium nitride in an electric car: in the traction inverter (where GaN improves efficiency by 20%, extending the driving range of the car on one battery charge), in the DC–DC converter (which allows a 75% reduction in size of the system), in the on-board charger, and in the LED lighting (where GaN lights the road during night driving). The All GaN Vehicle has recently been driven in and around Tokyo.

GaN Systems says that it continues to establish a strong position in the automotive industry with additional customers and strategic investors realizing the value proposition of GaN and using the transistors in EV powertrain applications, namely the traction inverter, on-board charger, and DC–DC converter.

"The combination of confidence in our best-in-class device performance, the release of the industry's highest-current-rated devices, and our device reliability exceeding the AEC-Q101 automotive industry standards, has contributed to more and more automotive OEMs and tier-1 companies investing in our company and using our devices," says CEO Jim Witham.

"After evaluating a variety of power semiconductor technologies and designs, GaN has emerged as a critical building block for power in automotive applications, and our investment in GaN Systems complements our vision to shape the future and impact our world," comments SPARX Group's president & CEO Shuhei Abe.

www.sparxgroup.com

Teledyne e2v and GaN Systems unveil high-rel 650V GaN power HEMT

Teledyne e2v HiRel of Milpitas, CA, USA (part of the Teledyne Defense Electronics Group that provides solutions, sub-systems and components to the space, transportation, defense and industrial markets) is launching a ruggedized 650V/60A gallium nitride power high-electron-mobility transistor (HEMT) based on technology from GaN Systems.

The new TDG650E60 GaN power HEMT is claimed to be the highest-voltage GaN power device on the market for hi-rel military and space applications, and is now available with both top- or bottom-side-cooled options.

Gallium nitride devices have revolutionized power conversion in other industries and are now available in radiation-tolerant, plastic-encapsulated packaging that has undergone stringent reliability and electrical testing to ensure mission critical success. The launch of the TDG650E60 GaN HEMT finally delivers the efficiency, size and power-density benefits required in critical aerospace and defense power applications, says Teledyne e2v HiRel.

For all product lines, the firm performs demanding qualification and testing tailored to the highest-reliability applications. This regime includes sulfuric test, high-altitude simulation, dynamic burn-in, step stress up to 175°C ambient, 9V gate voltage, and full temperature testing.

Teledyne says that its TDG650E60 GaN power HEMT has an extremely small form factor and leverages patented Island Technology from GaN Systems. This technology is a scalable, vertical charge dissipating system that gives the power transistor ultra-low thermal losses, high power density, no-charge storage, and very high switching speeds.

Unlike silicon carbide (SiC) devices, the GaN-based TDG650E60 can easily be implemented in parallel to increase the load current or lower the effective on-resistance (R_{DSon}). The use of exclusive GaNpx packaging allows very high-frequency switching and excellent thermal characteristics, enabling a significant reduction in the size and weight of power electronics, it is said.

"Teledyne e2v has a proud heritage of space products, and we are now bringing the unprecedented efficiency of GaN power to our customers," says Mont Taylor, VP of business development for Teledyne e2v HiRel. "These devices enable design engineers to create highly efficient, small power supplies and motor controllers which can comfortably function in high-radiation environments such as space."

Qualified TDG650E60 devices with either top-side or bottom-side cooling are now shipping and available for immediate purchase.

www.teledyne-e2v.com
www.gansystems.com

GaN Systems & ON Semiconductor make available 300W AC adapter reference design

GaN Systems Inc of Ottawa, Ontario, Canada (a fabless developer of gallium nitride-based power switching semiconductors for power conversion and control applications) and power semiconductor IC supplier ON Semiconductor of Phoenix, AZ, USA have announced the availability of what is claimed to be the highest-power-density 300W AC adapter reference design using GaN Systems' 650V, 15A GaN enhancement-mode high-electron-mobility transistors (E-HEMTs) and multiple ON Semiconductor controller and driver ICs: NCP51820, NCP13992, NCP1616 and NCP4306.

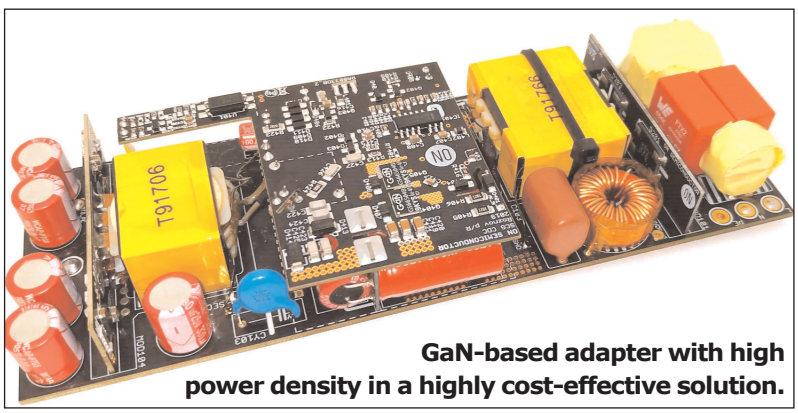
The complete system reference design is said to be highly versatile and low cost, allowing designers to easily develop and bring to market ultra-high-power-density adapters for various applications in HDTV power supplies, gaming notebook and console adapters as well as ultra-small power supplies for industrial and medical devices.

The kit and application note provide detailed technical information including schematic, PCB layout and BOM (bill of material) files, and EMI and efficiency data. The kit hardware has complete PFC, LLC and secondary stages, and features a high-efficiency synchronous PFC that meets the CoC T2 benchmark, a highly versatile low-cost 2-Layer design, and universal input with 19V output at 340W peak. System designers using this GaN-based reference design can reach power densities up to 32W per cubic inch, it is reckoned.

"Fast-switching GaN works effectively with our advanced controller and drivers to optimize system designs for high power density, removing design barriers and enabling designers to take advantage of the numerous benefits provided by GaN E-HEMTs," says ON Semiconductor's director of marketing Ryan Zahn,. "With rising interest and adoption of GaN, we look forward to continued collaboration with GaN Systems to support and meet the new power requirements taking place across many industries," he adds.

"Our collaboration combines ON Semiconductors' system applications expertise and industry-leading power IC products with the world's most advanced 650V GaN E-HEMTs," Charles Bailley, senior director, worldwide business development, at GaN Systems. "This reference design, developed in collaboration with ON Semiconductor, makes it easier and more cost effective to design as GaN gains popularity as a building block in the adapter market," he adds. "This release is the first of several systems and integrated packaging innovations in development, which will significantly expand the GaN ecosystem."

www.onsemi.com/pub/Collateral/EVBUM2684-D.PDF
www.gansystems.com



GaN-based adapter with high power density in a highly cost-effective solution.

Navitas wins Innovation Star award from Zhangjiang Hi-Tech, as well as investment-intent agreement

On 19 December, Navitas Semiconductor Inc of El Segundo, CA, USA was presented with the Shanghai Zhangjiang 895 and Zhangjiang Science City • ICV Pioneer Alliance 'Innovation Star' Award.

Navitas says its highly integrated, speed-optimized, next-generation GaNFast power IC technology can replace slow silicon switches to enable a new generation of fast-charging mobile adapters for smartphones, tablets and laptops at 27W to 300W+.

As a key element of the Shanghai Science and Technology Innovation Center, Shanghai Zhangjiang Hi-Tech Park Development Co Ltd takes technology investment banking as its strategic development direction, and aims to create new industrial real-estate operators, future-oriented high-tech industry integrators and technology and financial integration service providers.

Hosted by Zhangjiang Hi-Tech, the roadshow in December focuses on the development of the IC industry. In the 8th season of the competition, Navitas was selected from more than 100 projects to be one of 25 approved entrants. After three months of professional selection, the firm qualified for the final eight 'Starting from the Core Demo Day'. Over 80 technical and investment experts then reviewed and critiqued Navitas' GaNFast power IC approach.

"Navitas Semiconductor has demonstrated its core strength with its innovative GaNFast power IC technology, advanced company organization and deep market understanding, and has won recognition from us and from large professional investment institutions, earning the 'Innovation Star' award by outstanding performance and strength," commented Zhangjiang Hi-Tech's general manager Dajun He.

Zhangjiang Hi-Tech signed an investment-intent agreement with Navitas Semiconductor at the event, committing to free office space and free talent housing, and the group targets additional cooperation with Navitas in the future.

"Thanks to Zhangjiang Hi-Tech for organizing this 895 IC special session for industry investment and financial matchmaking, resource provision, and IC enterprise special courses after the start of business," says Navitas Semiconductor China's general manager Yingjie Zha. "As a third-generation semiconductor material, GaN has graduated from the laboratory to industry adoption and commercial acceptance, and Navitas Semiconductor is honored to receive the Demo Day Innovation Star."

www.navitassemi.com

Griffin unveils compact, fast USB-C wall chargers

At the Consumer Electronics Show (CES) in Las Vegas (7–10 January), Griffin Technology of Irvine, CA, USA, a brand of Incipio Group, has unveiled a range of USB-C wall chargers equipped with power delivery (PD) and gallium nitride technologies to deliver maximum fast charging power in an ultra-compact design. Engineered to provide a faster and safer charging experience in a smaller-sized package, Griffin's latest additions to its PowerBlock lineup includes three high-speed wall chargers powerful enough to charge most USB-C compatible smartphones, tablets and laptops.

"PD and GaN technologies deliver meaningful improvements in power adapter size, charging speed and safety," says Incipio Group's CEO Brian Stech. "As a brand with nearly 28 years of experience delivering dependable and iconic solutions to better serve mobile users worldwide, we are thrilled to introduce a range of purpose-built charging solutions with industry-leading technology to further improve our customer's everyday lives," he adds.

Griffin's most powerful and versatile PowerBlock offering yet, each USB-C PD wall charger is equipped with power delivery to charge compatible smartphones, tablets and laptops up to 70% faster than standard chargers. With the integration of GaN technology, PowerBlock USB-C PD wall chargers are engineered with more efficient internal components than traditional silicon chargers to provide high-capacity power solutions with safer charging temperatures but a fraction of the size.

By combining both technologies, Griffin's upcoming PowerBlock series allows users to save time charging while minimizing the number of chargers they need to power up all of their PD-compatible Apple and USB-C enabled smartphones, tablets and laptops.

Compared with most standard laptop chargers, GaN components allow the charger to be smaller (by 57%, 45% and 11%, respectively, for the 45W, 30W and 96W models), lighter and more efficient (which also provides safer temperatures while charging).

Power delivery provides high-speed charging; capable of charging a compatible device up to 70% faster than standard chargers for the PowerBlock 45W and 96W models, while the PowerBlock Dual 30W can charge two devices simultaneously.

Available in second-quarter 2020, PowerBlock USB-C PD wall chargers with GaN technology ($49.99 for the PowerBlock 45W, $69.99 for the PowerBlock Dual 30W and $79.99 for the PowerBlock 96W) join the brand's growing range of USB-C PD wall and car chargers, wireless charging, portable power and connectivity solutions.

www.griffintechnology.com

Navitas showcases GaNFast power IC technology in fast-chargers for mobile devices at CES 2020

Navitas Semiconductor Inc of El Segundo, CA, USA showcased its GaNFast power IC technology, in addition to partnerships with major electronics brands, at the 2020 Consumer Electronics Show (CES) in Las Vegas (7–10 January).

Founded in 2014, Navitas introduced what it claimed to be the first commercial gallium nitride (GaN) power ICs. The company says that its proprietary 'AllGaN' process design kit (PDK) monolithically integrates GaN power field-effect transistors (FETs) with GaN power, analog and logic circuits, enabling faster charging, higher power density and greater energy savings for mobile, consumer, enterprise, eMobility and new energy markets.

"Continued demand for more powerful smartphones, tablets and laptops with larger screens and 5G capability has created a multi-billion-dollar market for next-generation fast-chargers,' says CEO Gene Sheridan. "With 25 GaN chargers and adapters on display ranging from 27W to 300W, powering everything from phones to drones, the mobile charger market will never be the same again," he adds.

"Since 2018, millions of GaN chargers have been shipped by big-name brands such as Samsung, Oppo, Anker, Verizon and NVIDIA, with dozens more in progress," notes Stephen Oliver, VP of sales & marketing.

www.ces.tech

AUKEY debuts GaN power chargers at CES

At the Consumer Electronics Show (CES 2020) in Las Vegas, AUKEY debuted its Omnia Series of five GaN-based power delivery (PD) chargers (available online and at retail stores in second-quarter 2020) delivering fast charging speeds.

Designed to provide smaller, lighter and more powerful mobile charging, Omnia is up to 66% smaller than stock MacBook 13" chargers. Whether getting more from a new device or unlocking more performance from an older one, the Omnia Series offers a range of products with varying levels of power and size, says the firm.

"As the producer of the world's smallest PD chargers, the Omnia Series is a natural next step in our line and one that delivers on our promise while creating a reliable, compact charging experience," says AUKEY's CEO Lu Haichuan.

With the Omnia Series, AUKEY is introducing OmniaChip, a range of new integrated circuits built into

AUKEY Omnia Series of GaN-based chargers

the five chargers in the new line. Developed in partnership with Navitas, the chips are designed to increase both switching speeds and energy savings.

The new line also features AUKEY's proprietary Dynamic Detect technology, which maximizes charging efficiency. Suitable for people who want to streamline charging multiple devices with one charger, the Omnia Series supports a broad range of devices including the MacBook Pro 2018, Dell XPS 13, iPad Pro, iPhone (multiple models), Google Pixel devices, and Nintendo Switch.

www.aukey.com
www.navitassemi.com

GaNFast used in HYPER charger

Navitas has partnered with California-based HYPER by Sanho Corporation to introduce the HyperJuice 100W 4-port charger with GaNFast power IC technology to achieve what is said to be the world's smallest and lightest portable form-factor.

Measuring 85.3mm x 60.8mm x 28.9mm (150cc), the HyperJuice 100W is powerful enough to charge two 15" Macbooks simultaneously (via the 2x USB-C), with flexibility for two more mobile devices via the additional two USB-A ports.

"We wanted to make the smallest, most flexible 100W charger ever, so the circuit board and components are laid out in the most compact and space-efficient manner using only the industry's most efficient components that can deliver the best performance," says HYPER's CEO Daniel Chin. "GaNFast technology enables 45% lower energy loss than the old, slow silicon chargers in the market today, and for the ultimate in portability, at only 208g, it's 50% lighter than competition too," he adds.

The HyperJuice 100W uses power-sharing technology to deliver optimal charging to a vast array of multiple devices, from watches and air-pod chargers all the way to a single 100W for the new Apple 16" Macbook. Either of the USB-C outputs can deliver the maximum 100W as specified by the USB Power Delivery (PD) specification, with the two USB-A sockets providing up to 18W each for lower power, quick-charge or legacy systems. Capable of worldwide AC voltage input, HyperJuice comes with 'snap-fit' AC adapters (UK, EU/Korea, AU) to support international travelers without extra bulky, heavy converters.

"As shown by the $1.5m Kickstarter backing, confidence in the 100W HyperJuice is extremely high," notes Navitas' CEO Gene Sheridan.

EPC displays GaN-enabled consumer applications, including autonomous cars, wireless power, drones, robotics and high-end audio systems, at CES

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 — demonstrated the power of eGaN technology to enhance consumer applications, including self-driving cars, robots, drones, wireless power, world-class audio and cutting-edge automotive solutions, in its Demonstration & Hospitality Suite in the Venetian hotel at the 2020 Consumer Electronics Show (CES) in Las Vegas (7–10 January).

Wireless Power

- *In the home*: EPC had multiple wirelessly powered surfaces on display to demonstrate the myriad of consumer uses in the home for systems with enough power to simultaneously power a computer, power a lamp, power an alarm clock, communicate via a digital assistant, charge a cell phone and charge a wearable — all without running a single power cord to any of the devices.
- *Powering 5G*: The extreme interconnectivity of 5G communications will enable the Internet of Things (IoT) to grow more rapidly and push hundreds of thousands of IoT connections and millions of sensors out into the world. For these devices to scale with 5G, they will need dependable, safe, automatic power: wireless power. At CES, demonstrations of wireless power for 5G applications through glass windows and walls were on display.
- *Robotics*: Greeting visitors in the EPC suite was Misty, a wirelessly powered robotic digital assistant that can monitor its own charge levels, estimate the time needed to navigate back to the docking station, and manage recharging efficiently.

LiDAR

Also shown in the suite were multiple eGaN FET-based light detection and ranging (LiDAR) systems. LiDAR technology has emerged as the leading technology to act as the 'eyes' for self-driving cars, and is increasingly finding new applications in other time-of-flight systems for warehouse automation, augmented reality, drones, and even vacuum cleaners. GaN enables these systems to see further, faster and better.

Class-D Audio

The EPC suite displayed the latest in class-D audio amplifier technology using GaN to enable the highest-fidelity sound. Systems for the very high-end prosumer and down to the consumer-level digital-assistant-enabled speakers were playing in the suite.

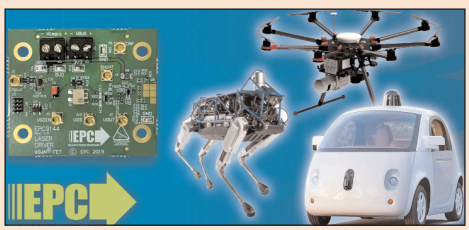
www.epc-co.com
www.ces.tech

EPC's new ToF demo board drives lasers with currents up to 28A with 1.2ns pulses using automotive-qualified eGaN technology

EPC has announced the availability of the EPC9144, a 15V, 28A high-current pulsed laser diode driver demonstration board.

In time-of-flight (ToF) systems, speed and accuracy of object detection is critical. As demonstrated on this board, the rapid transition capability of the AEC Q101-qualified EPC2216 provides power pulses to drive laser diodes, vertical-cavity surface-emitting lasers (VCSELs) or light-emitting diodes (LEDs) up to ten times faster than an equivalent MOSFET, in a small fraction of the area, energy and cost, it is claimed.

eGaN FETs and integrated circuits are said to provide the high current pulses, extremely narrow pulse widths and small size that make affordable, high-performance light detection and ranging



(LiDAR) possible. The short pulse width leads to higher resolution, and the small size and low cost make eGaN FETs suitable for time-of-flight applications from automotive to industrial, healthcare to smart advertising, gaming, and security.

The EPC9144 ships with an interposer board, which is a collection of break-away 5mm x 5mm square interposer PCBs with footprints to accommodate different lasers, RF connectors and a collection of other footprints designed for experimentation with different loads. The use of the interposers allows many different lasers or other loads to be mounted, allowing users to test the performance with the load requirements that are appropriate to their application.

EPC says that GaN is a critical factor making affordable, high-performance LiDAR possible, so the use of GaN components further expands the number of applications where increased accuracy is vital. These include self-driving cars and other time-of-flight applications such as facial recognition, warehouse automation, drones and topological mapping. The EPC9144 can also be used for applications requiring a ground-referenced eGaN FET; for example in class E or similar circuits.

FiDUS launches ultra-compact 200W desktop power supply features GaN switching

FiDUS Power of Aldermaston, UK, a technical power supply distributor specializing in solutions and products for system designers, has launched the model GDA200 external power supplies, in which the use of gallium nitride (GaN) rather than silicon switches provides increased efficiency, reduced heat losses and operation at higher frequencies (allowing the size of magnetics and other components to be reduced). The result is a compact 200W external desktop power supply with power density of 12.5W/in^2.

The GDA200 external power supply is targeted at designers of portable equipment and instrumentation for applications including high-end audio, test & measurement, bench-top and audio broadcast equipment.

The ultra-compact size is also advantageous for incorporating external power supplies into designs to speed up the approvals process, the firm claims. The small size of just 150mm x 54mm x 33mm (5.9" x 2.12" x 1.3") can also reduce total system package size, resulting in higher shipping and storage densities, especially when the closest competing product is some 2.5 times larger, it is reckoned.

"The ultra-high power density and exceptionally small size of our new GDA200 external power supply gives designers of portable products a great deal more value for money and design flexibility," says engineering manager Mark Gibbons. "This is the first of a new family of ultra-compact external desk-top products to be announced by FiDUS Power, with the 300, 160 or 150 and finally GDA 120W series to follow early next year," Gibbons adds.

The GDA200 is available in class I or class II (C14 and C8 inlet), with the C14 inlet model 11mm longer than the C8 model to accommodate the IEC input.

The power supply offers designers future proofing with the latest energy efficiency legislation; Department of Energy Level VI & Energy Related Products Tier 2, and latest general safety approval EN62368-1. The units offer global approvals for use in Japan (PSE), China (CCC) and Taiwan (BSMI) as well as the Americas (UL) and Europe (CE). They are suitable for use in ITE applications conforming to conducted and radiated emissions EN55032 level B.

Offering 192–200W of output power with output voltages available between 12V$_{DC}$ and 56V$_{DC}$, the GDA200 range has a FiDUS 5 year warranty.

www.fiduspower.com

Cardiff-based consortium gains £5.2m funding for SMARTExpertise RF-GaN project

Cardiff University's Centre for High Frequency Engineering and Compound Semiconductor Applications Catapult to develop high-frequency electronic devices

A consortium led by Cardiff University's Centre for High Frequency Engineering and the Compound Semiconductor Applications Catapult has won £2.4m in Welsh Government SMARTExpertise funding to develop high-frequency electronic devices for next generation technologies — from 5G and radar to satellite systems. Eleven industrial partners have pledged a further £2.8m of support.

The industry-led project will involve partners in the South Wales compound semiconductor cluster CSConnected, working in chip design, fabrication, waveform-based characterization, testing and production. It will help researchers to develop radio-frequency gallium nitride (RF-GaN) technologies to make high-speed, cost-effective, higher-reliability and smaller chips that outperform traditional silicon.

"Gallium nitride is quickly becoming the technology of choice for many emerging applications, including 5G communications, high-resolution phased-array radars, electronic warfare equipment, automotive collision avoidance radar, healthcare and imaging applications," says professor Khaled Elgaid, who leads the academic team. "The popularity of GaN stems from the attractive properties the technology exhibits, including high operating voltage and high operational frequency (supporting emerging 5G markets providing high-efficiency telecommunications system, with higher data rate and wider coverage area)," he adds. "In addition, the high power density and excellent thermal performance offers compact designs and operational robustness in hostile environments, including space applications."

The funding announcement coincided with a 'topping out' ceremony for Cardiff University's Translational Research Facility (designed by HOK London Studio) that will house researchers and industry involved in compound semiconductor and catalytic science. Wales' Education Minister Kirsty Williams, Bouygues UK chief executive Rob Bradley and Cardiff University's vice-chancellor professor Colin Riordan topped out the facility by adding their signatures to a beam on the building's highest point.

(r to l) Education Minister Kirsty Williams AM, Cardiff University president & vice-chancellor professor Colin Riordan and Bouygues UK's CEO Rob Bradley sign a beam to top out the Translational Research Facility.

"The program is part-funded by the European Regional Development Fund (ERDF) through the Welsh Government and offers financial support to innovative collaboration projects between industry and Welsh research organizations. These collaborative projects address strategic industrial challenges and provide opportunities to commercialize new products, processes or services and growth in key areas," notes Williams.

"The SMARTExpertise RF-GaN award perfectly complements the topping out of our state-of-the-art Translational Research Facility," says Riordan. "The building and the project are devoted to working with industry to unlock the power of research."

Cardiff University is a founding member of CSConnected — a cluster of compound semiconductor expertise across South Wales that brings together academic, industry and supply-chain partners.

The university has developed the Institute for Compound Semiconductors (ICS) — to be based within the TRF - and founded the Compound Semiconductor Centre (CSC), a joint venture with epiwafer foundry and substrate maker IQE plc of Cardiff, Wales, UK to help translate compound semiconductor academic expertise into job creation with industry.

Cardiff University's School of Engineering will work alongside the Compound Semiconductor Applications Catapult (CSA Catapult) and ICS to deliver the project.

"The CS Cluster has the opportunity to deliver a substantive project that will fill gaps identified in GaN RF devices across the UK supply chain," says Dr Tudor Williams, head of RF & Microwave at CSA Catapult. "The SMARTExpertise project has a strong consortium with end users in defence and consumer markets driving a tailored technology development," he adds. "SMART Expertise will be a catalyst for future projects and activities, leading to tangible economic benefits for both Wales and the UK."

www.compoundsemiconductorcentre.com
www.cardiff.ac.uk/institute-compound-semiconductors/industry/facilities
www.csa.catapult.org.uk

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For sales, product & distributor information, please visit https://americas.fujielectric.com/products/distribution-control/

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

GaN epi foundry IVWorks raises $6.7m in Series B funding

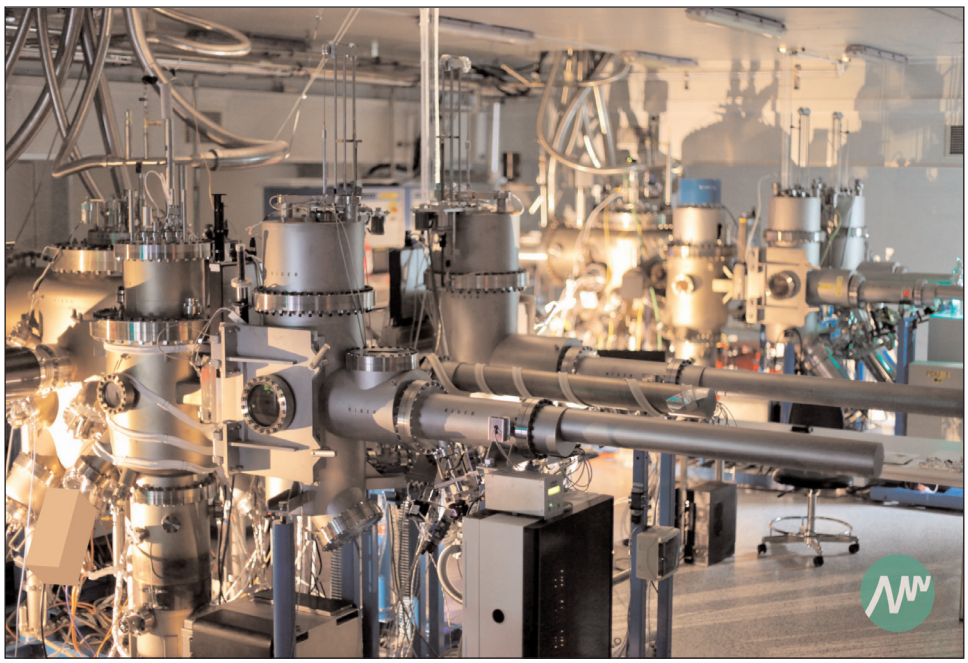
Seed investor Samsung plus new investors boost funding to $10m

South Korea-based IVWorks, which manufactures gallium nitride (GaN) epitaxial wafers, has raised $6.7m in Series B funding, including follow-on funding from seed-round investor Samsung Venture Investment, joined by new investors such as KB Investment, KDB Bank and Dt&Investment. This boosts total funding to $10m.

IVWorks, which claims to be the first South Korean GaN epiwafer foundry to develop 8" GaN-on-Si epiwafers and 4" GaN-on-SiC epiwafers, says that it has recently entered into ODM (original design manufacturer) contracts with USA and Korean semiconductor companies and begun mass production.

The proceeds are expected to be used for ODM production and a planned capacity expansion, as well as upgrading the firm's artificial intelligence (AI)-based epitaxy production system.

"We highly value its technological advantages, including the cost competitiveness it has secured through the advanced equipment technology and the defect reduction technology, as well as the revolutionary AI epitaxy technology," comments Samsung Venture Investment about IVWorks.



IVWorks' GaN epitaxy facility.

"GaN power devices, which are more efficient than existing silicon power devices and which can be miniaturized, are being applied to high-speed chargers, data-server power supplies, LiDAR sensors, etc, thereby rapidly replacing silicon power devices," says IVWorks' CEO Young-kyun Noh. "Additionally, as GaN RF devices are being used as an essential component in 5G communication base stations, the demand for GaN epiwafers, which is a core material in GaN RF devices, is also rapidly rising," he adds. "We expect to expand our market share rapidly through the supply of the contracted ODM volume and preemptive capacity expansion."

www.ivwkr.com

Entegris acquires CMP slurry manufacturer Sinmat

Specialty chemicals firm targets SiC and GaN power and RF markets

Entegris Inc of Billerica, MA, USA, which provides specialty chemicals and materials handling solutions, has acquired chemical-mechanical planarization (CMP) slurry manufacturer Sinmat of Gainesville, FL, USA for about $75m in cash (subject to customary purchase price adjustments). Sinmat is now part of Entegris' Specialty Chemicals and Engineered Materials (SCEM) Division.

Sinmat designs and produces CMP slurries for polishing ultrahard-surface materials, including silicon carbide (SiC) and gallium nitride (GaN) substrates used in the fast-growing end-markets of power electronics and advanced communications. The combination of Sinmat's slurry technology with Entegris capabilities in CMP cleans, filtration and applications technology is expected to enable new solutions for Entegris' CMP customers.

"The acquisition of Sinmat brings Entegris significant technical expertise, talent and, importantly, the addition of specialty CMP slurries to our already broad specialty chemicals portfolio," says Entegris' president & CEO Bertrand Loy. "Sinmat is a leader in CMP slurries for polishing high-performing materials in some of the fastest-growing end-markets globally, including electric vehicles and 5G communications infrastructure," he adds.

"Joining Entegris provides us a great opportunity to increase the value we deliver to our customers," believes Sinmat's CEO Rajiv Singh. "The combined technical expertise, global infrastructure, scale and operational resources will allow us to stay highly focused on product innovation and expand our global reach."

www.entegris.com
www.sinmat.com

JST's NexTEP program yields bulk GaN crystal growth equipment based on THVPE

Taiyo Nippon Sanso targets thicker GaN crystals for low-cost, high-performance devices

The Japan Science and Technology Agency (JST) has developed bulk gallium nitride (GaN) growth equipment based on the tri-halide vapor phase epitaxy (THVPE) method, a development topic of NexTEP (the 'Newly extended Technology transfer Program'). Development towards commercial application was carried out by the Innovation and R&D Division of Taiyo Nippon Sanso from August 2013 to March 2019, based on the research of professor Akinori Koukitsu of the Tokyo University of Agriculture and Technology. The team has hence developed GaN crystal manufacturing equipment that achieves high speed, high quality and continuous growth.

Most GaN substrates used in electronic devices are manufactured using hydride vapor phase epitaxy (HVPE). Compared with other practical vapor deposition methods such as metal-organic chemical vapor deposition (MOCVD) and molecular beam epitaxy (MBE), HVPE offers a faster growth rate (100μm per hour) together with the benefit of fewer carbon impurities.

However, it is difficult to produce thick GaN crystals using HVPE due to distortions in the crystal, and GaN crystals are grown on a heterogeneous seed crystal substrate, then repeatedly peeled off at a thickness of less than 1mm for use. Commercially practical manufacturing of GaN crystals has hence not been possible so far due to the cost and crystal quality, particularly in the light of the pre- and post-work required in the process, such as cleaning the furnace.

Taiyo Nippon Sanso has advanced the HVPE method to develop a GaN crystal production system that achieves high-speed, high-quality, continuous growth through the tri-halide vapor phase epitaxy method utilizing a gallium trichloride-ammonia reaction system. THVPE succeeds in forming high-quality crystals at a high growth rate three times faster than conventional methods, with only one-fifth the existing density of dislocation defects. The new THVPE method is also said to offer cost advantages over existing techniques, such as not degrading the quartz glass tube of the reactor, avoiding the reduction of crystal growth area, and reducing the occurrence of unnecessary polycrystals.

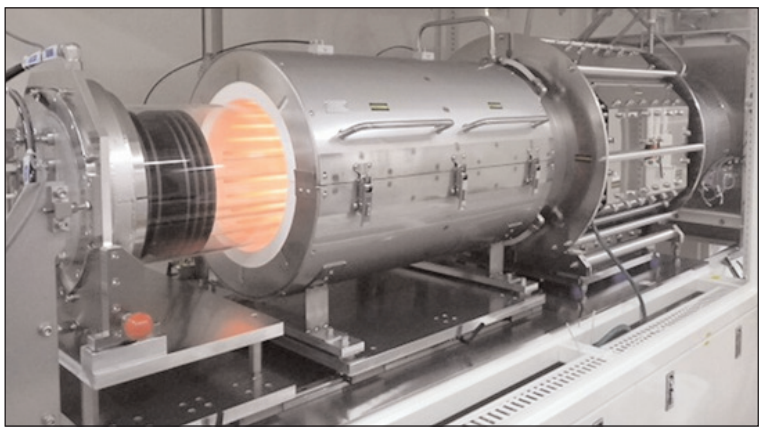


Figure 1. THVPE growth furnace. ©Taiyo Nippon Sanso Co.

In particular, when using the standard HVPE method to grow GaN crystals, a particular surface on the crystal will begin growing at a faster rate, and the crystal will continue growing from that surface point as it thickens. The crystal growth area hence decreases as it grows, leading to a turret-like shape. In contrast, THVPE uses the N-polar surface for crystal growth, opposite to the Ga surface. This leads to the reverse phenomenon, and the uppermost growth surface does not decrease even as the crystal grows.

If the THVPE technique can be further developed to achieve production of thick GaN crystals, it should allow the mass production of GaN crystal substrates through slicing. The new technique is reckoned to hold strong promise for achieving a breakthrough in the development of low-cost, high-performance GaN devices.

www.jst.go.jp/EN

Figure 2. Front side (left): transparent - no unnecessary polycrystals are generated on the wafer edge. Back side (right): since the surface is smooth, the fluorescent light is reflected.

UMS' GaN & GaAs PDKs for Pathwave ADS support enhanced thermal capability

United Monolithic Semiconductors (UMS), which designs and produces RF and millimeter-wave components and ICs at its facilities in Orsay, France and Ulm, Germany, says that the Pathwave ADS process design kit (PDK) for its 0.25µm gallium nitride (GH25) process will now support the new ElectroThermal capability (ETH) offered by Pathwave ADS (Advanced Design System) from Keysight Technologies Inc of Santa Rosa, CA, USA. This new functionality is not only included for the GH25 GaN PDK but also on the UMS PPH15X-20 gallium arsenide (GaAs) power pHEMT process PDK.

Designing packaged high-power amplifiers is a challenging task, since GaAs and GaN devices dissipate large amounts of power in a very small area, notes UMS. There are hence considerable thermal challenges. Device temperature can rise based on continuous-wave (CW) or pulsed operating conditions, different package materials used or the assembly process used. In addition, the temperature inside the transistor can also impact its properties and performance.

ADS' thermal simulation coupled with its electrical simulation allows full and complete analysis of the electro-thermal behavior of the device and optimization of the monolithic microwave integrated circuit (MMIC) inside its package, enabling users to extract the best performance from the RF GaN devices, says UMS.

Foundry customers can get the full electro-thermal simulation of their systems by specifying thermal parameters of their own assembly solution. UMS says that this provides an elegant method to simplify the calculation of the junction temperature, which is a critical step of MMIC design assessment. Implementation of thermal data in UMS' PDKs has been possible due to a strong partnership with Keysight experts and development teams.

UMS says that this partnership with Keysight is a key element that contributes to its foundry customers' satisfaction through regular innovative upgrades of the MMIC design tools.

www.keysight.com
www.ums-gaas.com

Shin-Etsu licenses Qromis' GaN substrate technology

Silicon wafer maker to develop large-diameter GaN-related products

Shin-Etsu Chemical Co Ltd of Tokyo, Japan has agreed to license the patented gallium nitride (GaN)-related technology of fabless firm Qromis Inc of Santa Clara, CA, USA (spun off from Micron Technology in 2015) as Shin-Etsu moves ahead with its development of GaN-related products.

Together with its silicon wafer manufacturing subsidiary Shin-Etsu Handotai Co Ltd, Shin-Etsu Chemical has been developing and selling substrates like silicon-on-insulator (SOI) wafers and GaN-on-silicon wafers besides its usual line of silicon wafers for power and high-frequency semiconductors.

Qromis' substrate technology (QST) is said to be fully diameter-scalable (6", 8", 12" and beyond) and engineered to alleviate stress from epitaxial layers, allowing the deposition of tens of microns of high-quality and low-dislocation-density bulk-like GaN on 6" or larger diameters.

Shin-Etsu aims to further expand its product portfolio by utilizing Qromis' patented substrate technology in addition to advancing the line-up of its existing products, and will address a wide range of customer needs by offering multiple materials and substrates solutions.

Shin-Etsu aims to further expand its product portfolio by utilizing Qromis' patented substrate technology in addition to advancing the line-up of its existing products

Shin-Etsu notes that the GaN market is expected to grow rapidly because the devices can help to resolve the conflicting issues of the need for energy conservation and the high-performance requirements essential for mobility evolution in areas such as autonomous driving, 5G communication and deeper digitalization.

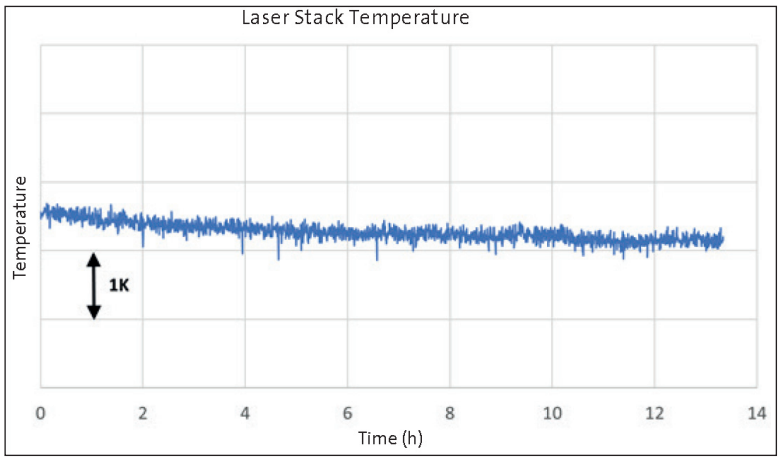
Shin-Etsu Group (which includes Shin-Etsu Chemical and Shin-Etsu Handotai) says that, by supplying large-diameter GaN-related products, it aims to contribute to the realization of an energy-efficient, sustainable society.

www.qromis.com
www.shinetsu.co.jp

LayTec's EpiTT FaceT chosen by high-power laser maker for yield improvement

In-situ metrology system maker LayTec AG of Berlin, Germany notes that it has been demonstrated for edge-emitting gallium arsenide (GaAs)-based lasers that the threshold for catastrophic optical mirror damage at the laser facets can be improved to levels higher even than the bulk damage threshold by zinc selenide (ZnSe) facet passivation in molecular beam epitaxy (MBE) (Zhang Q. et al, 'Nature Sci. Rep. 6', 19011; doi: 10.1038/srep19011 (2016)).

However, for high-yield processes of facet plasma cleaning and passivation with ZnSe in MBE it is vital to keep the temperature of the GaAs laser facets at a highly stable and accurate set-point. This has been a challenge for many years because the radiative transfer from the MBE heater to the multi-laser stacks is subject to several parameters that are not easy to control (such as the thermal contact resistance between the laser stacks and their fixtures, the absorption coefficient of fixtures and carriers that varies with their lifetime, etc).



Long-term stability of EpiTT FaceT's temperature reading of a selected single stack of lasers in a commercial production MBE for ZnSe facet passivation.

LayTec's EpiTT FaceT is a temperature metrology system designed specifically for improving the yield of the facet coating process in the temperature range between 150°C and 400°C. The firm says that a major supplier of industry-class high-power lasers has recently acquired an EpiTT FaceT for MBE facet coating in the mass production of multi-laser stacks. The Figure shows the long-term stability and low noise of the EpiTT FaceT's temperature reading of a selected single stack of lasers out of a set of laser stacks. The multiple stacks of lasers were mounted in fixtures on a carrier device in the MBE chamber under conditions identical to the real production process.

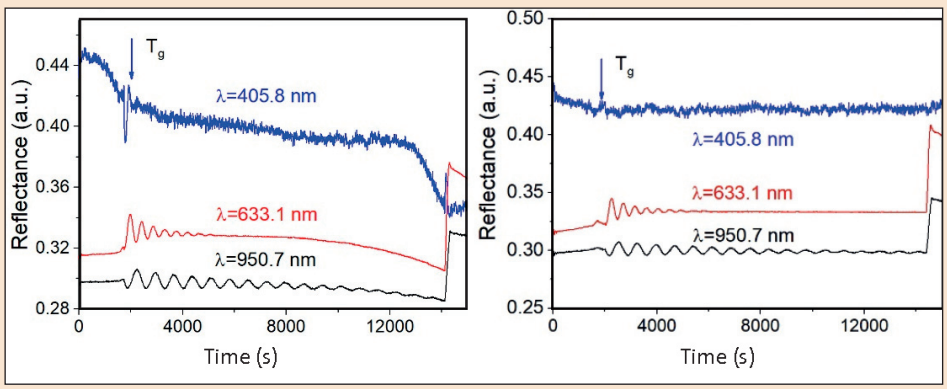
www.laytec.de/EpiTT

LayTec EpiTT used to optimize MBE growth of InP-based quantum cascade lasers

In their recent MBE project, researchers at the Institute of Electron Technology in Warsaw, Poland focused on optimizing the growth conditions of MBE-grown indium phosphide (InP)-based quantum cascade lasers (QCLs) (P. Gutowski et al., 'Materials 2019', 12, 1621; doi:10.3390/ma12101621).

For this purpose, their Riber Compact 21T MBE system was equipped with an EpiTT 3W tool from LayTec to perform in-situ analysis of the surface morphology and layer thickness. The EpiTT delivers reflectance at 950nm, 633nm and 405nm wavelengths as well as surface temperature.

The Figure demonstrates that reflectance measured by the EpiTT in-situ metrology tool is highly sensitive to defect-driven surface morphology changes during growth of these rather thick waveguide layers, especially at 405nm and 633nm. The in-situ data in (a) show a clear decrease in all three reflectance signals at 520°C growth temperature while (b) verifies that the surface of the waveguide layers stays smooth under optimized growth conditions at 480°C. The QCLs grown using the new recipe have shown lower threshold currents and substantially improved slope efficiency, LayTec notes.



EpiTT reflectance traces during growth of 2.5µm-thick InAlAs layers at V/III=12: (a) at T_g=520°C and b) at T_g=480°C.

LayTec metrology systems to be integrated into new Riber MBE cluster tool for ZSW's CIGS solar cell growth

In-situ metrology system maker LayTec AG of Berlin, Germany says it has been chosen by molecular beam epitaxy (MBE) system maker Riber S.A. of Bezons, France and its customer ZSW (Center for Solar Energy and Hydrogen Research) in Stuttgart, Germany to supply a multi-station metrology system for monitoring and controlling CIGS ($Cu(In,Ga)Se_2$) solar cell growth.

The multi-station metrology system will monitor multiple deposition steps, and comprise both in-situ and in-line methods including spectral reflectance, emissivity-corrected pyrometry and photoluminescence.

Beyond providing in-depth data for process analysis, the metrology systems will be directly embedded into the CRYSTAL XE control software of Riber's automatic platform combining two clustered 4-inch MBE 412 systems, as well as further deposition technologies.

With LayTec's metrology fully integrated into the new cluster tool, ZSW expects to gain deep insight into the effects governing the deposition processes for the manufacturing of CIGS thin-film solar cells. Resulting further process improvements are intended to boost CIGS solar energy conversion efficiency to values above 25%, i.e. beyond the existing record of 23.4%.

www.laytec.de
www.riber.com
www.zsw-bw.de

Riber receives orders from Asia for research MBE systems

Riber S.A. of Bezons, France — which manufactures molecular beam epitaxy (MBE) systems as well as evaporation sources and effusion cells — says that it has received an order from an Asian research center for an MBE 412 research system, for delivery during 2020.

The system will be used for the study of high-frequency lasers, whose main application will be in the biomedical field.

Riber has also received an order from an Asian university for two research MBE systems (for delivery during 2020), to be used for studying electronic and optoelectronic devices.

The first system, an MBE Compact 21, will be used for fundamental research in high-brightness LEDs and topological materials.
The second system, an MBE 412, is intended for the development of high-power lasers for laser cutting.

Riber receives order from Asian customer for fourth MBE 6000 multi-wafer production system

Riber has announced an order for a multi-wafer MBE production machine from a customer in Asia.

Specifically, the Asian industrial customer has ordered a fourth MBE 6000 system, intended for the production of electronic and optoelectronic devices. The new system will be delivered in 2020.

www.riber.com

Aixtron qualified for micro-LED production at PlayNitride

Follow-up order for AIX G5+ C MOCVD system placed as PlayNitride prepares high-volume manufacturing

Aixtron says that Taiwan-based PlayNitride Inc has qualified its AIX G5+ C metal-organic chemical vapor deposition (MOCVD) system for the manufacturing of gallium nitride (GaN)-based micro-LEDs, hence successfully concluding the joint collaboration agreement signed in January. At the same time (and based on the results achieved during that evaluation), PlayNitride has ordered another AIX G5+ C tool to expand its capacities for high-volume production of micro-LEDs at its new facility in Hsinchu Science Park.

Micro-LED technology is on the verge of displacing existing display technologies for next-generation consumer products, it is reckoned. Since displays made of micro-LEDs consist of micron-sized LED arrays forming individual sub-pixel elements, they offer the lowest power consumption while exhibiting superior pixel density, contrast ratio and brightness, it is claimed. Compared with existing liquid-crystal display (LCD) and organic light-emitting diode (OLED) technologies, micro-LEDs open up new opportunities for the design of consumer mobile products as well as premium TV displays.

"We were able to successfully qualify the AIX G5+ C by meeting the requirements for micro-LED processing," comments PlayNitride's CEO & chairman Dr Charles Li. "Aixtron's advanced Planetary technology addresses these tightened micro-LED industry standards at best: excellent wavelength uniformity, high yield and high-volume manufacturing against lowest cost per wafer," he adds.

"The qualification of our AIX G5+ C tool by PlayNitride as well as the company's decision to expand its high-volume production capacities for micro-LEDs with another AIX G5+ C system means an important milestone for Aixtron," says Aixtron's president Dr Bernd Schulte. "We are looking forward to continue our partnership in the micro-LED market and we value highly our common efforts to bring this promising technology to market."

www.playnitride.com
www.aixtron.com

Aixtron attains climate-neutral status

Deposition equipment maker Aixtron SE of Herzogenrath, near Aachen, Germany says that, through targeted measures, it has attained the status of a climate-neutral company. Additional steps, in particular to further reduce carbon dioxide (CO_2) emissions, will follow in the coming years.

Aixtron says that its technologies and the devices made by its customers, especially in the opto-electronics and power electronics industries, have long enabled it to improve energy efficiency worldwide and to assume an active role in reducing global CO_2 emissions.

Since 2014, Aixtron has had an ISO 50001-certified energy management system in place to improve energy efficiency. Since 2015, its headquarters in Herzogenrath alone has been able to reduce CO_2 emissions in relation to revenue by almost half. In 2017, Aixtron received the dena (German Energy Agency) Energy Efficiency Award for its energy management system.

To further reduce CO_2 emissions, the firm has this year also used renewable energy sources to generate all of its electricity. It offsets unavoidable CO_2 emissions from business travel, company vehicles and building heating by supporting certified climate protection projects in South America and Africa.

Certified carbon-offset projects

Specifically, the sustainable forestry project in the Madre de Dios region of Peru works with local residents to implement measures and initiatives for the sustainable use of the Amazon forest and provide alternative sources of income for the local population. Another project in Uganda aims to distribute energy-efficient cooking stoves in private households. The improved stoves help the families to save up to 50% fuel and thus reduce the contaminants in the air they breathe in their kitchens and living rooms.

"By supporting these two projects, we are saving exactly the same amount of CO_2 that is unavoidably emitted in our business activities," says president Dr Felix Grawert. "Both projects are certified to the highest standards and meet demanding, internationally recognized standards."

The emission savings achieved are regularly reviewed and confirmed by independent experts. In addition, the projects are said to bring further benefits to people and the local environment, for example by creating jobs and helping to protect valuable ecosystems.

Offseting CO_2 emissions under Clean Development Mechanism

Aixtron works with the 'Clean Development Mechanism', a uniform procedure for CO_2 offsetting created under the auspices of the United Nations Framework Convention on Climate Change in connection with the Kyoto Protocol in 2007 and now recognized worldwide. Offsetting emissions this way can complement measures taken to reduce avoidable greenhouse-gas emissions and make a contribution to achieving targets set out in the Paris Climate Protection Agreement.

Veeco promotes chief accounting officer & treasurer to chief financial officer

Epitaxial deposition and process equipment maker Veeco Instruments Inc of Plainview, NY, USA has promoted senior VP of finance, chief accounting officer & treasurer John P. Kiernan to senior VP & chief financial officer. He succeeds Shubham (Sam) Maheshwari, who recently announced his resignation. Kiernan will now have responsibility for all finance, tax, treasury and investor relations functions.

"John and I have a strong partnership built over the last 15 years," says CEO William J. Miller Ph.D. "Veeco's board of directors and I are highly confident in his ability to help execute our transformation strategy and to drive future growth," he comments. "I would like to thank Sam for his significant contributions to Veeco."

John P. Kiernan, Veeco's chief financial officer.

Since joining Veeco in 1994, Kiernan has held financial leadership roles of increasing responsibility including leading the controller, financial planning and analysis, tax and treasury teams. He also has significant operational experience including international assignments. Before joining Veeco, he was a senior manager at Ernst & Young LLP.

Kiernan is a CPA and holds a Bachelor of Science in Accounting from Long Island University.

"John's exceptional financial acumen, strong leadership qualities and deep understanding of Veeco's business make him the ideal CFO for the company," comments Kathleen Bayless, chair of the Audit Committee of Veeco's board.

"I am excited to be taking on additional responsibilities as we apply Veeco's high-value technology solutions to capitalize on significant opportunities," says Kiernan. "I look forward to continuing to partner with Bill and our leadership team as we leverage our technology investments in select growth markets, carefully manage our expenses, and improve our financial performance."

www.veeco.com

AXT adds finance executive to board

AXT Inc of Fremont, CA, USA — which makes gallium arsenide (GaAs), indium phosphide (InP) and germanium (Ge) substrates and raw materials — has appointed Christine Russell to its board of directors (effective 23 December), boosting the number of directors from four to five. Russell will serve on the audit, compensation and nominating/corporate governance committees.

Russell also serves on the board of directors and as audit committee chair of both QuickLogic Corp and eGain Corp. She is chairman emeritus and a director on the board of SVDX (Silicon Valley Directors Exchange), a professional organization that provides a forum for education, conversation about current issues, and peer interaction for boards of directors of Silicon Valley companies.

Since 2018, Russell has served as chief financial officer of PDF Solutions Inc, a provider of yield improvement technologies for the IC manufacturing process life-cycle. She previously served as CFO of Uni-Pixel Inc, a manufacturer of touch sensor films (which was sold to a China-based firm); Vendavo Inc, a SaaS-based pricing optimization software company addressing the Global 2000; and EAG Inc (Evans Analytical Group), a global provider of analytical testing for technology companies (including major semiconductor, chemicals and pharmaceuticals firms).

Prior to EAG, she served in the roles of both CFO and executive VP of business development at Virage Logic Corp, a Nasdaq-listed semiconductor intellectual property company that was sold to Synopsys Inc in 2010.

We look forward to drawing on her expertise as AXT continues to prepare for its next phase of growth and expansion

Russell holds a bachelor's degree and an MBA from Santa Clara University.

"She brings a tremendous depth of experience as a public company director and finance executive, and is well regarded in the investment community," comments CEO Morris Young.

"She joins at a time when AXT is positioned to take advantage of a number of market opportunities, and we look forward to drawing on her expertise as AXT continues to prepare for its next phase of growth and expansion," Young adds.

"I look forward to working with Jesse Chen, Morris, and the rest of the board as the company continues to achieve milestones in the relocation of its manufacturing facilities and prepares itself for market opportunities in 5G, data-center connectivity, optical components, LED lighting and lasers, and satellite solar cells, as well as a host of emerging applications that can help drive its future growth," comments Russell.

www.axt.com

Palomar presenting low-latency manufacturing for LiDAR at Photonics West

Photonics and microelectronic device assembly & packaging equipment maker Palomar Technologies Inc of Carlsbad, CA, USA is exhibiting (in booth #3051) its equipment and contract manufacturing/consulting solutions for the optoelectronic, laser and photonics markets, as well as giving presentations at Photonics West 2020 in San Francisco (4–6 February).

Palomar delivers solutions for photonics device assembly across a wide range of segments including aerospace, automotive (LiDAR & power modules), medical, microwave, RF/wireless, datacom, and telecom.

Specifically, on 4 February (at 4pm in Demo Area 2), product marketing manager Evan Hueners is presenting Palomar's solution for low-latency manufacturing for light detection & ranging (LiDAR).

Low-latency manufacturing utilizes collaboration between LiDAR developers and photonics device manufacturers during the commercialization phase, allowing greater agility and responsiveness, shortened time to market and reduced costs. The presentation will explore how low-latency bridges the gaps in manufacturing experience that often lead to late deliveries, high rejection rates of components, or increased costs due to design failures.

Palomar is also exhibiting at the following events:

- iMAPS Advanced Packaging for Medical Microelectronics 2020 — 28–29 January;
- Optical Fiber Communication Conference and Exhibition (OFC 2020) — 10–12 March;
- Applied Power Electronics Conference (APEC 2020) — 15–19 March.

www.palomartechnologies.com
www.apec-conf.org

StratEdge recruits Reginald Nocom as process engineer for manufacturing semiconductor packages and IC assembly services

StratEdge of Santee, near San Diego, CA, USA (which designs and manufactures high-frequency and high-power packages and provides chip assembly & test services for microwave, millimeter-wave and high-speed digital devices) says that Reginald (Regi) Nocom has joined it as a process engineer.

With over 20 years in the microelectronics industry and extensive experience in implementing Six Sigma practices, Nocom will lead StratEdge in the development of new processes for manufacturing semiconductor packages and enhancing its IC package assembly services.

StratEdge's new process engineer Regi Nocom.

"StratEdge moved into new facilities last year for designing and manufacturing high-speed, high-power DC–63+GHz packages, and includes cleanrooms for IC package assembly services," notes president & CEO Tim Going. "With the growth of our Assembly Services Division, we are excited to bring Regi on board to help further improve our manufacturing processes."

Nocom comes to StratEdge from Samtec, where he served as an R&D process engineer. He is certified in Six Sigma Green Belt training, has 5S and RETC semiconductor training, and has developed numerous manufacturing tools and processes.

www.stratedge.com

MRSI files lawsuit alleging infringement by Palomar of four patents regarding high-precision manufacturing products

Taking action against what it asserts is pervasive and repeated infringement of four separate US patents it owns, MRSI Systems LLC of North Billerica, MA, USA (which makes fully automated, high-precision high-speed die bonding and epoxy dispensing systems) has filed a patent infringement lawsuit against photonics and microelectronic device assembly & packaging equipment maker Palomar Technologies Inc of Carlsbad, CA, USA in the United States District Court for the Southern District of California.

The suit alleges that Palomar's die, wire and wedge bonder products infringe MRSI's US Patent Nos. 7,324,710 'Method and Device for Determining Nominal Data for Electronic Circuits by Capturing a Digital Image and Compare with Stored Nominal Data', 9,032,611 'Apparatus for Generating Patterns on Workpieces', 9,648,795 'Pick-and-Place Tool' and 7,109,510 'Method and Apparatus for Aligning a Substrate on a Stage'. These patents cover core functionalities used in Palomar's main product lines. International law firm Crowell & Moring LLP filed the suit on behalf of MRSI.

MRSI's key markets include telecom/datacom (data center), aerospace & defense, medical devices, computers and peripherals, and industrial.

"As parts get smaller and accuracies and volumes increase, value-based solutions providing superior performance is becoming extremely critical for leading companies worldwide, and our precision products are regarded as industry benchmarks, based on our own proprietary technology," claims Cyriac Devasia, MRSI's VP engineering.

"We pride ourselves as a leading innovation company that will thoroughly enforce its patent rights to protect our on-going investment in groundbreaking, high-speed, highly accurate and reliable placement technology and capabilities," says president Michael Chalsen. "Palomar's continued infringement of our protected technology must stop, and we found no alternative but to bring this lawsuit to protect our intellectual property."

MRSI has also continued to challenge an ongoing patent lawsuit filed by Palomar in 2015 in Southern California that MRSI successfully transferred to its home district court in Boston, Massachusetts in 2018 (Palomar Technologies Inc versus MRSI Systems LLC, Case No. 1:18-cv-10236-FDS (D. Mass.)). MRSI maintains that the Palomar's US Patent No. 6,776,327 asserted in that lawsuit is invalid on numerous grounds, including because the patent claims are directed to ineligible subject matter, and are invalid in light of prior art as well as MRSI's marketing and sales of the relevant technology in its own products many years before Palomar filed for its invalid patent. MRSI previously invalidated one of Palomar's three independent claims through the Inter Partes Review process before the US Patent & Trademark Office.

"MRSI will continue to aggressively defend itself in the ongoing litigation in Boston, and has already filed numerous motions addressing discovery violations by Palomar in connection with that litigation," says Brian Paul Gearing Ph.D., an IP litigation partner in Crowell & Moring's New York office and lead counsel for MRSI in both litigations. "MRSI will also seek its attorneys' fees from Palomar by showing that Palomar repeatedly engaged in misconduct throughout its meritless lawsuit brought against MRSI."

www.mrsisystems.com
www.palomartechnologies.com

Nitride Semiconductor wins UV LED patent lawsuits in USA against RayVio

Nitride Semiconductor Co Ltd of Tokushima, Japan says that it has won a patent infringement lawsuit against RayVio Corp of Haywood, CA, USA, which is commercializing deep-ultraviolet (UV) LEDs and consumer disinfection solutions for health and hygiene applications.

On 13 January, the California Northern District federal court issued a judgment declaring that RayVio had infringed Nitride Semiconductor's patent and that the asserted claims of Nitride's patent are not invalid.

A month ago, the US Patent Office also confirmed the validity of the key claims of Nitride's patent in its final judgments of the Inter Parte Review case filed by RayVio.

Together with professor Shiro Sakai at Tokushima University, in 2000 Nitride Semiconductor developed what it claims were the first highly efficient UV-LEDs, and it has since continued to manufacture and sell UV-LED, involving huge investment in R&D.

Nitride Semiconductor says that it regards its intellectual property rights as vitally important assets, and it will accordingly take resolute actions against infringers in any country where appropriate and necessary to protect its patents and other intellectual property rights.

www.nitride.co.jp
www.rayvio.com

BluGlass and Luminus collaborating to evaluate RPCVD tunnel-junction-enabled cascade LED technology

Firms aiming to demonstrate high-performance LEDs for entertainment, display and projection markets

BluGlass Ltd of Silverwater, Australia (which was spun off from the III-nitride department of Macquarie University in 2005) and Luminus Devices Inc of Sunnyvale, CA, USA — which designs and makes LEDs and solid-state technology (SST) light sources for global illumination markets — have entered into a non-exclusive collaboration agreement to co-develop cascade LEDs for the rapidly growing entertainment, display and projector application markets.

Luminus aims to exploit the performance potential of BluGlass' tunnel-junction technology, developed using the firm's unique remote-plasma chemical vapor deposition (RPCVD) capabilities, to further improve its projector lighting technologies.

Projectors require ultra-high-performance LEDs and could benefit from the smaller form factor, higher-performance (intensity) and lower-cost benefits that RPCVD-enabled cascade LEDs potentially offer, says BluGlass. Projectors are also heat-sensitive devices, ideally operated at lower current densities to achieve peak efficiencies — a key benefit enabled by cascade LEDs. Traditional LEDs suffer from efficiency droop as current density is raised to drive higher light output intensities, resulting in significant performance loss in the form of heat.

Luminus develops LED technology for high-performance, high-value LEDs in industrial, medical, horticulture and entertainment applications. It works hand-in-hand with firms in the automotive, display and projection industries to illuminate everything from heads-up displays to projection systems for the next generation of vehicles and consumer technologies.

BluGlass is developing and commercializing RPCVD as a low-temperature, ammonia-free alternative to traditional manufacturing technologies. RPCVD is said to offer electronics manufacturers performance advantages including higher-performing, lower-cost devices. The firm recently demonstrated a technical breakthrough with its patented 'active as grown' RPCVD tunnel junctions for LED wafers, which provide a solution for the challenge of efficiency droop by combining multiple LEDs in a single vertical LED stack (with the potential to generate greater light output for less power).

The two firms will work together to combine their unique technologies to demonstrate high-performance LEDs for the entertainment, display and projection markets. Each party will bear their own costs for the initial trials. The purpose is to evaluate RPCVD tunnel junctions and demonstrate cascade LED performance in these markets.

Working with BluGlass to enhance its technology for ultra-high-performance LED specialty lighting markets will "give our customers more design flexibility to create even more unique and differentiated products," reckons Luminus' CEO Decai Sun.

"BluGlass is continuing to work with the world's leading innovators that are developing the next generation of lighting technologies in high-growth, high-value markets," says BluGlass' CEO & managing director Giles Bourne. The projection market represents "a strong fit" for the firm's RPCVD tunnel-junction technology, he concludes.

www.luminus.com
www.bluglass.com.au

James Walker appointed non-executive chair, replacing Bill Johnson

James Walker has accepted the role of BluGlass' non-executive chair, from 7 February 2020 after Bill Johnson's resignation from the board takes effect.

Walker has served on the board since July 2017 and is currently chair of the Audit and Risk Committee (a role that he will relinquish).

As an experienced leader in commercializing new technologies across global markets, Walker will work closely with the executive team to further drive the focus on delivering near-term commercial revenue and business opportunities.

"With the technical advances made, in particular in the area of RPCVD tunnel-junction development, the company has never been closer to generating business revenues and proving the value of its extensive intellectual property portfolio," comments Walker. "I also believe the laser diode business will provide validation in the coming year of the wider commercial opportunities this technology will bring," he adds.

After almost three years as chair and ten years as a director, Johnson has decided to step down to focus on his other business interests. "I am proud to have played a role in the company's progress from being focused on pure research to now working towards delivering commercial outcomes," says Johnson.

"Since joining the board in 2010, Bill has been instrumental in the company's development and provided invaluable industry insight, guidance and support to the board, management and technical team," comments Walker.

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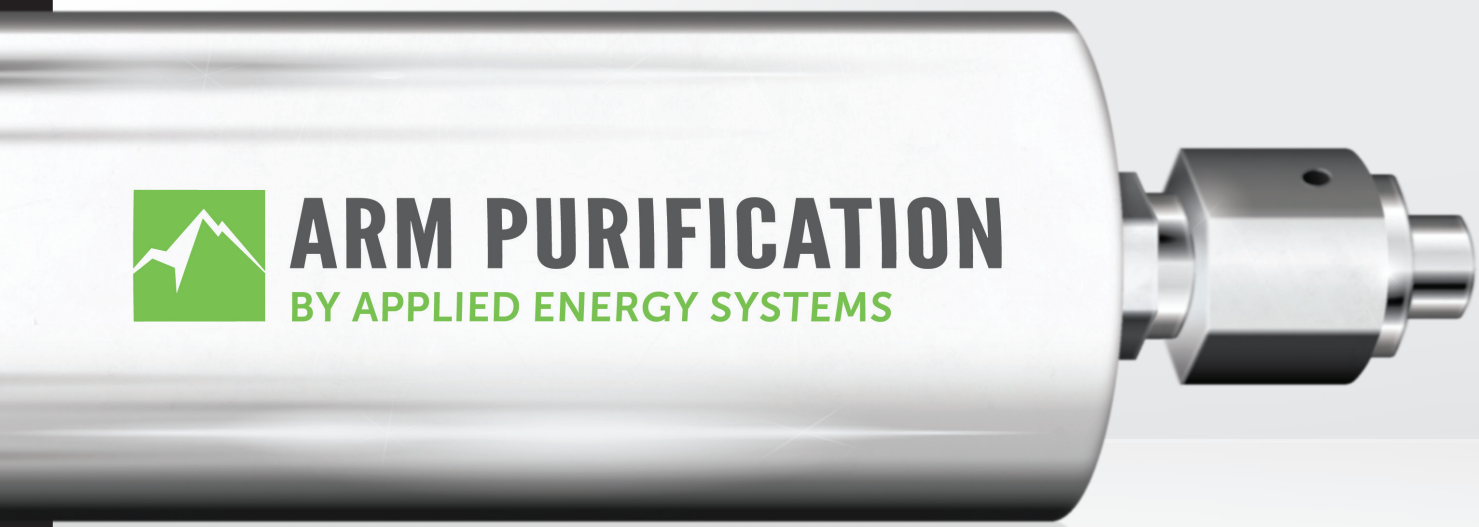

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Plessey develops native red InGaN LEDs on silicon for micro-LED displays

Production of full-RGB micro-LED displays targeted in 2020

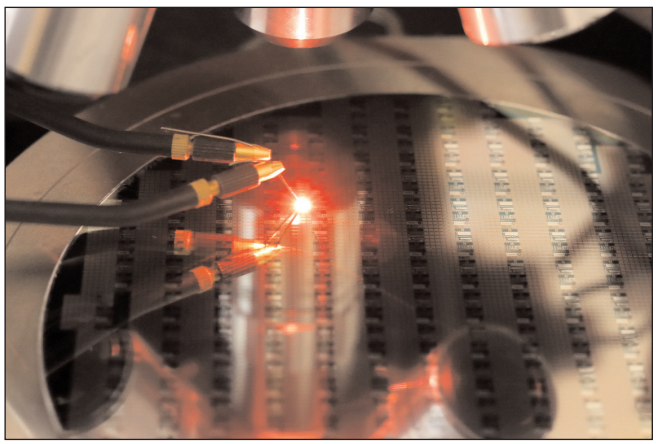
Plessey of Plymouth, UK, which develops embedded micro-LED technology for augmented-reality and mixed-reality (AR/MR) display applications, has developed what it claims is the first gallium nitride on silicon (GaN-on-Si)-based red LED.

While indium gallium nitride (InGaN)-based blue and green LEDs are commercially available, red LEDs are typically based on aluminium indium gallium phosphide (AlInGaP) material or color-converted red LEDs. For augmented-reality applications, achieving high-efficiency ultra-fine-pitch red pixels (<5µm) remains elusive due to severe edge effects from AlInGaP material and cavity losses from color-conversion processes.

InGaN-based red LEDs offer lower manufacturing costs, scalability to larger 200mm- or 300mm-diameter wafers and better hot/cold factor over incumbent AlInGaP-based red LEDs. However, achieving red spectral emission with InGaN material is challenging due to the high indium content inducing significant strain in the active region, subsequently reducing crystal quality and creating numerous defects. Plessey says that it has overcome these challenges by using a proprietary strain-engineered active region to create an efficient InGaN red LED.

Plessey's InGaN red micro-LEDs have a wavelength of 630nm at an injection current density of 10A/cm^2, a full width at half maximum (FWHM) of 50nm, hot/cold factor over 90% and higher efficiencies over conventional AlInGaP and color-converted red LEDs at ultra-fine pixel pitches. With this result, Plessey now has the capability to manufacture native blue, green and red InGaN material or to tune wavelengths from 400nm to 650nm using its GaN-on-Si platform.

"It creates a path towards low-cost manufacturing of ultra-fine-pitch and efficient red InGaN pixels,



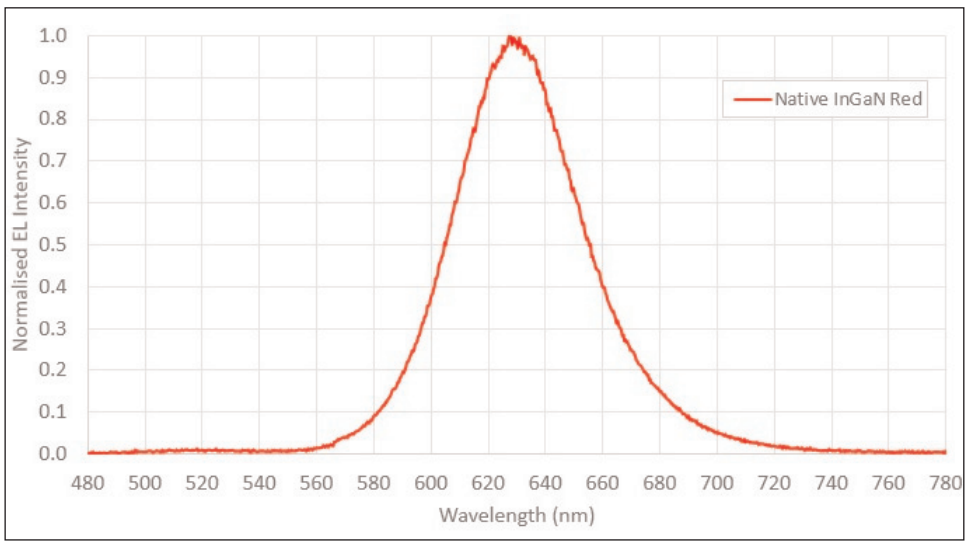
which will accelerate the adoption of micro-LEDs in both AR micro-displays and mobile/large display applications," says Dr Wei Sin Tan, Plessey's director of Epitaxy and Advanced Product Development.

Other recent milestones from Plessey include what is claimed to be the first wafer-level bonded monolithic 3000ppi (pixel-per-inch) GaN-on-Si micro-LED emissive display hybridized to an active-matrix CMOS backplane, as well as native blue and green emission layers on the same wafer. Plessey is continuing to rapidly develop micro-LED display solutions, with its roadmap including the production of full-RGB micro-LED displays in 2020.

Plessey exhibited at the 2020 Consumer Electronics Show (CES) in Las Vegas (7–10 January). The firm is joining forces with Compound Photonics of Vancouver, WA, USA (a provider of compact high-resolution micro-display technologies for AR/MR applications) to develop what is reckoned to be the smallest 1080p micro-LED-based near-eye display solution for AR/MR applications.

Demonstrated at CES were active-matrix displays in both native blue and green; as well as the new direct-drive display with the first-generation development kit. The technology was showcased within a head-mounted display (HMD) head-up display (HUD) projection system.

www.plesseysemiconductors.com/products/microleds



TowerJazz and Aledia agree process development partnership for nanowire-LED technology

Specialty foundry TowerJazz of Migdal Haemek, Israel and Aledia S.A of Grenoble, France (a developer and manufacturer of 3D LEDs for display applications based on its gallium nitride nanowires-on-silicon platform) have announced a process development partnership to bring Aledia's nanowire-LED technology into commercialized volume production.

The development is based on Aledia's IP and utilizes TowerJazz's Transfer Optimization and Development Process Services (TOPS). Funded by Intel Capital and others, Aledia's nanowire-LED technology offers solutions for the global display market's constant growing demand.

"We chose TowerJazz due to its vast expertise in the field of process development, its high-quality and extensive production capabilities, well serving our long-term production roadmap," says Aledia's CEO Giorgio Anania.

Aledia's 3D LED technology is said to enable high brightness (x1000 of today's average screen), high-resolution, low-power and cost-effective displays, all key parameters in a variety of existing and future mobile display applications including laptops, tablets, mobile phones, augmented/virtual reality (AR/VR) and smart watches. With an ever-growing rate of consumers using mobile screens in their daily lives, this market has an enormous potential growth rate, it is reckoned.

TowerJazz's TOPS services should enable and facilitate quick transfer and manufacturability of Aledia's technology. The firm's global manufacturing capabilities — two plants in Israel (150mm and 200mm), two in the USA (200mm) and three in Japan (two 200mm and one 300mm) — provide volume production in scalable wafer sizes, which are claimed to enhance its cost competitiveness, capacity assurance and future roadmap alignment.

"This technology provides significant differentiators addressing all the main feature requirements of the micro-LED displays market and holds profound potential growth for both companies," comments Dani Ashkenazi, VP & general manager of TowerJazz's TOPS business unit. "Bringing Aledia's solutions into volume production is a major step in establishing its role as a leading provider of next-generation display panel technology".

www.aledia.com
www.towerjazz.com/manufacturing/process-services-tops

MICLEDI raises €4.5m from imec.xpand, PMV, FIDIMEC

MICLEDI Microdisplays BV of Leuven, Belgium, a spin-off from nano-electronics research centre imec, has raised €4.5m seed capital from imec.xpand, with participation from Brussels-based PMV (which funds start-ups in Flanders) and FIDIMEC (imec's investment arm, supporting the creation and growth of spin-off companies). The funds will be used to develop micro-LED displays for next-generation AR glasses.

MICLEDI says that its vision is to enable AR for everyday personal use — smart glasses that are small, lightweight, with long battery life, and at reasonable cost. The firm is hence developing what are targeted to be the world smallest and brightest displays. The key innovation is the new integration technology for micro-LEDs on 300mm wafers developed in collaboration with imec.

MICLEDI was founded by chief technology officer Dr Soeren Steudel and chief operating officer Dr Alexander Mityashin, both researchers from imec with expertise in R&D and display development. They are joined by semiconductor industry veteran Sean Lord as CEO.

"AR glasses may replace our smartphones in the future, and display technology is a key enabler for such a transition," says Steudel. "Today's display technologies cannot fulfil the specifications needed for next-generation AR glasses," he adds. "At MICLEDI we are tackling this challenge and have developed displays that are 100x brighter than commercial alternatives."

To implement the vision that future consumer AR devices will be powered by a tiny display, MICLEDI has raised the €4.5m seed investment from imec.xpand, PMV and FIDIMEC. "We look forward to working with them and to enable technology that will be at the core of future AR devices and will change how digital information is presented to consumers," comments Cyril Van_ura, a partner at imec.xpand.

MICLEDI's will develop its μiLED technology and first prototypes on imec's 300mm pilot-line infrastructure.

"Hardware development takes courage, capital and time. We are proud of the entrepreneurship of our engineers to bring promising technology developments originating from our R&D to the market," says imec's president & CEO Luc Van den hove. "Based on an original concept launched now more than two years ago by the MICLEDI team, imec together with imec.xpand incubated this into a promising technology base and exciting business case. It leverages imec's extensive R&D in organic displays, 300mm integration and wafer-scale optics technologies."

"MICLEDI's new-generation display for AR glasses fits in PMV's strategy of supporting early-stage technology with a large-scale international potential, hence strengthening Flanders' position as a top region," says Roald Borré, PMV's head of equity investments.

www.micledi.com

Seoul Semiconductor and Viosys showcase first 1-pixel μLED enabling 42–220" 4K-resolution TV

At the Consumer Electronics Show (CES) in Las Vegas (7–10 January), South Korean LED maker Seoul Semiconductor Co Ltd unveiled the concept display 'Micro Clean LED' — developed by its ultraviolet (UV) LED product manufacturing subsidiary Seoul Viosys Co Ltd and ready for mass production — which realizes 4K-resolution TV sizes from 42" to 220" with one RGB LED per pixel. Also at CES, the Micro Clean LED solutions for a smart watch display were demonstrated to main strategic partners by appointment.

The firm says that Seoul Viosys possesses the necessary technologies, from metal-organic chemical vapor deposition (MOCVD) for epitaxial growth of all three colors (RGB) to the transfer of small-sized micron-scale RGB chips. Seoul Semiconductor also possesses the tiling technology and substrate connectivity technology for large-screen displays due to readying surface-mount technology (SMT) manufacturing processes at the customer's request in its own factory.

Furthermore, since it is developed as 1 pixel, it resolves three main challenges for micro-LEDs, which are the transfer technology, color mixing and the individual color and intensity of light control. By resolving these three challenges, costs can be reduced by a third, it is reckoned. Also, product reliability testing has been completed.

Seoul Semiconductor notes that, in the LED market, the first wave was the adoption of LED technology in mobile phone applications in the 2000s. The second wave was LED TV and lighting applications in the 2010s. As the third wave grows to a $100bn market with LCD and OLED displays, micro-LED are expected to capture a significant portion of the next generation display market. They are also suitable for light sources in the virtual reality/augmented reality (VR/AR) and mixed reality (MR) sectors. The micro-LED is reckoned to be the only light source that can deliver 1000 times faster response times, a 30% reduction in internal and external power consumption, and infinite contrast range compared with existing LCD and OLED displays.

www.seoulviosys.com
www.SeoulSemicon.com

Rohinni and BOE launch JV to develop mini- and micro-LED-based LCD displays and video walls

Semiconductor display maker BOE Technology Group Co Ltd of Beijing, China (the world's biggest manufacturer of TFT-LCD panels for mobile phones, tablets, notebooks, monitors and TVs) and Rohinni LLC of Coeur d'Alene, ID, USA (which has developed a proprietary method for transferring mini- and micro-LEDs to substrates) have officially launched the joint venture BOE Pixey, aiming to bring the power and brilliance of micron-scale LEDs to mass-market fruition.

In development for more than two years, BOE Pixey will design and build LCD display backlights, direct-emission displays and display-related sensors for high-performance televisions, video walls and other large-format end products. The JV rolls out at Consumer Electronics Show (CES 2020) in Las Vegas (7–10 January), with demonstrations offering visitors a glimpse of the future of high-performance display products.

BOE Pixey is integrating Rohinni's high-speed and high-accuracy mini- and micro LED manufacturing process with BOE's display panel expertise to create ultra-thin high-performance displays. Consumer devices utilizing BOE Pixey mini- and micro-LED-based displays are expected to become available for purchase in second-half 2020.

"With BOE Pixey, consumer electronics developers can now have more opportunities to design unique, cutting-edge end products that feature displays made with our technology," says BOE Pixey chairman Dong Xue.

LCDs using mini-LED backlights outperform other LCD technologies in a range of parameters including thickness, contrast ratio, brightness and consistency. Direct-emission displays based on mini- and micro-LEDs, including video walls, are made by precisely placing hundreds of thousands of mini- or micro-LEDs directly on a substrate using BOE Pixey's approach, and are said to offer much better viewing than existing video walls made from packaged LEDs.

"Mini- and micro-LEDs' promise has long been touted, but they have not been commercialized for these kinds of products before because making them in high volumes wasn't possible," says Rohinni's CEO Matthew Gerber. The combination of expertise of the two companies will bring new development opportunities to the display industry, he reckons.

As BOE Pixey ramps its production capabilities, the team aims to implement plans for new advances that will further enable customers to develop next-generation products, including faster LED placement, integration of new substrate materials, and addressing a wider range of form factors.

www.ces.tech
www.rohinni.com
www.boe.com/en

Seoul Semiconductor extends patent portfolio auction deadline to 28 February

South Korean LED maker Seoul Semiconductor Co Ltd has extended the auction date for its radio-frequency (RF) semiconductor patent portfolio and high power LED package patent portfolio to 28 February.

"Numerous companies have expressed enthusiastic interest in the patent portfolios, and have asked enough time to review them," says Seoul Semiconductor's founder Chung Hoon Lee and SETi's CEO Chae Hon Kim. "So we have decided an extension of the bid deadline for both auctions, given the market interest," he adds.

In the first auction, Seoul Semiconductor is seeking the top bidder for 98 patent assets related to power amplifiers and gallium nitride (GaN) RF semiconductors, including 55 US patents.

In the second auction, Seoul Semiconductor will auction 177 patents, including 76 US patents, related to high- and mid-power LED packages, chip-scale packages (CSP) and adaptive lighting.

The auction process is being handled by GoodIP, the digital licensing platform that helps tech companies and research centers to identify licensing partners for their intellectual property. GoodIP is supported by Fluxunit/Osram Ventures and the LMU Entrepreneurship Center.

www.goodip.io
www.SeoulSemicon.com

Seoul Semiconductor's SunLike Series natural-spectrum LEDs adopted by formalighting architectural lighting brand

South Korean LED maker Seoul Semiconductor Co Ltd says that, using its SunLike Series natural-spectrum LEDs in cooperation with Casambi Technologies Oy, a developer of wireless lighting control systems based on Bluetooth Low Energy (BLE), it has created a smart lighting design that has been adopted for the Italian-designed architectural lighting brand formalighting Ltd, a global manufacturer of architectural lighting systems and solutions for a new product line that offers a motorized luminaire with smart wireless controls.

The SunLike COB (chip-on-board) LED packages have been adopted by formalighting for the new fixtures Moto-Zero 40 Compasso and Moto-Zero 66 Zoom in a track-mounted motorized spotlight range. The Moto-Zero 40 Compasso is said to be as the smallest motorized fixture in this sector, while the Moto-Zero 66 Zoom is focused on the best selection of LED lighting for museum, art galleries and commercial spaces. The integrated technology within the motorized luminaires offers more smart control over the beam angle and movements of the fixture, which can be tilted vertically 90° in two directions as well as rotated horizontally 360°. The intensity and white color tuning of the light is controlled by Casambi bluetooth technology.

The embedded SunLike Series LEDs are claimed to be the first LEDs to produce light that closely matches the spectrum of natural sunlight, optimized to natural light spectra and color rendering index of CRI-97 (close to the CRI-100 of sunlight, and higher than the CRI-80 of conventional LEDs). The spotlight fixtures are designed to bring out the most natural color tones of objects which are particularly color-sensitive. Also, by restricting the blue light peak (similar to the sunlight spectral curve), which enables the reduction of scattered reflection and glare, they are said to deliver benefits including vivid color, detailed contrast and homogeneous quality of light.

SunLike Series LEDs also deliver human-centric lighting, identified as a key light source for promoting human well-being, based on the results of a recent sleep study by professor Christian Cajochen and his team at the University of Basel in Switzerland ('Effect of Daylight LED on Visual Comfort, Melatonin, Mood, Waking Performance, and Sleep', Journal of Lighting and Research Technology, 24 March 2019). "We have evidence that a daylight [natural spectrum] LED solution has beneficial effects on visual comfort, daytime alertness, mood, and sleep intensity in healthy volunteers," said the authors.

"The nature of light is critical to the success of the display for museum, art galleries and retail stores by providing a high color rendering, and to promotion of well-being by creating a more healthy and productive working environment in indoor spaces," notes Seoul Semiconductor's Europe sales VP Carlo Romiti. "SunLike Series natural-spectrum LEDs will enable lighting designers to meet the most challenging design requirements," he adds. "Combination of the healthy light source LED and new technology with smart wireless control will provide consumers with both significant vivid color benefits and well-being," he believes.

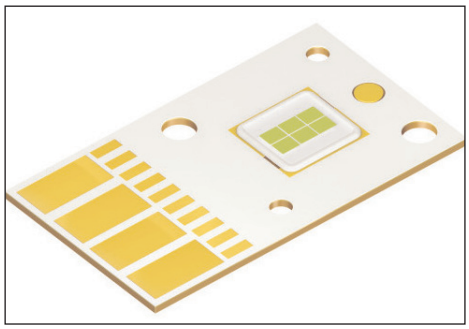
Seoul Semiconductor developed SunLike Series natural-spectrum LEDs in collaboration with Toshiba Materials' TRI-R spectrum technology in 2017 as the first LED light source to closely match the spectrum of natural sunlight.

www.formalighting.com

Osram boosts Ostar Projection Power LED family beyond 3000 ANSI lumens, rivaling high-pressure discharge lamps

As projectors have become more and more popular in home entertainment systems, so have the expectations of users. In addition to ever-higher resolution, the focus is also on richer colors, contrasts and higher brightness. Osram Opto Semiconductors GmbH of Regensburg, Germany says that, with the Ostar Projection Power family, it has succeeded for the first time in achieving projector brightness levels beyond the 3000 ANSI lumen barrier using LEDs instead of conventional lamps, making them accessible to a broad market.

Depending on the ambient light conditions and the distance to the projection surface, requirements differ for the light source. Osram says that, with 12 new products, it can now offer three different power classes for RGB solutions in deep blue (440nm), blue (456nm), converted green (520nm) and amber (614nm) wavelengths. In the lowest power class, two chips of the same color per component provide projector brightness of up to 1500 ANSI lm. In the mid-power class, four chips of the same color per component can achieve 2500 ANSI lm. In the highest-power class, six chips of the same color per LED can achieve more than 3000 ANSI lm. As a result, products from the Ostar Projection Power family present an alternative to the high-pressure discharge lamps previously used in projectors above 2000 ANSI lm.



Osram Ostar Projection Power LED.

Osram says that this leap in performance was achieved by, among other things, improved chip and package technology. The developers have fundamentally modified the individual LED chips, allowing them to be electrically connected in a series on the copper board. The system designer benefits not only from a significantly lower operating current (with the same power consumption) and reduced complexity of the LED driver but also from the much simpler contacting of the component, says the firm. In addition, direct coupling of the LEDs to a heat sink is possible, without additional isolation costs.

The mechanical design remains largely unchanged compared to previous products, enabling fast and uncomplicated exchange of the products in existing projector systems.

"With products from the Osram Ostar Projection Power family, we have successfully crossed the 3000 ANSI lumens barrier using LED technology," says Wolfgang Schnabel, product manager in the Visualization & Laser division. "Our customers can easily integrate the new components in their desired power class into their system design and replace conventional lamps with state-of-the-art LED systems," he adds.

www.osram.com

New Oslon Boost HM LED enables ultra-slim designs for headlights

In recent years, technological progress in car lighting has led to light becoming an essential design element in modern cars. Smaller and brighter light sources are leading to more compact and versatile headlamps. Germany's Osram says that its powerful new Oslon Boost HM LED furthers this trend by enabling ultra-slim headlamp designs in vehicles.

In addition to numerous features such as adaptive front lighting (often called bend lighting or matrix lighting), the miniaturization of this component plays a particularly important role. With the Oslon Boost HM, Osram developers have achieved brightness of 415lm at a drive current of 1.5A with a very small chip area of just 0.5mm^2.

The package is also particularly compact at 1.9mm x 1.5mm x 0.73mm, providing a finger-width front headlamp solution, without compromising light output. The luminance of 255cd/mm^2 at 1.5A is reckoned to be best-in-class for this type of LED.

In addition to headlamps, the Oslon Boost HM can also be used in combination with other LEDs to provide an additional high beam. Due to its luminance, the LED is also suitable for use in MEMS-based adaptive front lighting systems.

Osram Opto Semiconductors says that it was able to draw on its expertise in package design to create the new product. The robust ceramic package of the Oslon Boost HM allows for easy thermal management within the component due to an electrically insulated pad. The special internal design structures mean that heat can be easily dissipated from the LED. Furthermore, the LED has a particularly low thermal resistance of only 4.62K/W.

"With the Oslon Boost HM, we are not only expanding our Oslon Boost product family to include particularly high luminance levels but are also helping our customers create ultra-slim headlamp designs," notes Florian Fink, marketing manager for Automotive Exterior at Osram Opto Semiconductors.

www.osram.com

Bolb launches superbug-inactivating DUV emitters for lowering healthcare costs and enhancing food safety

Germicidal LED (G-LED) supplier Bolb Inc of Livermore, CA, USA has announced further advances in its deep-ultraviolet emitter arrays to combat the rise of antibiotic-resistant pathogens by launching new products offering configurable features for generating from 2W to over 10W of targeted optical power in a convenient fixture.

Bolb says that, in a recent test by a third-party laboratory, its Blazar G-LED fixture has demonstrated 5log10 kill of methicillin-resistant staphylococcus aureus (MRSA), a dangerous pathogen that is resistant to penicillin and amoxicillin (among other common antibiotics). Such a high kill rate was achieved with its deep-ultraviolet G-LED array in under 1 minute from a distance of 1m to the targeted surface, covering about $1m^2$ in area. Using compact solid-state G-LED technology, this is claimed to be unmatched performance against a particularly egregious pathogen. Multiple arrays can be assembled and positioned to cover larger areas for quick disinfection.

The development is timely, reckons Bolb, given that global public health officials continue to sound the alarm concerning the unabated rise in antimicrobial-resistant pathogens (superbugs). According to the United States Centers for Disease Control and Prevention, more than 3 million antibiotic-resistant infections occur in the USA each year, and more than 47,800 people die as a result. The United Nations projects 10 million annual deaths worldwide due to superbug infection by 2050 if the current trend continues. Urgent actions are needed to counter the lack of effective new antibiotics and the spiraling costs associated with protecting patients and healthcare workers, including effectively dealing with contaminated surfaces and biohazard waste in acute care, surgical and clinical facilities, as well as compounding pharmacies and mobile medicine.

G-LED emitters now enable universal and cost-effective pathogen reduction solutions where footprint, upfront and operational cost, and ease of implementation matter, says Bolb. The firm claims that every 10W of implemented optical power can result in saving a typical hospital $1m in annual expenses. Given that the market for such solutions can reach over 100M optical watts generated per year by 2025, $10bn in global Healthcare Delivery cost savings is achievable (significant, considering that $30bn was spent just in the USA in 2019 on environmental cleaning and waste remediation and removal, and overcoming medical complications and legal liabilities due to patients suffering Healthcare Associated Infections).

Bolb says that GLED technical advancement enables ubiquitous distributed disinfection solutions for a highly contaminated and highly mobile world. The realization of such capabilities has accelerated deep ultraviolet adoption by OEM manufacturers in additional high-growth segments such as point-of-consumption drinking water treatment, enhanced-functionality white goods and appliances, and life-science analysis. Similar solutions are soon to be implemented in concentrated farm and horticulture operations, where chemical-free preventive disinfection measures are crucial for animal health, plant protection, supply chain sanitation, and consumer food safety.

www.bolb.co

Lumileds appoints auto industry veteran Matt Roney to lead Automotive business unit

Lumileds LLC of San Jose, CA, USA has recruited Matt Roney as president of its Automotive business unit, based at its Farmington Hills office.

Roney joins Lumileds from Stanley Infrastructure (a division of Stanley Black & Decker), where he was chief operating officer. He has extensive experience in both private equity companies and the automotive industry. Prior to its acquisition by Stanley, Roney was president of Paladin Attachments (backed by private equity firm KPS Capital Partners). Before that, he was VP & general manager of the Global Steering Business at TRW Automotive (a $2.5bn global manufacturer of electronic and hydraulic steering systems). Roney has a BS in Electrical Engineering from Cornell University, an MSE in Mechanical Engineering from Purdue, and an MBA from Harvard Business School.

"His track record of success in the automotive industry and experience in private equity will help Lumileds continue to grow in the critical markets of automotive lighting and sensors," comments Lumileds CEO Jon Rich.

At Lumileds, Roney succeeds Mircea Buzgar-Nazare, who becomes the firm's first senior VP for business transformation (in the newly created Business Transformation Group), responsible for optimizing the asset and cost structure of Lumileds and leading its mergers and acquisitions activities.

"I am grateful to Mircea for his long tenure of leadership at Lumileds and look forward to working closely with him in his new role," says Rich.

www.lumileds.com

IN BRIEF

Nitride Semiconductor wins UV LED patent lawsuits in USA against RayVio

Nitride Semiconductor Co Ltd of Tokushima, Japan says that it has won a patent infringement lawsuit against RayVio Corp of Haywood, CA, USA, which is commercializing deep-ultraviolet (UV) LEDs and consumer disinfection solutions for health and hygiene applications.

On 13 January, the California Northern District federal court issued a judgment declaring that RayVio had infringed Nitride Semiconductor's patent and that the asserted claims of Nitride's patent are not invalid.

A month ago, the US Patent Office also confirmed the validity of the key claims of Nitride's patent in its final judgments of the Inter Parte Review case filed by RayVio.

Together with professor Shiro Sakai at Tokushima University, in 2000 Nitride Semiconductor developed what it claims were the first highly efficient UV-LEDs, and it has since continued to manufacture and sell UV-LED, involving huge investment in R&D.

Nitride Semiconductor says that it regards its intellectual property rights as vitally important assets. The company adds that it will accordingly take resolute actions against infringers in any country where it is appropriate and necessary to protect its patents and other intellectual property rights.

www.nitride.co.jp
www.rayvio.com

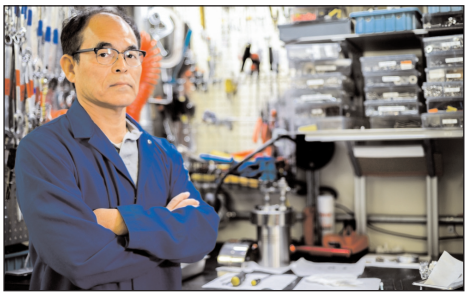
Nakamura to receive NAS Award for Industrial Application of Science

Shuji Nakamura, a professor of materials and of electrical and computer engineering at University of California Santa Barbara (UCSB), has been selected to receive the National Academy of Sciences (NAS) 2020 Award for the Industrial Application of Science for "pioneering discoveries, synthesis and commercial development of gallium nitride LEDs and their use in sustainable solid-state light sources, which are reducing global greenhouse-gas emissions while also reducing costs to those adopting this technology". Presented triennially, the award (which this year focuses on sustainability) "recognizes applications in industry of significant achievements in science".

The award "recognizes the huge impact of GaN LEDs and lasers," says Nakamura, who also co-directs UCSB's Solid State Lighting & Energy Electronics Center. "LED lighting is over 80% energy efficient and saves consumers vast amounts on their electricity costs while reducing greenhouse-gas emissions," he adds. "I'm also excited about emerging applications such as micro-LED displays and laser lighting — which is 100 times brighter than LEDs — and promises automobile headlamps, laser projectors, and a next generation of general illumination sources."

In practical use since the 1960s, the red LED was invented first, followed by orange, yellow and green LEDs within a decade or so. However, as the technology behind those LEDs improved, blue (with its short wavelength and high frequency) remained beyond the reach of conventional materials and methods for about two decades.

As a researcher for Nichia Chemical Industries Ltd in Japan in the 1990s, Nakamura began to experiment with GaN, which was then prone to defects. By developing a technique of two-flow metal-organic chemical vapor deposition (MOCVD), he



enabled the growth of high-quality GaN crystals, providing the foundation for bright-blue LEDs. After joining the faculty at UCSB in 2000, in 2014 Nakamura won the Nobel Prize in Physics for the blue LED, along with Hiroshi Amano and Isamu Akasaki of Nagoya University.

Nakamura's research "made widespread LED lighting possible," comments Rod Alferness, dean of the UCSB College of Engineering.

The recipient of many awards and honors, Nakamura has also been recognized with the Materials Research Society Award, the Institute of Electrical and Electronics Engineers Jack A. Morton Award, the Millennium Technology Prize, the Prince of Asturias Award for Technical Scientific Research, the Order of Culture Award in Japan, the Global Energy Prize and the Zayed Future Energy Prize. He is a fellow of the National Academy of Engineering and of the National Academy of Inventors and has been inducted into the National Inventors Hall of Fame.

Nakamura continues his work on solid-state lighting with his colleagues at UCSB, improving on the techniques for producing ultraviolet, blue, green, yellow and red LEDs, as well as developing laser-based lighting, vertical-cavity surface-emitting lasers (VCSELs) and high-efficiency power electronics.

Nakamura will receive the award (which includes a prize of $25,000) at a ceremony during April's NAS annual meeting in Washington DC.

www.materials.ucsb.edu/people/faculty/shuji-nakamura

TDK Ventures invests in GaN laser light firm SLD Laser

New application areas targeted for Soraa spin-off's semi-polar GaN-based products

Electronics company TDK Corp of Tokyo, Japan says that subsidiary TDK Ventures Inc has added to its growing portfolio of companies by investing in SLD Laser of Goleta, near Santa Barbara, CA, USA (a spin-off from LED lighting firm Soraa Inc of Fremont, CA that is commercializing visible laser light sources for automotive, mobility, medical, LiFi communication, sensing, specialty lighting and consumer applications).

SoraaLaser was spun off in 2013 from Soraa Inc of Fremont, CA, USA — which develops solid-state lighting technology built on 'GaN on GaN' (gallium nitride on gallium nitride) substrates — and was co-founded by Dr Shuji Nakamura (the 2014 Nobel Laureate in Physics), Dr Steve Denbaars, Dr James Raring and Dr Paul Rudy.

SLD Laser is TDK Ventures' third investment from its $50m fund since its July 2019 launch with a mission to invest its expertise in startups in innovative materials science, energy/power and related areas (typically underrepresented in venture capital portfolios) for a sustainable world.

"Their vision of digital and energy transformation matches our vision of developing real-world applications for intelligent illumination, sensing and communication that weren't thought possible," comments said SLD Laser's CEO & cofounder Steve Denbaars about TDK Ventures. "We have already identified a number of areas where TDK will help us pioneer the future of light faster," he adds.

"We look for fundamental solutions to the hardest problems, and offer our expertise, experience and industry connections to startups and growth-phase companies to help them more quickly achieve their full potential to make a positive world impact," says TDK Ventures' managing director Nicolas Sauvage. "SLD Laser is a true pioneer in innovative and meaningful applications leveraging semi-polar GaN materials, and we are very impressed by their team and their ambitious roadmap of a wide spectrum of applications around the future of light," he comments.

SLD Laser holds an intellectual property portfolio with over 500 patents. Their recently released products are claimed to be more than ten times brighter than existing LED lights, capable of illuminating objects 1km away while using less power than traditional technology. Their Beyond Lighting technology combines dynamic illumination with high-resolution sensing and ultra-high-speed LiFi communication. Products are used in applications including automotive & mobility, specialty & portable lighting, entertainment & outdoor, projection & AR/VR displays, biomedical instrumentation & therapeutics, industrial imaging & material processing.

www.SLDLaser.com
www.tdk-ventures.com

University of Louisville's renewable energy prize awarded to Shuji Nakamura for LED lighting

The University of Louisville has given the 2019 Leigh Ann Conn Prize for Renewable Energy to University of California Santa Barbara (UCSB) materials professor Shuji Nakamura for "outstanding renewable energy ideas and achievements with proven global impact".

Nakamura is recognized for scientific innovations and commercialization of efficient solid-state LEDs, which have revolutionized electronics and lighting at more than 10 times the efficiency of incandescent lighting, more than twice the efficiency of fluorescents and a durability of 30–40 years. His innovations have enabled efficient use of energy, reduced the burden on the environment and helped create sustainable lighting worldwide, notes the University of Louisville.

Solid-state lighting and electronics are expected to save $98bn in cumulative energy consumption by 2030 in the USA (equivalent to 30 1GW power plants). Worldwide, the effects are five times greater.

In March 2020, Nakamura will give a free public talk in Louisville about his work and achievements, trials and tribulations. He will receive the Conn Prize medal and $50,000 award at a formal ceremony.

"Dr Nakamura is a world-class scientist dedicated to the viability of LED technologies," comments University of Louisville's president Neeli Bendapudi, who conferred the award. "In a world where energy use must be environmentally responsible, he is an outstanding winner of the Leigh Ann Conn Prize."

The prize, administered by the University of Louisville's Conn Center for Renewable Energy Research at the J.B. Speed School of Engineering, is named after the late daughter of Hank and Rebecca Conn, who are center supporters and the prize benefactors. "LED lighting touches people in all economic strata, saving energy and money with global reach," notes Hank Conn.

Nominations for the 2021 Leigh Ann Conn Prize competition run from 1 January to 31 December 2020.

www.leighannconnprize.org
www.louisville.edu
www.materials.ucsb.edu

Ambarella, Lumentum & ON Semi collaborate on 3D sensing platform for access control & smart video security

Lumentum's VCSELs expanding into video security and AI vision

At the Consumer Electronics Show (CES) in Las Vegas (7–10 January), artificial intelligence (AI) vision silicon company Ambarella Inc, Lumentum Holdings Inc of Milpitas, CA, USA (which makes lasers for industrial and consumer markets) and ON Semiconductor of Phoenix, AZ, USA (which supplies CMOS image sensors) demonstrated a new joint 3D sensing platform for the development of intelligent access control systems and smart video security products such as smart video doorbells and door locks. The platform is based on Ambarella's CV25 CVflow AI vision system on chip (SoC), structured-light powered by Lumentum's vertical-cavity surface-emitting laser (VCSEL) technology, and ON Semi's AR0237IR image sensor.

Traditional structured-light solutions need to use both an infrared camera and a separate red-green-blue (RGB) camera and typically, a dedicated application-specific integrated circuit (ASIC) for depth processing. This new platform leverages a single ON Semiconductor AR0237 RGB-IR CMOS image sensor to obtain both a visible image for viewing and an infrared image for depth sensing. The Ambarella CV25 AI vision SoC powers depth processing, anti-spoofing algorithms, 3D facial recognition algorithms, and video encoding on a single chip, significantly reducing system complexity while improving performance.

"Lumentum has worked to enable diverse applications of our VCSEL technology into next-generation 3D sensing products," says Dr Andre Wong, vice president, product line management 3D Sensing, at Lumentum. "We are excited to partner with Ambarella to help expand the use of 3D sensing in new applications including video security and more broadly AI vision," he adds.

"ON Semiconductor's RGB-IR sensor technology enables single-sensor solutions to provide both visible and IR images in security and vision IoT applications," says Gianluca Colli, VP & general manager of ON Semi's Commercial Sensing Division. "Ambarella's CV25 computer vision SoC, with its next-generation image signal processor (ISP), brings out the best image quality of our RGB-IR sensor, while providing powerful AI processing capability for innovative use cases in security applications," he comments.

"We are delighted to partner with Lumentum and ON Semiconductor to deliver a hardware platform for the next generation of intelligent access control systems and video security devices," says Ambarella's president & CEO Fermi Wang. "It delivers 3D sensing with reduced system complexity as well as improved reliability and security."

Ambarella's CV25 chip includes a powerful image signal processor (ISP), native support for RGB-IR color filter arrays and high-dynamic-range (HDR) processing, which results in "exceptional" image quality in low-light and high-contrast environments. The CV25's CVflow architecture delivers the computational power required for liveness detection and 3D face recognition, while running multiple AI algorithms for features such as people counting and anti-tailgating. CV25 includes a suite of security features to protect against hacking including secure boot, TrustZone and I/O virtualization.

www.lumentum.com
www.onsemi.com
www.ambarella.com

ON Semi signs LiDAR collaboration MOU with SOS LAB

On 7 January at CES 2020, ON Semiconductor of Phoenix, AZ, USA signed a collaboration memorandum of understanding (MOU) with SOS LAB of Gwangju, South Korea — a light detection & ranging (LiDAR) startup for self-driving cars — to use their respective technologies jointly to accelerate the development and commercialization of LiDAR systems focused on the automotive and smart factory markets.

SOS LAB provides high-power VCSEL light sources and Metalens optical technology while ON Semi offers high-resolution single-photon avalanche diode (SPAD) arrays used for sensing single photons, making the combination suitable for solid-state LiDAR time-of-flight.

ON Semi is a provider of intelligent sensing solutions for automotive and autonomous perception, with technology targeting all sensing methods including image sensors, radar and LiDAR. SOS LAB Co Ltd is currently focusing on developing small-scale, accurate and affordable LiDAR sensors for self-driving cars, autonomous things, hyper automation, AI security, and other related industries.

Attending CES for the third consecutive year, SOS LAB launched two types of LiDAR system: a front long-range LiDAR (SL) using hybrid scanning technology and a side-by-side solid-state type LiDAR (ML) using VCSEL and Metalens technology. SOS LAB scan hence provide a LiDAR solution that can measure front, rear and full range for autonomous vehicles/ADAS (advanced driver assistance systems).

"We expect to develop (solid-state)-type LiDARs more quickly and plan to mass produce LiDARs for vehicles with built-in headlamps and bumpers within 2-3 years," says SOS LAB's CEO JiSeong Jeong.

www.soslab.co/en/products-en

II–VI launches high-speed datacom VCSELs on 150mm GaAs for optical HDMI cables in consumer electronics

Engineered materials and optoelectronic component maker II–VI Inc of Saxonburg, PA, USA has introduced high-speed vertical-cavity surface-emitting lasers (VCSELs) on its vertically integrated 150mm gallium arsenide (GaAs) technology platform to serve the growing demand for optical high-definition multimedia interface (optical HDMI) cables in consumer electronics.

The growing trend in television and computer displays toward higher resolution, larger size and thinner profiles is driving the demand for high-speed data cables that connect screens to remotely located driver electronics, notes the firm. II–VI's high-speed VCSELs developed for data-center transceivers are now available on its scalable 150mm GaAs platform to meet the expected high-volume demand for optical HDMI cables.

"To our knowledge, II–VI is the first to produce datacom VCSELs on a vertically integrated 150mm GaAs technology platform developed in-house," says Dr Karlheinz Gulden, vice president, Laser Devices and Systems business unit. "Our ability to leverage the economies of scale of our existing 150mm GaAs technology platform for 3D sensing enables us to be very competitive in the VCSEL market for optical HDMI cables," he adds. "We expect to continue over time to leverage our 150mm platform in more applications, including eventually in markets that we already serve with GaAs semiconductor lasers."

Our ability to leverage the economies of scale of our existing 150mm GaAs technology platform for 3D sensing enables us to be very competitive in the VCSEL market for optical HDMI cables

II–VI's broad portfolio of components for high-speed transceivers includes directly modulated lasers (DMLs), externally modulated lasers (EMLs), high-speed detectors, micro-optics, and driver electronics.

II–VI is showcasing its portfolio of optoelectronic devices, micro-optics and module assemblies for consumer electronics in booth #1427 at SPIE Photonics West 2020 in San Francisco (4–6 February).

http://spie.org/photonics-west.xml
www.ii-vi-photonics.com

II–VI wins Excellent Core Partner Award from FiberHome

II–VI Inc has won the Excellent Core Partner Award from FiberHome Technologies Co Ltd (one of China's largest providers of fiber-optic and communications equipment).

At the supplier day event in early December, FiberHome vice president Jianming He presented II–VI with the award in recognition of II–VI's strong performance as a supplier of a broad portfolio of products, including coherent transceiver modules, pluggable transceivers, wavelength-selective switches and optical channel monitors.

"II–VI continues to be recognized and regarded by customers as it continues to receive prestigious supplier and industry awards in China, demonstrating our strong commitment to local customer support and our success in leveraging our local operations infrastructure across the cities of Fuzhou, Guangzhou, Shanghai, Shenzhen, Suzhou, and Wuxi, into all regions of China and around the globe," says Frank Fu, senior VP, Greater China Sales Region and head of the Photonic Solutions Technical Sales Specialist Group at II–VI.

www.ii-vi-photonics.com

II-VI ranks first in competitiveness for optical components in global markets at ODC awards ceremony in China

Engineered materials and optoelectronic component maker II-VI Inc of Saxonburg, PA, USA says that it has been recognized twice at a recent industry awards ceremony in China.

At the awards ceremony during the 13th China Optical Communications Development and Competitiveness Forum (ODC 2019) in Shanghai, II-VI was ranked #1 in the category 'Top 10 competitiveness enterprises in the optical components and auxiliary equipment field of global market in 2019' and ranked #8 in the category 'Top 10 brand competitiveness enterprises in the optical communications field of China market in 2019'.

On 5 November 2018, II-VI inaugurated its Asia Regional Headquarters in Fuzhou, China, to begin a manufacturing expansion of its 5G wavelength-management products in two new buildings with a combined 300,000ft^2 of space. II–VI maintains a large manufacturing operation and product development presence in China in the cities of Fuzhou, Guangzhou, Shanghai, Shenzhen, Suzhou and Wuxi.

www.ii-vi.com

CompoundTek launches Southeast Asia's first silicon photonics testing services hub in Singapore

Open-testing platform independent of CompoundTek's foundry services

Singapore-based silicon photonic (SiPh) foundry services provider CompoundTek Pte Ltd, has launched its maiden SiPh test facility, believed to be Southeast Asia's first site offering production and engineering test services accessible to commercial industry players. The testing service is independent of CompoundTek's foundry services, enabling non-CompoundTek customers the opportunity to leverage the open-testing platform.

Housing SiPh on-wafer testing and equipment, instrument controls and test methodologies, the facility is custom-built by CompoundTek and its partners. The hub caters to the development of solutions targeting data-transmission capabilities sought after in data centers, interconnectivity, light ranging & detection (LiDAR), smart sensors and other high-growth applications that are expected to transition to high-volume production over the next five years, driven largely by advances in smart city applications.

CompoundTek team working on the tester in its SiPh testing facility.

Established at CompoundTek's Jurong East International Business Park office, the test facility is staffed by a resident SiPh test team, bringing into the technology ecosystem proven talents with international expertise in both manual and automatic silicon photonics testing on either 8" or 12" wafers.

The cleanroom is accredited as class 1000/10000, with its equipment designed to achieve fast and reproducible optical coupling, including 6-axis probe-position optimization and polarization alignment, wafer probing for conventional DC and RF electrical testing in the optical domain, and is capable of supporting both the O- and C-band. The facility will also enable the testing of electro-optical components up to 67GHz and is suitable for electro-optical components for 400Gbit/s or higher.

"With the added on-wafer-level automated SiPh optical/electrical/RF testing facility, customers will be able to limit packaging costs to good dies (known-good-die) only and avoid module packaging-level testing turn-around time losses," says chief operating officer K.S. Ang. "This complements our rapidly growing solutions portfolio designed to drive mass-production volume with fast cycle-time," he adds. "Offered alongside our world-class commercial foundry capabilities, we are able to accelerate customers' time-to-market to subsequently meet their commercialization goals."

https://compoundtek.com

Emcore agrees sale and leaseback deal for Concord MEMS manufacturing facility

$13.4m deal to close in first-quarter 2020

Emcore Corp of Alhambra, CA, USA has entered into a purchase agreement for a sale and leaseback transaction.

Under the terms of the purchase agreement, Emcore agreed to sell its quartz micro-electro-mechanical system (MEMS) manufacturing property in Concord, California for a total of $13.4m.

Emcore expects that the close of the sale and leaseback transaction will occur in first-quarter 2020, subject to the satisfaction of certain customary closing conditions for transactions of this type.

Emcore aims to raise $30m in offering

Emcore (which provides mixed-signal optics products for defense systems and high-speed communication network infrastructure) has filed a shelf registration statement on Form S-3 with the US Securities and Exchange Commission (SEC) to offer and sell from time to time, in one or more offerings, common stock, preferred stock, debt securities, warrants, rights to purchase any of the foregoing securities, or units consisting of two or more of these classes or series of securities, up to a total not exceeding $30m.

The shelf registration statement is intended to give Emcore additional flexibility to finance the business by accessing the capital markets on a timely and cost-effective basis.

Any offering of the securities is by prospectus and an accompanying prospectus supplement.

www.emcore.com

CompoundTek collaborates with Cadence and Lumerical to deliver integrated electronic-photonic design automation process design kit for silicon photonics ICs

Singapore-based silicon photonic (SiPh) foundry services provider CompoundTek Pte Ltd is collaborating with electronic design automation (EDA) software provider Cadence Design Systems Inc of San Jose, CA, USA and photonics design and photonic simulation software provider Lumerical Inc of Vancouver, British Columbia, Canada on the delivery of a new CompoundTek process design kit (PDK) for SiPh ICs. The PDK consists of a new electronic–photonic design automation (EPDA) flow with features aimed at further advancing the development of differentiated SiPh solutions.

The PDK is based on the Cadence Virtuoso custom IC design platform, utilizing the Cadence CurvyCore engine, Cadence Spectre simulation platform and the electrical–optical co-simulation capability in Lumerical's photonic integrated circuit simulator INTERCONNECT. The kit includes active and passive devices such as optical waveguide devices, fiber-to-waveguide couplers, high-speed waveguide germanium (Ge) photodetectors and high-speed modulators to enable SiPh designers to design and verify their photonics products more quickly and efficiently before fabricating physical prototypes.

"Our strategic collaboration with Cadence and Lumerical enables customers to leverage an integrated EPDA PDK which features an open SiPh manufacturing platform to accelerate the adoption of SiPh solutions for various applications ranging from datacom transceivers, smart sensor, bio-medical, automotive lidar, quantum computing and artificial intelligence," says CompoundTek's chief operation officer KS Ang.

"As the market moves toward more highly integrated electro-optical designs, accurate co-simulation of electrical and optical components becomes critical," says Lumerical's chief technology officer Dr James Pond. "CML Compiler allows foundries and end-users to easily build and maintain accurate photonic compact models for co-simulation with Cadence Spectre Simulator and Lumerical INTERCONNECT. Our collaboration with CompoundTek and Cadence is enabling these key capabilities for our customers," he adds.

"Through our collaboration with CompoundTek and Lumerical, customers can now design photonics IC chips, leveraging the complete Virtuoso platform, from high-performance curvilinear shape generation with CurvyCore-based PCells to entire system-level thermal and EM analysis," notes Glen Clark, corporate VP research and development in the Custom IC & PCB Group at Cadence. "The PDK incorporates the Cadence schematic and layout-driven photonics design flow, enabling mutual customers to achieve SoC design excellence and deliver products to market faster."

https://compoundtek.com
www.lumerical.com
www.cadence.com/go/virtuosorfni

Inphi qualifies TowerJazz for production of silicon photonics integrated circuits for data-center connectivity

Inphi Corp of Santa Clara, CA, USA (a provider of high-speed mixed-signal ICs for communications, computing and data-center markets) has qualified specialty foundry TowerJazz of Migdal Haemek, Israel for the production of silicon photonics integrated circuits for data-center interconnects based on its open-foundry silicon photonics platform. It is reckoned that Inphi's high-speed optics platform expertise and market presence, combined with TowerJazz's foundry capabilities in RF silicon and photonics platforms, form the basis for additional co-development and technology roadmap alignment.

Inphi's silicon photonics PAM4 (pulse amplitude modulation) technology is claimed to be the industry's first low-power, cost-effective 100G DWDM platform solution in QSFP28 form factor for between data-center interconnects.

TowerJazz says that its PH18 silicon photonics platform offers a set of optical components including ultra-high-bandwidth modulators and photodetectors, serving the demand in data-center and infrastructure optical communication markets. The platform complements its silicon germanium (SiGe) BiCMOS processes, providing enhanced solutions to its customer base serving optical communication needs in the growing data transport markets.

"We worked with TowerJazz due to their unique ability to develop new cutting-edge technology and offer it in a high-volume, high-quality environment," says Dr Radha Nagarajan, chief technology officer, Interconnect, at Inphi. "With Inphi's proven design expertise and first-to-market success in the areas of high electrical and optical speed data interconnects, we are looking forward to the continued partnership with TowerJazz in developing the next generation of silicon photonics integrated circuit components," he adds.

www.inphi.com
www.towerjazz.com/technology/rf-and-hpa/silicon-photonics-rf

Inphi sampling new COLORZ II – first 400ZR QSFP-DD transceiver for cloud data-center interconnects

Inphi Corp of Santa Clara, CA, USA (a provider of high-speed mixed-signal ICs for communications, computing and data-center markets) has announced engineering sampling of COLORZ II, which is claimed to be the first 400ZR QSFP-DD pluggable coherent transceiver for cloud data-center interconnects (DCIs) to major cloud operators and OEMs.

COLORZ II enables large cloud operators to connect metro data centers at a fraction of the cost of traditional coherent transport systems and allows switch and router companies to offer the same density for both coherent DWDM and client optics in the same chassis. This eliminates a layer of network connectivity that was previously required and supports high-capacity DWDM connectivity directly from data-center switches.

COLORZ II 400ZR QSFP-DD is the culmination of several industry firsts, including:

- 400G single-chip, coherent silicon photonics integrated circuit (PIC) that includes all transmit and receive functions;
- low-cost, passive alignment of fiber to the PIC that eliminates the complicated active alignment, using traditional optics;
- low-power, high-performance 7nm CMOS-based coherent DSP (digital signal processor) enabling 400ZR as well as extended-reach 100/200/300/400G ZR+ modes;
- integrated industry-standard firmware management interface that enables full performance monitoring previously only available in DCI or transport systems directly from the optical module.

COLORZ II is said to represent a massive increase in switch rack capacity, while reducing the power consumption by as much as 80%. It delivers up to 14.4T of capacity per rack unit (RU), compared to 2.4T or 3.6T per RU on competing solutions, representing a 4–6x increase in throughput per chassis. Even emerging competing solutions with higher capacity per lambda are less than 50% capacity per 1RU line card, says Inphi. This improved density on COLORZ II is achieved via new levels of silicon photonics integration as well as dramatically decreased power consumption on all elements of the coherent transceiver.

COLORZ II enables cloud end users to lower the cost of scaling out their cloud data centers around the globe, says the firm. As cloud service providers continue to scale for rapidly increasing bandwidth demands with lower latency for their customers, the trend towards distributed regional data-center architectures accelerates. Compared with traditional massive data centers residing in single campus facilities, a more distributed architecture within each metro region provides several advantages including higher resilience and availability for end users.

400ZR is an interoperable standard with broad industry support. Motivated by the need to lower the cost and power consumption of DCI, leading cloud operators, OEMs, module and chip vendors have joined the Optical Interworking Forum (OIF) in the development of an industry standard for 400ZR. COLORZ II is claimed to be the first publicly announced product designed specifically for this application. Customers that deploy COLORZ II will be supported by a multi-vendor industry-wide ecosystem and not get locked into proprietary single-vendor solutions.

This improved density on COLORZ II is achieved via new levels of silicon photonics integration as well as dramatically decreased power consumption on all elements of the coherent transceiver

For end users looking for performance beyond 400ZR, Inphi's new Canopus 7nm coherent DSP offers a multitude of reach and data rate options for metro and long-haul performance. As recently announced, there is wide support with a large ecosystem of system and module OEMs utilizing Inphi's Canopus DSP that allows for interoperability with COLORZ II even for these extended-reach modes, including higher gain forward error correction (FEC), probabilistic shaping and encryption.

"We provide an expanding suite of choices for cloud network operators and OEMs to gain the flexibility of high-bandwidth DWDM connectivity in between data centers with the ability to rapidly scale their capacity," says Dr Loi Nguyen, senior VP, Optical Interconnect, at Inphi. "By meeting the needs of cloud network companies that require extended link reaches, the 400ZR opens up new possibilities for DCIs to reduce total cost of ownership of cloud networks. As a fabless company we have proven our capability to quickly increase manufacturing and market share for our COLORZ 100G DWDM modules and are ready to meet our customers demand for COLORZ II," he adds.

"Inphi's sampling of the 400ZR module is the first to bring pluggable 400G coherent optics into the data center," comments Andrew Schmitt, directing analyst at market research firm Cignal AI. "This groundbreaking technology economically enables edge data-center architectures for large cloud vendors and gives network operators worldwide the first look at standards-based pluggable coherent solutions."

www.inphi.com

Inphi ships 100,000th COLORZ transceiver

Inphi Corp of Santa Clara, CA, USA (a provider of high-speed mixed-signal ICs for communications, computing and data-center markets) has shipped over 100,000 units of its COLORZ transceiver, which is claimed to be the first, lowest-power and most cost-effective 100G silicon photonics PAM4 (4-level pulse amplitude modulation) platform solution for 80km DWDM connectivity in a QSFP28 form factor.

"This significant accomplishment underscores Inphi's commitment to delivering technological innovations that dramatically increase the speed of data movement between data centers and help reduce total cost of ownership for cloud network operators," comments CEO Dr Ford Tamer.

Demand for bandwidth, driven by streaming video, social networking, cloud computing and mobile e-commerce, is motivating network operators to deploy cloud applications closer to the end users, says Inphi. Low latency and scalability requirements combined with geographical limitations favor the virtualization of connected regional data centers. This trend is resulting in a compound annual growth rate (CAGR) of 55% in DWDM bandwidth for sub-80km links, and early COLORZ adopters have made an architectural shift to IP over DWDM for data-center interconnects (DCIs), says the firm.

By integrating its PAM4 CMOS with its silicon photonics technology, Inphi says it took a unique approach to create a platform that achieves a 60% saving in cost and a 75% saving in power. Accomplishing the COLORZ ramp to 100,000 units within just three years also validates the network inflection point in the adoption of switch pluggable DWDM optics, the firm adds.

Initially developed for the requirements of Microsoft, the COLORZ platform has now been deployed by more than 40 network operators, ranging from wireless carriers to military and educational networks. The operational simplicity combined with the economic value continues to drive the adoption of COLORZ in the market place, Inphi says.

Yousef Khalidi, corporate VP, Azure Networking, Microsoft Corp. said, "Inphi shares our vision for DCI connectivity and we applaud their achievement of a significant milestone. Inphi's COLORZ platform has been an important contributor to Microsoft's high bandwidth metro design, to help enable greater cloud performance in a highly scalable solution."

www.inphi.com

Source Photonics appoints Weiming Li as president & CEO

Source Photonics Inc of West Hills, CA, USA (which provides optical connectivity products for data centers, metro and access networks) has appointed Weiming Li (a returning veteran of the firm) as president & CEO.

Li succeeds former CEO Doug Wright, who resigned from the company. "Mr Li is an experienced executive with extensive telecom industry experience and a diverse operational background," comments Jiang Run, a director of Source Photonics and a partner at its lead investor. "He has also served as general manager of Source Photonics China between 2007 to 2013," he adds. "Li will provide the leadership necessary to take the company to the next level of success."

The board believes that the job of CEO requires additional attributes to execute on the firm's strategy. It adds that Li has a track record of growing businesses, building teams and improving operations, as well as an understanding of the optical communications technology, products, markets and customers' needs.

Prior to joining Source Photonics in 2007, Li was VP operations & general manager at Auxora Networks. He was also VP manufacturing of Photop Group & general manager of Photop Koncent in Fuzhou, China. In addition, he served as VP of business development at Oplink.

Prior to these posts, Li held various positions in general management, technology strategy and product development in various fiber-optic, industrial automation and machinery industries in both the USA and China.

Li holds a bachelor's degree in Mechanical Engineering from Chong Qing University in China and a master's degree in Mechanical Engineering, Systems Control from San Jose State University.

www.sourcephotonics.com

NeoPhotonics samples 400ZR ClearLight OSFP coherent transceivers for Cloud data-center interconnects

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 sampled its new 400ZR ClearLight OSFP transceiver to a leading Cloud-related customer. The product utilizes NeoPhotonics' silicon photonics coherent optical subassembly (COSA) and low-power-consumption, ultranarrow-linewidth Nano-ITLA tunable laser, combined with the latest generation of 7nm-node digital signal processing (DSP) technology, to provide full 400ZR transmission in a standard data-center OSFP form factor that can be plugged directly into switches and routers. This greatly simplifies and cost reduces data-center interconnect (DCI) networks by enabling the elimination of a layer of network equipment and a set of short-reach client-side transceivers, the firm says.

As hyper-scale Cloud architectures have evolved from concentrated data centers to multiple locations distributed around a metropolitan area, the need for seamless interconnection between data centers located at distances up to 120km apart has grown dramatically, notes NeoPhotonics. The ClearLight OSFP transceivers plug directly into the front panel of a switch or router to provision 400G connections over metro distances in a manner virtually the same as connections inside one data center. It is compliant with the OIF 400ZR Implementation Agreement and is interoperable with other manufacturers' 400ZR modules that utilize a standard forward error correction (FEC) encoder and decoder.

The ClearLight OSFP modules are built using internally produced integrated coherent optical solutions from NeoPhotonics, including its new compact and low-power-consumption Nano-ITLA and silicon photonics COSA. This new OSFP module is capable of tuning to 75GHz- or 100GHz-spaced wavelength channels, as specified in the OIF agreement, and operates in 400ZR mode for Cloud DCI applications. For longer metro reaches, the module is designed to support 400ZR+ modes.

The ClearLight OSFP module can also be optionally provisioned to tune over the entire 'Super C-Band', or up to 6.4 Terahertz, increasing the capacity of an optical fiber by up to 50% over standard implementations. NeoPhotonics provides arrayed waveguide gratings for multiplexing and de-multiplexing with 75GHz and 100GHz wavelength channel spacings, supporting 85 and 64 channels respectively, with filter responses optimized for high-baud-rate coherent signals.

"This new OSFP module joins our ClearLight DCO transceiver line and takes full advantage of our highly integrated and low-power-consumption Nano-Tunable Laser and silicon photonics COSA to enable a full metro coherent transceiver in the form factor and electrical interface designed for short-reach interconnections inside the data center," says chairman & CEO Tim Jenks. "We are now sampling these OSFP transceivers so that customers can evaluate the simplicity, cost and operating savings that can be realized by plugging coherent optics directly into switches and routers, and we are applying this same technology to additional form factors such as QSFP-DD," he concludes.

www.neophotonics.com

NeoPhotonics ships initial units of extended-tuning-range 400G-capable ClearLight CFP2-DCO coherent transceivers for end-customer trials

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 shipped its new 400G-capable ClearLight CFP2-DCO transceiver for end-customer trials.

This is said to be the first transceiver module able to deliver as much as 32 Terabits of capacity per fiber – significantly higher than existing 200G CFP2-DCO capacity or the emerging 400G CFP2-DCO capacity– by using internal optics that can support 80 channels of 64Gbaud data at 75GHz wavelength channel spacing combined with the latest generation of 7nm node digital signal processing (DSP) technology for superior optical signal-to-noise ratio (OSNR) and power consumption. The new product effectively increases the capacity of an optical fiber by as much as 50% over standard systems at comparable distances.

The ClearLight CFP2-DCO is the first in a series of coherent module solutions based on NeoPhotonics' patented photonic integrated circuit (PIC) platform, which will enable cloud operators and carriers to create optical interconnects with much greater capacity and density with reduced complexity in the high-capacity dense wavelength division multiplex (DWDM) optical networks used in hyper-scale cloud and telecom infrastructure applications.

NeoPhotonics' ClearLight CFP2-DCO module incorporates several coherent solutions from NeoPhotonics in a pluggable module, including its new extended-tuning-range ultra-narrow-linewidth tunable C++ LASER.Micro-ITLA (integrated tunable laser assembly). It also features its high-bandwidth 64Gbaud C++ ICR Receiver and C++ CDM Modulator. This module supports tuning across the full Super C-band and is said to provide up to 50% more spectrum and resulting capacity than standard modules.

The ClearLight CFP2-DCO module tunes to 75GHz-spaced wavelength channels when operating at 64Gbaud and 16 QAM to support 400G transmission in 400ZR and 400ZR+ modes for cloud data-center interconnect (DCI) and metro telecom applications. NeoPhotonics also provides arrayed waveguide gratings for multiplexing and demultiplexing with 75GHz channel spacings and filter responses optimized for 64Gbaud coherent signals, including for Super C-band use.

For long-haul and regional applications, the CFP2-DCO module utilizes 64Gbaud and QPSK modulation to deliver 200G-per-wavelength transmission. This is made possible by an OSNR of less than 14dB and enhanced performance to enable substantially longer reaches than standard 32Gbaud, 16 QAM systems.

If the application requires that a 50GHz channel wavelength spacing be used, this CFP2-DCO module can tune over 120 channels and operate at 200G with an OSNR of less than 16dB (again, substantially better than existing standard CFP2-DCO transceivers).

The module is compliant with the OIF-CFP2-DCO-01.0-Implementation Agreement and has a superior watt per gigabit performance. The module will also be available in standard C-band tuning range for applications that do not require the significantly higher capacity per fiber that this module enables.

"This new module joins our ClearLight CFP-DCO transceiver line, which has been shipping since 2017, and is our first in a series of DCO modules for 400G transmission and providing the benefits of extended C++ tuning range," says chairman & CEO Tim Jenks. "We are pleased to announce these initial shipments of our ClearLight CFP2-DCO coherent transceiver modules to customers," he adds. "This new series will utilize our leading 64Gbaud silicon photonics or indium phosphide PICs, together with our new Tunable C++ LASER Micro-ITLA. This will increase the capacity and distance performance in a network well above that available in systems today."

www.neophotonics.com

JinkoSolar partners with Shanghai Institute of Space Power-Sources

High-efficiency solar cells to be developed using silicon wafer as bottom cell and substrate

Solar module manufacturer JinkoSolar Holding Co Ltd of Shanghai, China (which has more than 15,000 staff across seven production facilities worldwide) has signed a memorandum of understanding (MOU) with Shanghai Institute of Space Power-Sources (SISP) to co-develop high-efficiency solar cell technology for both space and terrestrial applications. Innovators and engineers from both sides will co-develop space-based photovoltaic cells with a more efficient, low-cost, robust silicon wafer as the supporting bottom substrate and bottom cell.

Taking advantage of using inexpensive silicon wafers, the high-efficiency solar technology is easy to manufacture at large scale but can achieve a higher solar energy conversion rate. Also, as well as having the much lower degradation required for next-generation solar cells in space, it also has a more robust and rugged design. Due to its unprecedented efficiencies, it could also be used in other applications such as auxiliary power units in vehicles, solar roof tiles, power plants, and smart grid systems. This is an early-stage technology requiring additional development, but the partnership between two firms will fuel much needed development, it is expected.

Taking advantage of using inexpensive silicon wafers, the high-efficiency solar technology is easy to manufacture at large scale but can achieve a higher solar energy conversion rate. It also has a more robust and rugged design

"In the future, we will continue to increase technical cooperation, leading our industry in the name of technical innovation and providing more efficient solar panels with a wider range of choices for global customers," says JinkoSolar vice president Dr Jin Hao.

www.jinkosolar.com

First Solar reaches agreement to settle pending class action lawsuit

First Solar Inc of Tempe, AZ, USA — which makes thin-film photovoltaic modules based on cadmium telluride (CdTe) as well as providing engineering, procurement & construction (EPC) services — has entered into a memorandum of understanding (MOU) to settle the class action litigation 'Smilovits versus First Solar Inc et al (No. 2:12-cv-00555-DGC)' filed in 2012 in the United States District Court for the District of Arizona.

First Solar has agreed to pay $350m to settle the claims brought on behalf of all persons who purchased or otherwise acquired the firm's shares between 30 April 2008 and 28 February 2012. The parties have agreed to negotiate in good faith to execute definitive stipulations of settlement and related documents to be filed with the court, which will not contain any admission of liability, wrongdoing or responsibility by any of the parties and will provide that, upon final approval of the settlement, it will be dismissed with prejudice, with mutual releases by all parties. The settlement is subject to approval by the United States District Court for the District of Arizona.

"While we are confident in the facts and the merits of our position, we believe it is prudent to end this protracted and uncertain class action litigation process, and focus on driving the business forward," says CEO Mark Widmar. "We remain in a strong financial position, are pleased with our progress with Series 6 and our contracted customer pipeline, and are focused on executing our global strategy and serving our customers," he adds.

As previously disclosed, given the uncertainties of trial, First Solar says that it had not been in a position to assess the likelihood of any potential loss or adverse effect on its financial condition or to estimate the range of potential loss in connection with the class action. As a result of the MOU, the firm expects that the $350m will be incorporated into the results of operations and financial condition of the company for the fiscal year ended 31 December 2019.

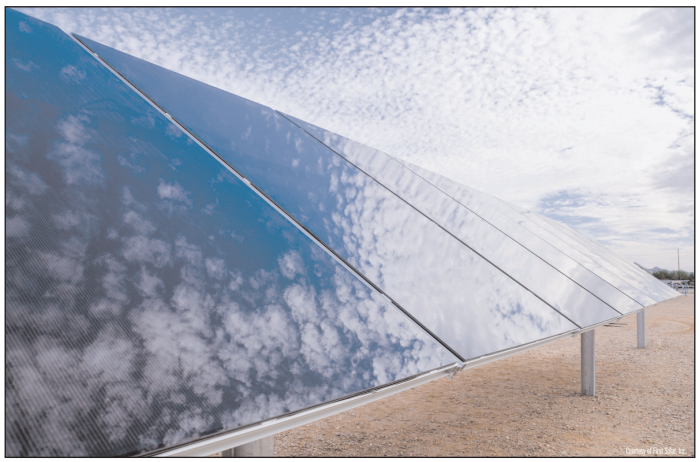
The previously disclosed lawsuit 'Maverick Fund L.D.C. versus First Solar Inc et al (No. 2:15-cv-01156-ROS)', filed in Arizona District Court by putative stockholders that opted out of the class action, remains pending. The previously disclosed derivative lawsuit 'Bargar et al versus Ahearn et al (No. CV2013-009938)', filed in the Superior Court of Arizona, Maricopa County, also remains pending.

www.firstsolar.com

EDP and ConnectGen complete acquisition of First Solar projects in Arizona, California and Nevada totaling 278MW

Cadmium telluride (CdTe) thin-film photovoltaic module maker First Solar Inc of Tempe, AZ, USA says that a partnership composed of EDP Renewables (whose principal shareholder is global energy firm Energias de Portugal S.A.) and North American renewable energy and energy storage project developer ConnectGen of Houston, TX, USA (founded in 2018 and backed by private equity capital provider Quantum Energy Partners) has completed the acquisition of three projects in the USA with a total nameplate design of 278MWAC. First Solar previously disclosed that the sale of these projects was subject to certain conditions that have since been satisfied.

The projects include the 154MWAC Sun Streams 1 project in Maricopa County, Arizona, the 20MWAC Windhub A project in Kern County, California, and the 103MWAC Sunshine Valley project in Nye County, Nevada. All three are scheduled to achieve substantial completion by the end of fourth-quarter 2019.



All three projects are powered by First Solar's thin-film module technology, developed and innovated in the USA.

The USA is EDP Renewables' biggest market in terms of installed capacity and production. EDP Renewables North America commissioned its first two solar parks in California in January 2015, subsequently adding three solar parks in South Carolina to its operational portfolio.

"This deal furthers our goal to provide long-term, cost-effective, renewable energy solutions in the United States," says ConnectGen's CEO Caton Fenz.

"We've proven, once again, that investors are focused on the winning formula: responsible development, attractive project economics, and long-term power purchase agreements, underpinned by high-performance PV modules and a partner that stands behind its commitments," says First Solar's chief commercial officer Georges Antoun.

Once commissioned, the projects will be operated by First Solar Energy Services which, with over 10GW under management, is the solar industry's most experienced operations and maintenance (O&M) service provider for large-scale solar power plants, it is claimed.

www.edpr.com
www.connectgenllc.com
www.firstsolar.com

First Solar recruits new chief human resources officer

First Solar says that Caroline Stockdale will lead its human resources and communications function, overseeing a global workforce of over 6500. She replaces Chris Bueter, who will continue in an advisory role until his retirement on 1 April.

"Caroline brings strategic thinking and problem-solving skills gained from working in disruptive industries that have had to be nimble to adapt and evolve," comments CEO Mark Widmar. "These attributes are critical to our success in an ever-changing marketplace."

Stockdale has more than 20 years of operating experience in finance, human resources, business leadership and process excellence, ranging from large global companies to entrepreneurial start-ups. She was most recently CEO of First Perform, a provider of human resources services for a variety of customers from the Fortune 100 to cyber start-ups. She served as chief human resources officer for Medtronic and Warner Music Group among others, and as senior human resources leader in global divisions of American Express and General Electric. Stockdale is also a member of several advisory groups including the Forbes Human Resources Council.

First Solar is celebrating both its 20th anniversary and the shipment of 25GW$_{DC}$ of photovoltaic (PV) modules (the only US solar manufacturing company to achieve this milestone). It recently announced the start of production at its new PV module manufacturing facility in Lake Township, Ohio (its second factory in the USA). First Solar's expanded manufacturing footprint in the USA, which represents over $1bn in cumulative investment and directly created about 500 new jobs, makes it the largest solar manufacturer in the USA and the Western Hemisphere. First Solar also operates manufacturing facilities in Vietnam and Malaysia, and has a commercial presence on five continents.

www.firstsolar.com

Midsummer announces completion of first installation of Bender SunWave solar roof panels

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 announced completion (at a townhouse outside Stockholm) of the first installation of Bender SunWave (solar panels fully integrated with roof tiles after a collaboration with Sweden-based roof manufacturer Benders). "If you didn't know, you would never believe that there are solar panels on the roof — it looks like just any beautiful shingled roof," says Benders' CEO Ove Bender.

Last May, Midsummer announced a unique solar panel solution developed specifically for Sweden's most popular 3-barrel roof tile, the Bender Palema. Since October, customized solar panels that precisely follow the shape of these roof tiles have been delivered from Midsummer's new production facility, and now the first end-customer installation is complete.

The customized solar panels are brought to the market by Benders under the brand Bender SunWave and are installed as easily on an existing roof as on a new roof, it is claimed, resulting in completely integrated solar panels that are not visible or noticeable.

First installation of Bender SunWave roof tiles, incorporating Midsummer's solar panel technology, on a townhouse outside Stockholm, Sweden.

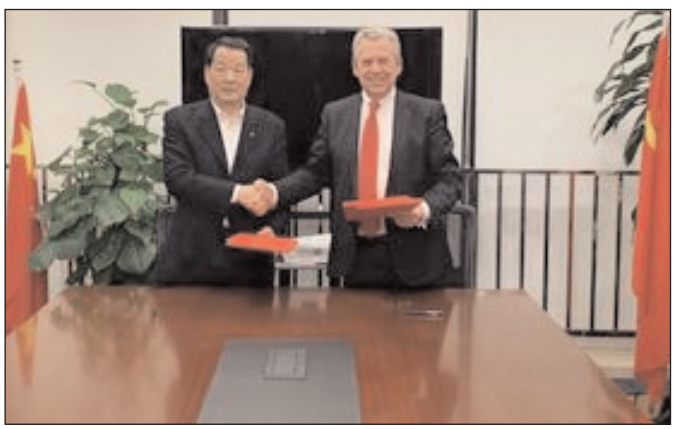
"The great interest for Palema SunWave and our other building-integrated solar products proves that solar panels are becoming like any other building material, with natural high expectations on both technical performance and aesthetics," says Midsummer's CEO Sven Lindström. "For us and our customers, it is instrumental to develop and supply solar roofs that are beautiful, which often means as invisible as possible to accentuate the natural beauty of the roofs," he adds. "This is a key feature that our thin film technology enables but that framed silicon panels simply cannot achieve."

The partnership with Benders is part of Midsummer's new strategy to develop and manufacture solar panels both in-house and via contract manufacturers for sale through selected partners, in addition to the firm's core business of producing equipment for the manufacturing of solar cells. Midsummer claims that its DUO system is the world's most widespread manufacturing tool for flexible CIGS solar cells.

www.midsummer.se
www.benders.se

Singulus receives €50m order from CNBM for CIGS solar module production systems

Singulus Technologies AG of Kahl am Main, Germany (which makes production equipment for the optical disc and solar sectors) says that its customer Bengbu Design and Research Institute of Glass Industry Co Ltd, a subsidiary of Beijing-based China National Building Materials (CNBM), has placed a large order, worth €50m in the first stage of expansion, for the delivery of copper indium gallium diselenide (CIGS) solar module production systems to its site in Xuzhou.

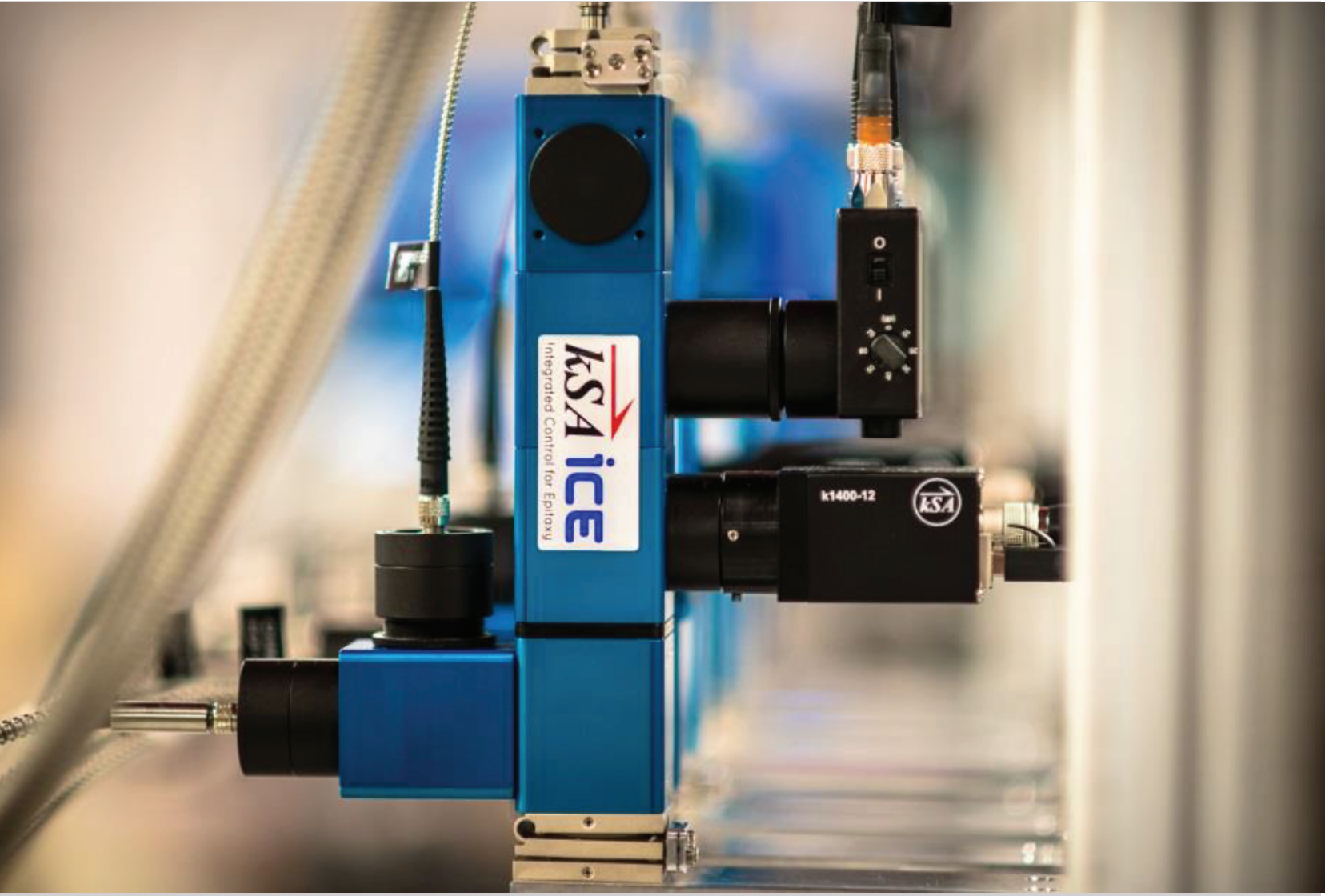


CNBM's executive director Peng Shou and Singulus' CEO Dr Stefan Rinck after signing the order.

CNBM acquired a minority 16.8% stake in Singulus in January 2018. "CNBM is continuing to expand CIGS technology in China as planned and is by far the largest manufacturer of CIGS solar modules," notes Singulus' chairman Dr Stefan Rinck.

The planned final output of the Xuzhou factory is 300MW, to be achieved in a second expansion stage.

www.singulus.com



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NREL demos first growth of AlInP and AlGaInP by HVPE

Adding aluminium to D-HVPE enables parity on efficiency with solar cells made by more costly MOVPE

The US National Renewable Energy Laboratory (NREL) says that it has integrated an aluminium source into its hydride vapor phase epitaxy (HVPE) reactor then demonstrated the growth of aluminum indium phosphide (AlInP) and aluminum gallium indium phosphide (AlGaInP) for what is claimed to be the first time by this technique.

"There's a decent body of literature that suggests that people would never be able to grow these compounds with hydride vapor phase epitaxy," says Kevin Schulte, a scientist in NREL's Materials Applications & Performance Center and lead author of the paper 'Growth of AlGaAs, AlInP, and AlGaInP by Hydride Vapor Phase Epitaxy' (ACS Applied Energy Materials (12 December 2019) https://doi.org/10.1021/acsaem.9b02080). "That's one of the reasons a lot of the III–V industry has gone with metal-organic vapor phase epitaxy (MOVPE), which is the dominant III–V growth technique. This innovation changes things," he reckons.

III–V solar cells are commonly used in space applications. Notable for high efficiency, these types of cells are expensive for terrestrial use, but researchers are developing techniques to reduce those costs.

A method pioneered at NREL relies on the new growth technique dynamic hydride vapor phase epitaxy (D-HVPE). Traditional HVPE, which for decades was considered the best technique for producing light-emitting diodes and photodetectors for the telecoms industry, fell out of favor in the 1980s with the emergence of MOVPE. Both processes involve depositing chemical vapors onto a substrate, but the advantage belonged to MOVPE because of its ability to form abrupt heterointerfaces between two different semiconductor materials, a place where HVPE traditionally struggled. NREL says that that has changed with the advent of D-HVPE.

The earlier version of HVPE used a single chamber where one chemical was deposited on a substrate, which was then removed from the chamber. The growth chemistry was then swapped for another, and the substrate returned to the chamber for the next chemical application. D-HVPE relies on a multi-chamber reactor. The substrate moves back and forth between chambers, greatly reducing the time to make a solar cell. A single-junction solar cell that takes an hour or two to make using MOVPE can potentially be produced in under a minute by D-HVPE, it is reckoned.

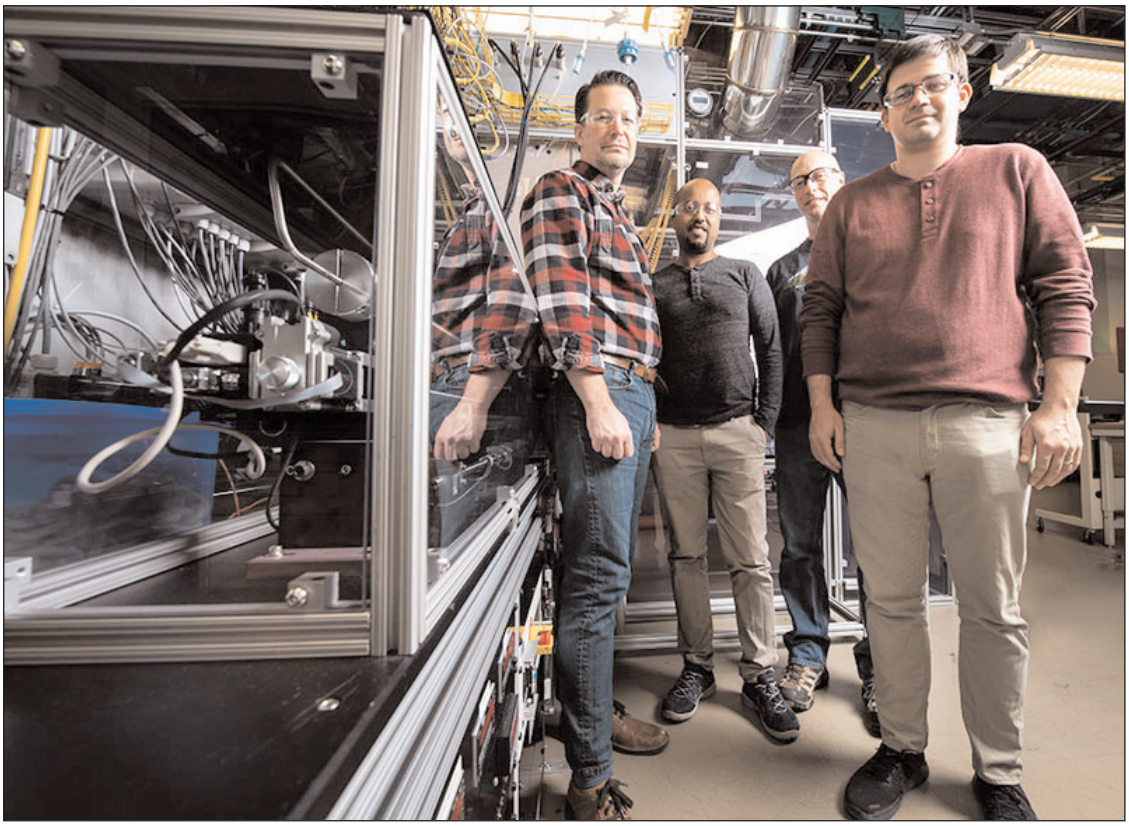
Sample aluminium III-V solar cells, grown using HVPE, are shown as Alx(Ga1-x)0.5In0.5P thin films after removing the GaAs substrate bonded to a glass handle substrate for transmission measurements. The difference in color is due to the difference in the composition of Al and Ga. Specifically, yellow samples are AlInP (no Ga) and orange samples are AlGaInP. Photo by Dennis Schroeder, NREL.

Despite these advances, MOVPE still held another advantage: the ability to deposit wide-bandgap aluminium-containing materials that enable the highest solar cell efficiencies. HVPE has long struggled with the growth of these materials due to difficulties with the chemical nature of the usual aluminium-containing precursor, aluminum monochloride.

The researchers always planned on introducing aluminium into D-HVPE, but first focused their efforts on validating the growth technique. "We've tried to move the technology forward in steps instead of trying to do it all at once," says Schulte. "We validated that we can grow high-quality materials. We validated that we can grow more complex devices. The next step now for the technology to move forward is aluminium."

Schulte's co-authors from NREL are Wondwosen Metaferia, John Simon, David Guiling and Aaron J. Ptak. They also include three scientists from Kyma Technologies Inc of Raleigh, NC, USA (which provides wide-bandgap semiconductor crystalline materials and crystal growth equipment). The firm developed a method to produce a unique aluminium-containing molecule, which could then be flowed into the D-HVPE chamber.

The researchers used an aluminium trichloride generator, which was heated to 400°C to generate an aluminium trichloride from solid aluminium and hydrogen chloride gas. Aluminium trichloride is much more stable in the HVPE reactor environment than the monochloride form. The other components — gallium chloride and indium chloride — were vaporized at 800°C. The three elements were combined and deposited on a substrate at 650°C.



NREL researchers (from left to right) Aaron Ptak, Wondwosen Metaferia, David Guiling and Kevin Schulte are growing aluminium-containing materials for III-V solar cells using HVPE. Photo by Dennis Schroeder, NREL.

Now that aluminium has been added to the mix of D-HVPE, the researchers reckon that they should be able to reach parity with solar cells made via MOVPE. "The HVPE process is a cheaper process. Now we've shown a pathway to the same efficiency that's the same as the other guys, but with a cheaper technique. Before, we were somewhat less efficient but cheaper. Now there's the possibility of being exactly as efficient and cheaper"

Using D-HVPE, NREL has previously been able to make solar cells from gallium arsenide (GaAs) and gallium indium phosphide (GaInP). In these cells, the GaInP is used as the 'window layer', which passivates the front surface and permits sunlight to reach the GaAs absorber layer below where the photons are converted to electricity. This layer must be as transparent as possible, but GaInP is not as transparent as the aluminium indium phosphide (AlInP) used in MOVPE-grown solar cells. The existing efficiency record for MOVPE-grown GaAs solar cells that incorporate AlInP window layers is 29.1%. With only GaInP, the maximum efficiency for HVPE-grown solar cells is estimated to be only 27%.

Now that aluminium has been added to the mix of D-HVPE, the researchers reckon that they should be able to reach parity with solar cells made via MOVPE.

"The HVPE process is a cheaper process," notes Ptak, a senior scientist in NREL's National Center for Photovoltaics. "Now we've shown a pathway to the same efficiency that's the same as the other guys, but with a cheaper technique," he adds. "Before, we were somewhat less efficient but cheaper. Now there's the possibility of being exactly as efficient and cheaper."

The US Department of Energy's Solar Energy Technologies Office funded the D-HVPE research. ■

https://pubs.acs.org/doi/full/10.1021/acsaem.9b02080

www.nrel.gov

GaAs photodetector on thin germanium-on-silicon virtual substrate

Researchers hope the technique can be extended to other III-V high-performance optoelectronic systems in visible and near-infrared bands.

Researchers based in United Arab Emirates have used germanium-on-silicon templates to produce gallium arsenide (GaAs) metal–semiconductor–metal (MSM) photodetectors [Ghada Dushaq et al, J. Appl. Phys., vol126, p193106, 2019]. The team from New York University Abu Dhabi, and from Khalifa University, comments: "The extension of this method to other III–Vs and lattice-mismatched systems may enable high-performance optoelectronics in visible and near-infrared bands."

Monolithic integration of III–V materials on silicon is also hoped to reduce costs with high yields and production volumes, and further allowing combination with mainstream complementary metal–oxide–semiconductor (CMOS) electronics and silicon photonics platforms.

III–V materials like GaAs are more optically active than indirect-bandgap silicon. GaAs and other materials thus have higher photodetection performance. In addition, the creation of efficient light sources — LEDs and lasers — overwhelmingly mandates the use of direct-bandgap materials, the most highly developed of which are the III–V class of compound semiconductors.

The deposition of III–V materials on silicon is hampered by mismatched lattice and thermal expansion parameters. In their work, the researchers used a germanium layer that was much thinner than the ~10μm graded silicon germanium layers often employed to bridge between silicon and III–V semiconductors.

The germanium-on-silicon template or 'virtual substrate' consisted of a 700nm radio-frequency plasma-enhanced chemical vapor deposition (PECVD) layer on (100) silicon. The GaAs came from a metal-organic chemical vapor deposition (MOCVD) process involving tertiarybutylarsine (TBA) and trimethylgallium (TMGa) precursors.

Before the GaAs deposition the Ge surface was baked at 400°C and 700°C for 5 min and 10 min, respectively. The aim of these thermal treatments was to enable the

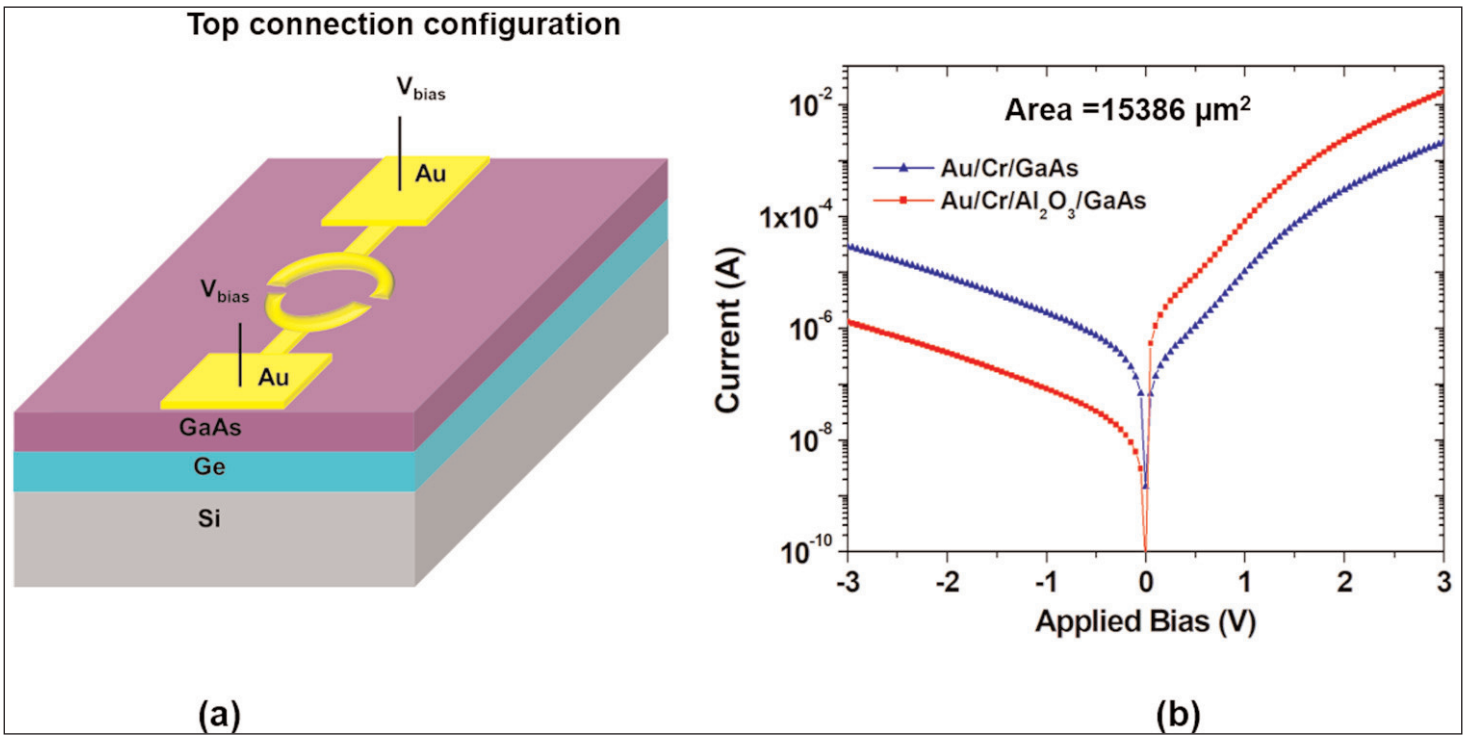


Figure 1. (a) Top electrical connection of GaAs MSM detector and (b) current–voltage rectifying behavior at the metal–semiconductor junction with/without Al_2O_3 interlayer.

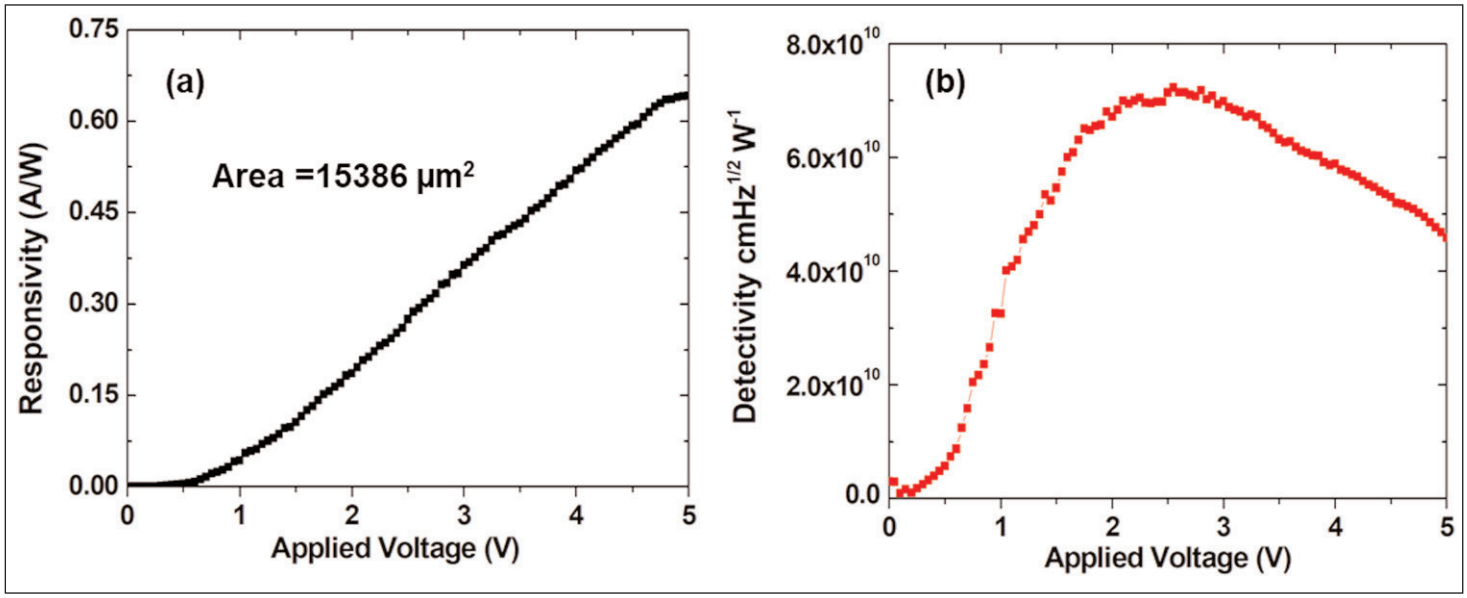


Figure 2. (a) Responsivity and (b) detectivity as function of reverse bias voltage.

transition from non-polar Ge to polar GaAs without introducing antiphase boundaries (APBs), dislocations and stacking faults. The researchers describe the treatment as "an essential step toward increasing the density of double atomic steps, adsorbing the Ge native oxide, and enhancing surface quality before starting the GaAs deposition."

The GaAs was deposited in two steps: at 500°C for 5 minutes, creating a seed layer, and then at 550°C for the remainder of the growth. The device layer was undoped, aiming at intrinsic conduction behavior with a view to low-voltage operation. In fact, interdiffusion of germanium into the GaAs layer introduced trapping states and extended defects that gave p-type conduction with $5x10^{17}/cm^2$ hole concentration, resulting in a sheet resistance of ~200mΩ/square.

The GaAs surface was cleaned and subjected to oxygen plasma treatment before passivation with 1–2nm of sputtered aluminium oxide (Al2O3), which targeted a good-quality Schottky contact. Evaporated chromium (Cr) and gold (Au) were used as the metal contacts of the MSM photodetector. The 15nm chromium acted as an adhesion and seed layer for the gold contact.

The Al_2O_3 interlayer reduced leakage in the Schottky junction by a factor of ~20 at 1V reverse bias (Figure 1). The on/off current ratio with Al_2O_3 passivation was around 10^3 for ±1V bias. The interlayer also reduced the Schottky barrier height to 0.62eV, compared with 0.67eV without Al_2O_3 passivation.

The interlayer avoided the severe Fermi-level pinning resulting from bare-surface GaAs defect states. Further the aluminum oxide improved photon collection efficiency.

The dark current density in devices of 30–140μm diameter was ~$6mA/cm^2$.

The optical response was measured using 850nm monochromatic laser light (Figure 2). Passivated and unpassivated devices had similar response characteristics. The passivate device was superior in terms of reduced dark current. The responsivity at 5V reverse bias was as high as ~0.54A/W. The researchers estimate an 85% quantum efficiency. Variation in response of different devices ranged between 0.4 and 0.64A/W.

The researchers compared their response with theoretical expectations of 0.41A/W, based on the bulk GaAs absorption coefficient. The ~1.55x enhancement measured in the experiments on the 0.64A/W device is attributed to an increased absorption in the non-bulk GaAs body of the device.

The researchers comment: "In the theoretical calculation, we considered the absorption coefficient of bulk GaAs. However, in the heteroepitaxy thin-film GaAs structure, the optical parameters are significantly affected by growth condition, layer thickness, and the material beneath it. Additionally, Ge is a highly absorbent material at 850nm."

In particular, the team points to x-ray analysis showing that the Ge and GaAs layers are tensile strained. The researchers believe the strain leads to increased absorption of light from a reduced energy bandgaps. A further 1.5% boost is attributed to light reflected at the GaAs/Ge interface.

The detectivity, extracted from photo-current and dark-current responses, was ~$4.6x10^{10}$cm-$Hz^{1/2}$/W.

The junction capacitance was ~500fF at 1V reverse bias. The researchers say that the small capacitance means that the bandwidth of the device is limited instead by the carrier transit time across the device. The team estimates the 3dB bandwidth at up to 9GHz, and around 4GHz with 1V bias.

Reduced response time could result from scaling down the device, but there is a trade-off from reduced photoresponse with decreased active area. The trade-off could be improved with transparent electrodes. ■

https://doi.org/10.1063/1.5120705

Author: Mike Cooke

Toward photodetector arrays based on indium gallium nitride micro-LEDs

Researchers implement a 2-transmitter, 2-receiver visible light communication setup with data rates up to 175MHz.

Fudan University in China and University of Toronto in Canada have been exploring the use of indium gallium nitride (InGaN) micro-light-emitting diode (μLED) arrays in photodiode (PD) mode for multiple input, multiple output (MIMO) visible light communications (VLC) [Xiaoyan Liu et al, ACS Photonics, (2019) vol6, no12, p3186]. The team suggests that the technology could lead to integration of display, fast data transmission and photodetectors, powered photovoltaically either through the signal itself or through solar illumination.

The researchers comment: "Such a multifunctional μLED information display is very useful for applications where high-speed wireless network

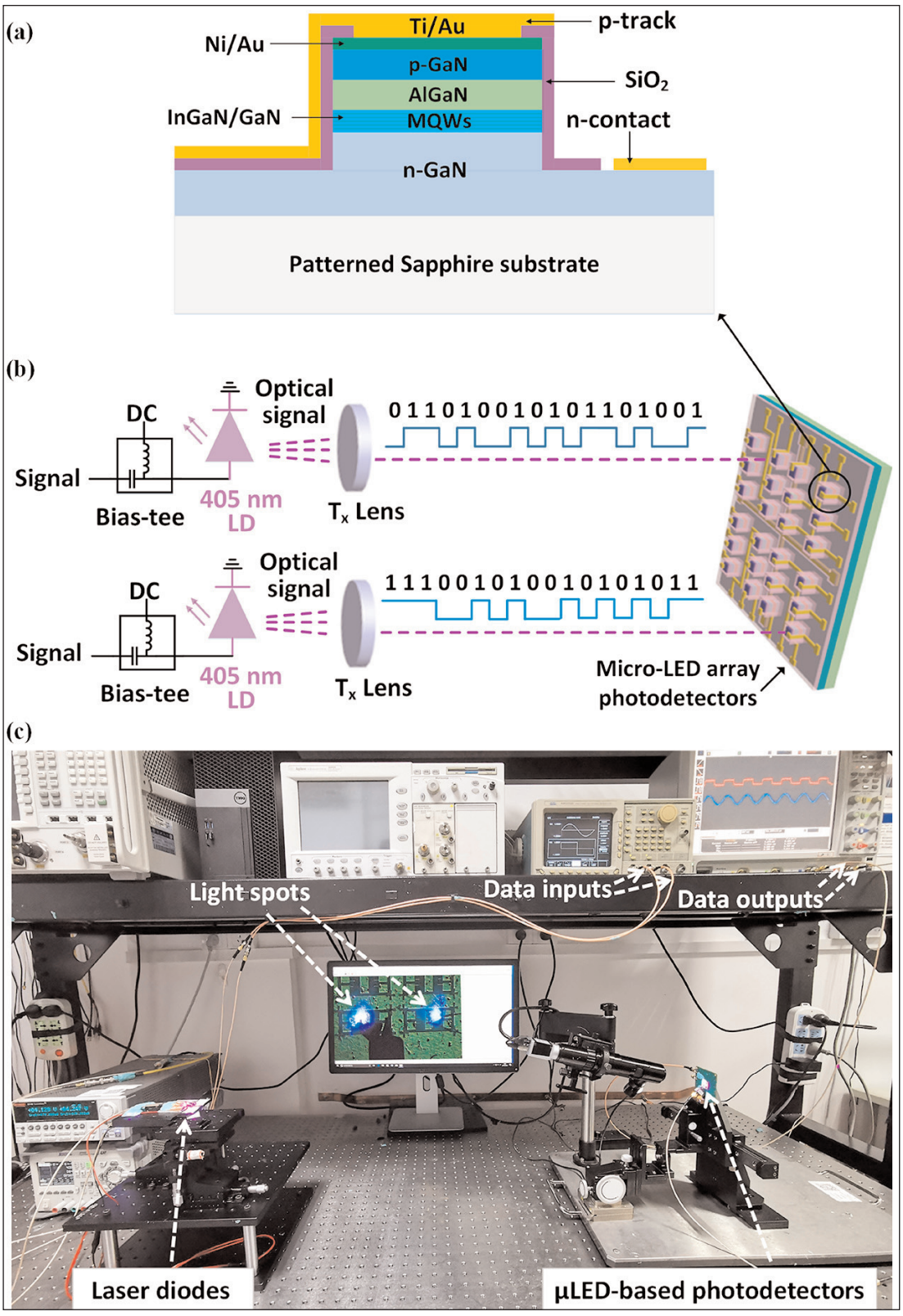


Figure 1. (a) Schematic diagram of μLED, (b) setup for MIMO VLC, and (c) photograph of experiment.

and considerable electrical power are required, for instance information display chips for wearable virtual reality/augmented reality (VR/AR) devices, and outdoor large-screen display."

VLC is seen as a wireless communication technology that could be deployed in environments where electromagnetic interference from radio frequencies could be problematic such as aircraft or hospitals.

The small size of μLEDs is expected to result in higher bandwidths due to smaller parasitic resistances and capacitances. Although single μLED photodetectors have been studied, the researchers report that parallel array structures of such devices have not been presented up to now.

The 2x2 MIMO system consisted of transmissions from 405nm violet laser diodes (LDs) transmitted over a free-space distance of 1m onto 450nm blue μLED structures used as photodetectors (Figure 1). The laser diodes were used due to reduced crosstalk between the two signal sources with reduced divergence angle of the beams. The laser light was collimated using lens systems.

The researchers fabricated their devices using commercial metal-organic chemical vapor deposition (MOCVD) material grown on patterned sapphire substrates. The light-sensitive region was indium gallium nitride (InGaN) multiple quantum wells (MQWs) with GaN barriers. An aluminium gallium nitride (AlGaN) electron-blocking layer was included in the structure. The silicon dioxide (SiO_2) insulation was applied using plasma-enhanced chemical vapor deposition (PECVD). Nickel/gold (Ni/Au) was used for current spreading. The n- and p-contact pads consisted of titanium/gold (Ti/Au).

The photodetector diameters varied between 40μm and 100μm. At zero bias, the photo/dark current ratio, or 'photosensitivity', was of order 10^9. This high value resulted from the very low dark current at zero bias of 10^{-14}A. The laser diode power density reached as high as 11.0W/cm^2.

With the devices biased at -5V, the photo/dark current ratio was 10^7 for the smaller devices, and 10^8 for the larger. The researchers say that these values match the best reported results and are "higher than previously reported values of the GaN photodetectors with photoconductive, p–i–n, or heterojunction structures". The team expects the high values to benefit the signal/noise ratio and minimum detection limits of the devices.

When the illumination was at 11.0W/cm^2, the short-circuit current was 27.4μA for the 40μm-diameter μLED. This increased to 188μA for 100μm diameters. The open-circuit voltages were all 2.6V. This photovoltaic effect could be used to power other parts of a circuit. The researchers report that they have used such harvested energy to power a 660nm laser diode.

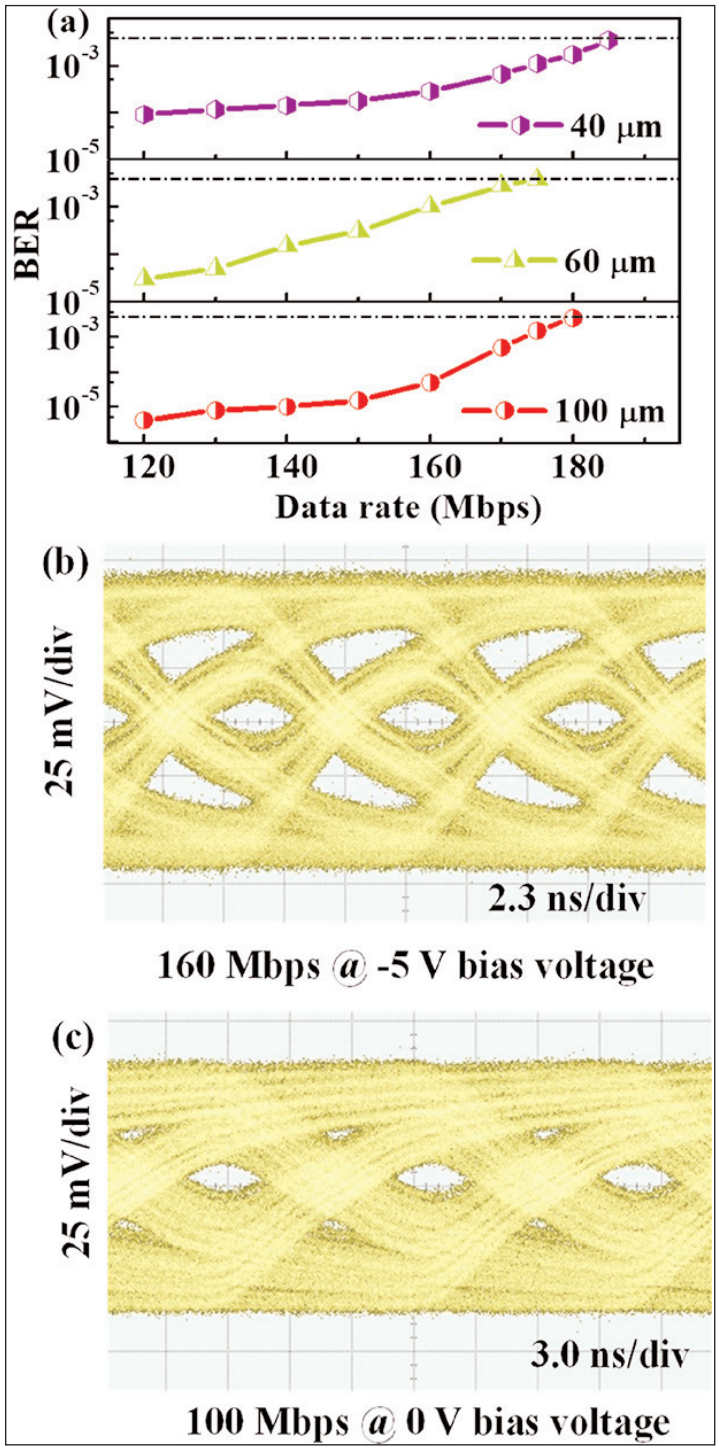


Figure 2. (a) BER versus data rate at –5V bias for μLED-based photodetectors with various diameters. Black solid line and black dash line represent –3dB bandwidth and FEC threshold, respectively. Eye diagrams captured at data rates of 160 (b) and 100Mbps (c) for 60μm μLED-based photodetector at –5V and 0V bias, respectively.

The team sees potential for such setups to be used in powering systems in hazardous and harsh environments.

The responsivity of the self-powered μLEDs with 11.0W/cm^2 laser power density was 0.24A/W for 40μm diameters, and 0.21A/W for 100μm. A 60μm-diameter

μLED achieved 0.29A/W response. The researchers estimate the quantum efficiency to be 74%, 88% and 62% for 40μm-, 60μm- and 100μm-diameter μLEDs, respectively.

Biasing the devices at −5V gives corresponding responses of 0.27, 0.31 and 0.24A/W — and quantum efficiencies of, in the same order, 82%, 96% and 73%. The researchers attribute the increased performance to the enhanced separation and collection of electrons and holes under reverse bias.

The team comments: "The values of responsivities are higher than that of a commercial Si-PIN photodetector at the wavelength of 405nm and are slightly better than the GaN-based photodetectors in previous reports without internal photocurrent gain."

The specific detectivity that measures the effects of bandwidth and noise on the μLED-PD was around 10^{13}Jones (cm-$Hz^{1/2}$/W) at zero bias — $7.5x10^{12}$Jones for 40μm diameters and $1.5x10^{13}$Jones for 60μm. The values decreased somewhat for −5V bias due to increased dark current −—$1.11x10^{11}$Jones for 40μm and $2.3x10^{12}$Jones for 60μm diameters.

For high-speed communications, fast response to changes in illumination are needed. Smaller devices are likely to have faster rise and fall times. At zero bias, the rise and fall times in response to 11.7W/cm^2 laser diode illumination were 22.0ns and 23.7ns, respectively, for the 40μm-diameter μLED. These times reduced with −5V reverse bias to 13.2ns and 13.7ns, respectively.

The researchers explain: "In comparison with 0V bias, the photoresponse time turns out to be shorter at a −5V bias, which is attributed to the increase of drift speed of carriers under reverse bias.

In fact, the 60μm-diameter μLED had improved rise/fall times: 17.2n/20.2ns at zero bias, and 12.2ns/12.7ns at −5V.

The −3db electrical-to-optical modulation bandwidths at −5V reverse bias were 56.8, 56.2 and 53.5MHz, respectively, for the 40μm, 60μm and 100μm devices. These values reduced at zero bias with corresponding values of 40.3, 41.2 and 38.6MHz.

In on-off keying (OOK) modulation transmissions, the researchers achieved 185 megabits per second (Mbps) with the 100μm device reverse biased at −5V (Figure 2). The bit error rate (BER) was $3.5x10^{-3}$, lower than the $3.8x10^{-3}$ upper limit for forward error correction (FEC) to be possible.

The 60μm device achieved 120Mbps with zero bias and $3.6x10^{-3}$ BER. Under −5V reverse bias, the same devices achieved 175Mbps and $3.7x10^{-3}$ BER. The researchers comment: "In the proposed 2x2 MIMO VLC, ideal real-time data rates of 350Mbps (under a −5V bias) and 240Mbps (under zero-bias) can be accomplished using 60μm μLED-based photodetectors as optical receivers."

Applying scaling arguments, the team suggests that 18Gbps could be achieved with 10x10 arrays, and several terabits per second with 128x128 setups. However, "it is worth noting that there are significant challenges to achieve such extension to multi-Gbps transmission in practical applications because of the inevitable crosstalk and collimation difficulty for more and more arrays," the team warns. ■

https://doi.org/10.1021/acsphotonics.9b00799

Author: Mike Cooke

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Monolithic optoelectronic integration of gallium nitride transistor

Researchers combine a normally-off 6V threshold GaN MOSFET device with a light-emitting diode on a silicon substrate.

Nanjing University of Posts and Telecommunications in China claims the first enhancement-mode metal-oxide-semiconductor field-effect transistors (MOSFETs) fabricated on a gallium nitride (GaN)-on-Si light-emitting diode (LED) epitaxial wafer [Jiabin Yan et al, IEEE Electron Device Letters, vol41, issue1 (January 2020), p76]. Enhancement-mode devices (that are 'normally-off' at 0V gate potential) are often preferred with respect to lower power consumption.

The research team also demonstrated the MOSFET's ability to control an indium gallium nitride (InGaN) LED on the same platform. The researchers hope that such monolithic optical electronic integrated circuits (OEICs) could lead to applications such as smart lighting, display and visible light communication (VLC). The Nanjing group has been developing VLC systems on silicon for a while [see e.g. www.semiconductor-today.com/news_items/2019/jun/nupt-130619.shtml, which contains further links].

The team sees advantages to the low-cost silicon platform as including integration with micro-electro-mechanical system (MEMS) batch fabrication processes. Although LEDs, photodiodes, waveguides, couplers and other photonic structures are relatively easy to process, up to now GaN transistor structures are usually implemented using different epitaxial structures, impeding low-cost integration.

The III–nitride structure on silicon (Figure 1) included a 250nm InGaN/GaN multiple quantum well (MQW) layer sandwiched between n- and p-type GaN, as used in light-emitting diodes. The wafer was 2-inches in diameter. The silicon substrate was thinned to 300μm thick by grinding and polishing.

The transistor was formed using the n-GaN as source and drain, while the channel was through the undoped GaN layer. Insulation and the gate dielectric consisted of 100nm silicon dioxide (SiO_2). The gate metal was deposited in the trenches, covering the undoped GaN channel and the recess sidewalls. The electrodes were ring-shaped to increase the width/length ratio for a larger output current. The channel length was 20μm. The radius of the recess ring center was 135μm.

The fabrication began with removal of the p-GaN and InGaN/GaN layers using inductively coupled plasma reactive-ion etch from the transistor area. The gate recess also used a similar etch process, but at slow

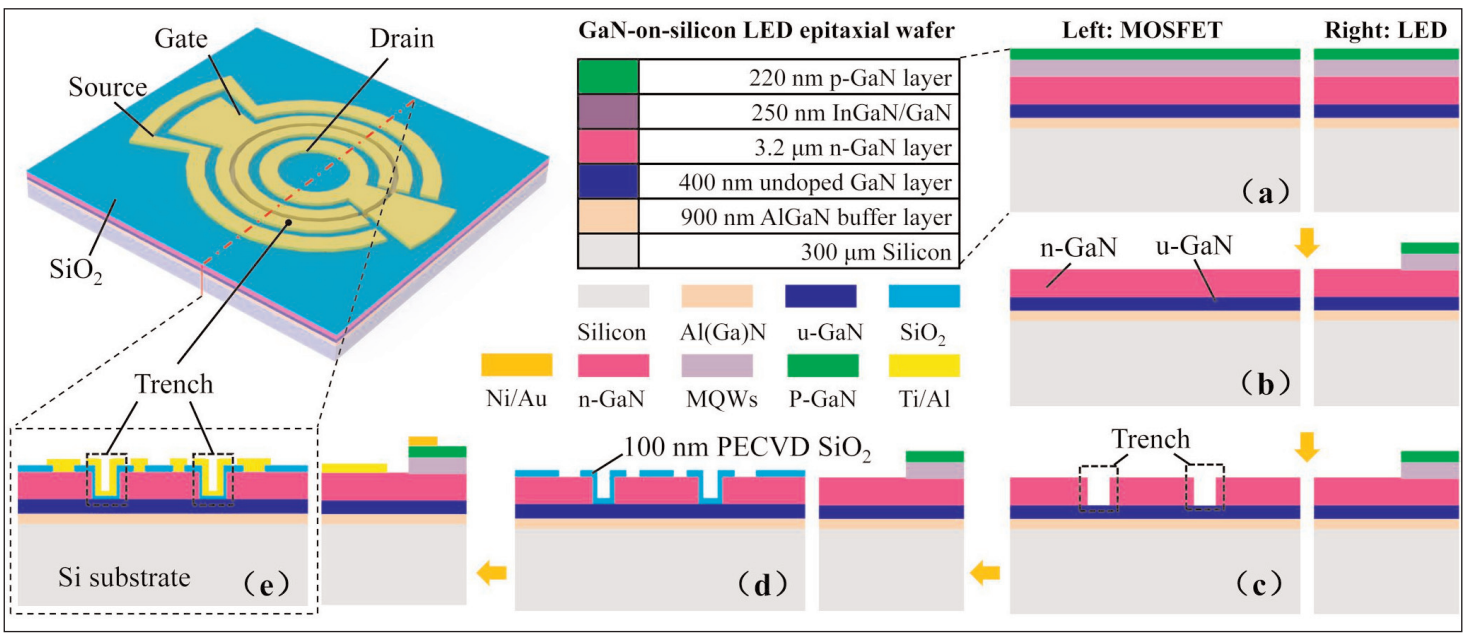


Figure 1. Schematic overview of proposed devices based on GaN-on-Si platform and fabrication process steps.

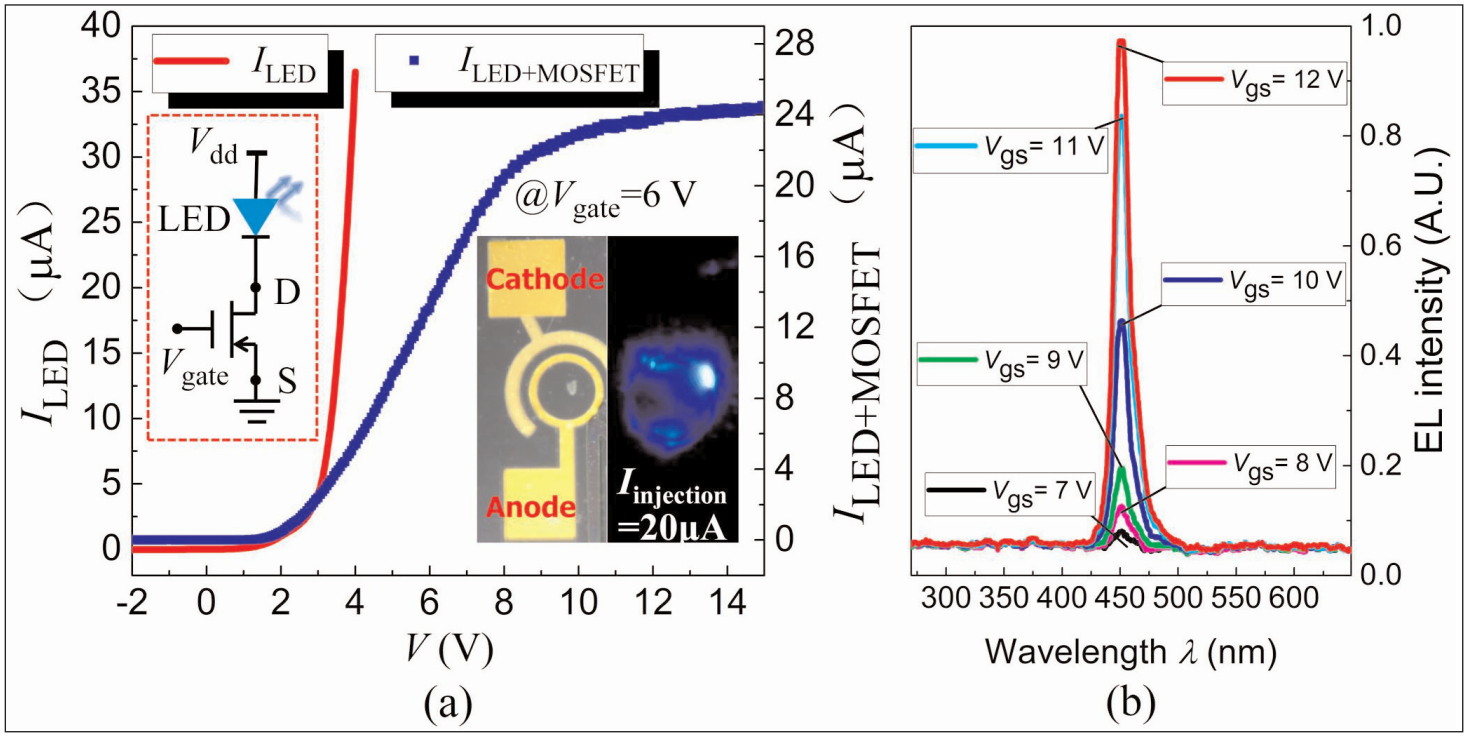


Figure 2. (a) Current–voltage (IV) characteristics of individual LED and LED-MOSFET (LED and MOSFET in series according to inset circuit diagram); (b) electroluminescence (EL) spectra of LED with different MOSFET gate voltages.

speed to ensure accurate depth with full removal of the n-GaN and non-removal of undoped GaN. Despite the slow etch, the sidewalls of the recess were rough.

The SiO_2 was applied using plasma-enhanced chemical vapor deposition (PECVD) and patterned with reactive-ion etch. The transistor metals were titanium/aluminium, annealed to improve the source/drain ohmic contacts.

In DC testing the minimum on-resistance of 5Ω-m was achieved at 12V gate potential. The team comments: "Even though the output current is relatively low compared with that of some published GaN-based FETs, the proposed MOSFET can still meet the requirements of numerous low-power applications, especially the micro-LED for smart display (typical driving current from several μA to hundreds of μA)."

The research team also demonstrated the MOSFET's ability to control an InGaN LED on the same platform. The researchers hope that such monolithic optical electronic integrated circuits could lead to applications such as smart lighting, display and visible light communication.

The team sees advantages to the low-cost silicon platform as including integration with MEMS batch fabrication processes. Although LEDs, photodiodes, waveguides, couplers and other photonic structures are relatively easy to process, up to now GaN transistor structures are usually implemented using different epi structures, impeding low-cost integration

The subthreshold behavior was pretty poor with 2.78V/decade swing at 1V drain bias. This must be seen in the context that the theoretical minimum is 60mV/decade (0.06V/decade) at room temperature. Further, other reported GaN MOSFETs have achieved values as low as 218mV/decade. The researchers hope to improve the subthreshold behavior with tetramethylammonium hydroxide (TMAH) or fluorine treatments to reduce surface roughness of the recess sidewalls.

By contrast, the threshold voltage was a high 6.01V. The peak transconductance was 3.78μS/mm with the on-resistance at 7.96Ω-m. The drain bias was 0.1V. The gate and drain leakage currents were 120nA/mm (0V drain, 12V gate) and 5μA/mm (5V drain, 0V gate), respectively. An analysis of the parasitic capacitance suggests a cut-off frequency of the order of tens of megahertz. Reduced device dimensions would increase switching speed at the expense of drive current.

The researchers also integrated the MOSFET with an LED on the same substrate. The LED used titanium/aluminium and nickel/gold as cathode and anode electrodes, respectively. The MOSFET allowed control of the light output with increased gate potential (Figure 2). ■

https://doi.org/10.1109/LED.2019.2952905

Author: Mike Cooke

Record power-density AlGaN barrier transistors

Researchers use freestanding gallium nitride substrates to achieve output power density of 2W/mm at 40GHz.

Researchers in France claim record power performance at 40GHz from aluminium gallium nitride (AlGaN)-barrier high-electron-mobility transistors (HEMTs) on freestanding gallium nitride substrates [Mohamed-Reda Irekti et al, Semicond. Sci. Technol., vol34, p12LT01, 2019]. The output power density reached 2W/mm with 20.5% power-added efficiency.

Although higher power densities have been achieved at lower frequency, the device from University of Lille, Laboratoire d'Analyse et d'Architecture des Systèmes, and Université Côte d'Azur, beat a previous high at 40GHz of 1W/mm.

The researchers used 2inch-diameter freestanding GaN substrates commercially produced by Saint-Gobain Lumilog via hydride vapor phase epitaxy (HVPE). The substrate had a resistivity of less than 30mΩ-cm.

Metal-organic chemical vapor deposition (MOCVD) by the researchers added epitaxial layers of 10μm resistive GaN buffer, 1.5nm AlN, 11nm $Al_{0.26}Ga_{0.74}N$ barrier and 3nm in-situ silicon nitride cap (Figure 1). The resistive buffer was grown in two steps: 3μm carbon-doped

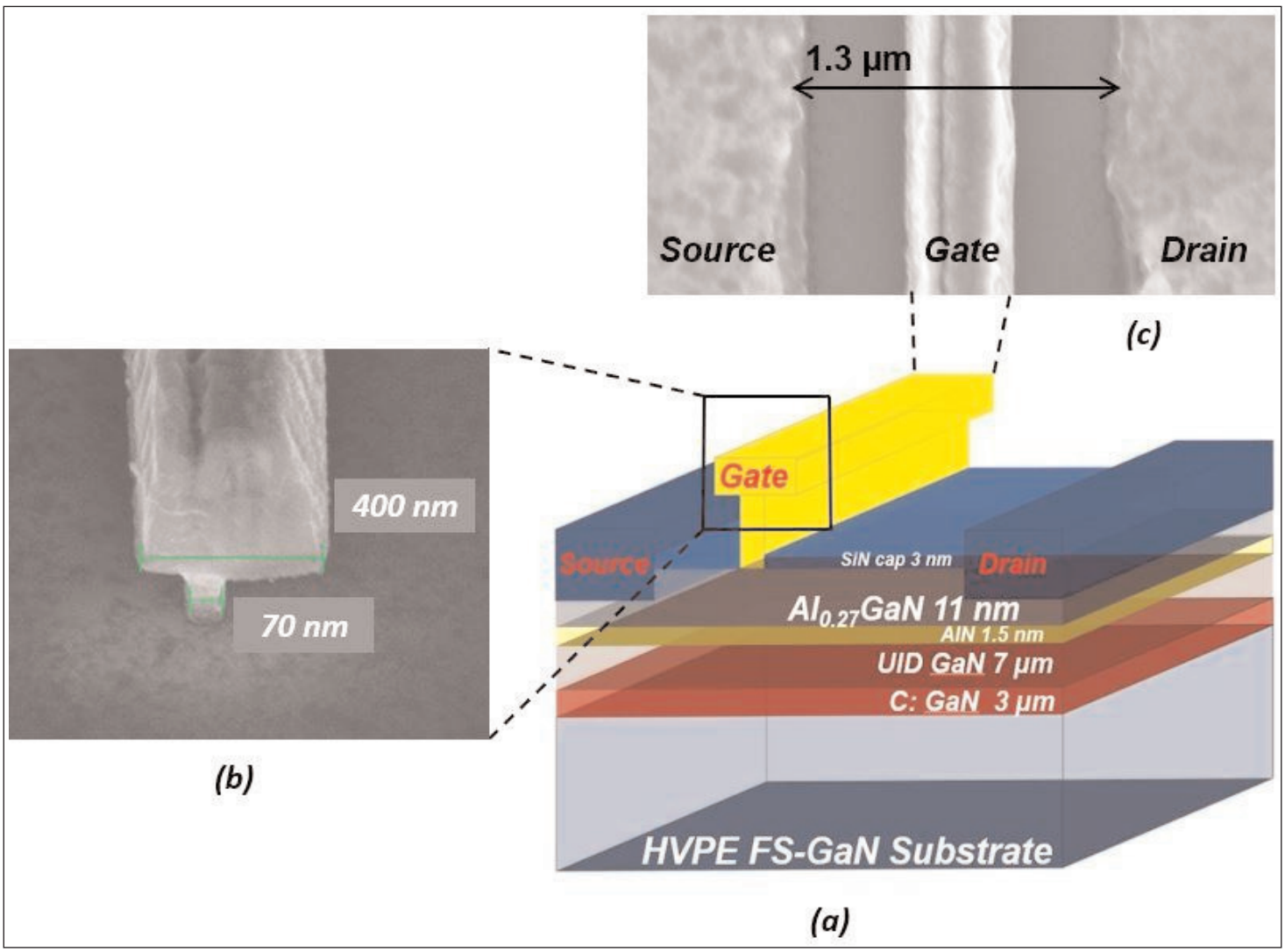


Figure 1. (a) Schematic of as-fabricated AlGaN/GaN HEMT on freestanding GaN substrate before passivation. Scanning electron micrographs: (b) after gate lift-off and (c) top view after gate fabrication.

GaN (C:GaN) and 7μm unintentionally doped GaN.

The exclusion layer aimed to reduce alloy scattering and enhance confinement of the electron carriers in the two-dimensional electron gas (2DEG) that formed the channel in the undoped GaN buffer near the interface. Hall-effect measurements gave $8.5x10^{12}/cm^2$ electron density and $2200cm^2/V\text{-}s$. The corresponding sheet resistance was 356Ω/square.

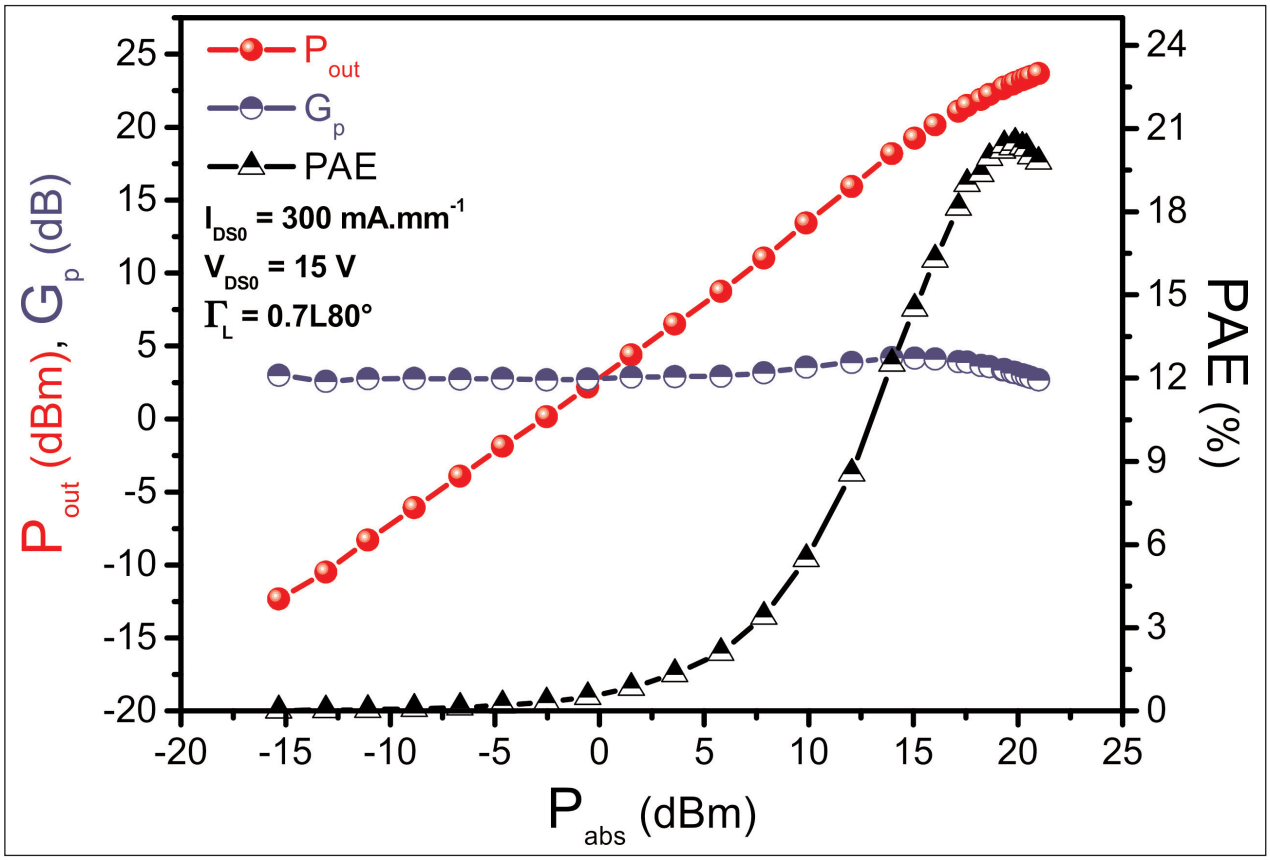


Figure 2. Output power, power gain and power-added efficiency vs absorbed power at 40GHz.

The use of freestanding GaN substrates avoids the need for nucleation layers, which simultaneously create thermal barriers. Nucleation layers are needed when growing III–nitrides such as GaN on silicon carbide or silicon. These layers are highly dislocated to allow growth of lattice and thermal expansion mismatched materials.

The source–drain regions of the HEMTs were fabricated by argon-ion-beam etching more than half way through the AlGaN barrier layer and electron-beam evaporating and annealing titanium/aluminium/nickel/gold metal contact stacks. The etching brought the contact metals closer to the 2DEG channel, reducing access resistance.

The devices were electrically isolated using nitrogen-ion implantation. T-shaped nickel/gold gates were formed with a 70nm foot on AlGaN barrier. A 20-minute 400°C anneal was carried out in nitrogen to improve the Schottky contact, reducing trap states.

The devices were passivated with 340°C plasma-enhanced chemical vapor deposition (PECVD) of silicon nitride. Metal connections with the device contacts were made with titanium/gold evaporation and patterning.

The tested devices consisted of two 50μm-wide gate fingers in a 1.3μm source-drain gap. The source–gate distance was 500nm.

With the gate at 1V relative to the source, the maximum drain current was 950mA/mm, and the on-resistance was 3Ω-mm. The transconductance under 6V drain bias peaked at 300mS/mm, when the gate was at −2.5V. The threshold was -3.5V. The gate leakage was as low at $3x10^{-7}A/mm$, giving an on/off drain current ratio of more than 10^6.

Radio-frequency testing between 250MHz and 67GHz gave de-embedded/intrinsic gain cut-off frequency (f_T) and maximum oscillation (fmax) values of 100GHz and 125GHz, respectively. The researchers believe that these parameters can be increased with optimization of the C:GaN layer, improving the trade-off between crystal quality and buffer isolation.

Power performance was assessed at 40GHz with active load-pull measurements under continuous-wave operation (Figure 2). The drain bias was 10V with the current at 300mA/mm, giving AB-class operation. The output power density was 1.2W/mm with 26.2% power-added efficiency. Increasing the drain bias to 15V, but keeping the current flow the same, increased the power density to a 2W/mm record, while decreasing the efficiency to 20.5%. The linear gain was 5dB with 10V drain, and 4.2dB at 15V.

The researchers comment: "Up to now, this result constitutes the state-of-the-art large signal at 40GHz for AlGaN/GaN HEMTs on freestanding GaN substrate." ■

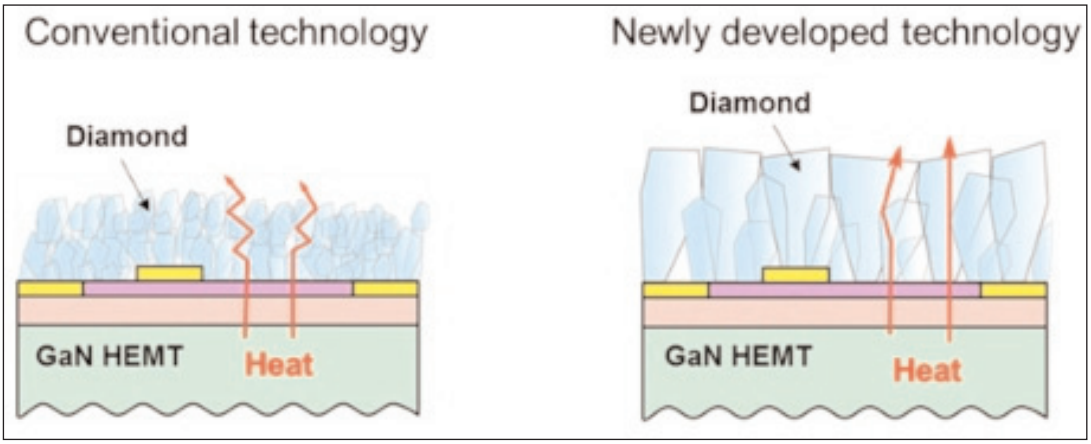
https://doi.org/10.1088/1361-6641/ab4e74

Author: Mike Cooke

Fujitsu grows diamond film to boost heat dissipation efficiency of GaN HEMT

New design reduces heat generation by 40%, enabling smaller radar systems.

At the 2019 MRS Fall Meeting in Boston, MA, USA (1–6 December), Fujitsu Ltd and Fujitsu Laboratories Ltd reported what is reckoned to be the first technology for growing a diamond film with highly efficient heat dissipation on the surface of gallium nitride (GaN) high-electron-mobility transistors (HEMTs).



Development background

In recent years, GaN HEMTs have been widely used as transistors for high-frequency amplifiers in weather radar and wireless communications equipment. In the future, achieving breakthroughs in areas like the highly accurate observation of localized torrential downpours and the creation of a stable millimeter-wave high-speed communication environment for 5G communications will require considerably increased deployed of radars and base stations worldwide.

However, the limitations inherent to existing designs continue to prevent an increase in the number of installations. The transistors used in radar systems have higher output power due to the need to operate over- greater distances, which increases the amount of heat they generate. Cooling equipment is required because of the performance degradation caused by overheating. This remains expensive, and the large size of the entire system, including the cooling apparatus, limits the installation location, making simplification and miniaturization of the cooling equipment an important challenge for designers.

Challenges

One way to reduce the size and complexity of the cooling system is to increase heat dissipation efficiency by covering not only the back surface of the GaN HEMT but also the front surface with a diamond film. This diamond film, which possesses excellent heat dissipation properties, would effectively lower the internal temperature of the GaN HEMT. To achieve this, however, a diamond crystal with large grain size is required to pass heat efficiently so that heat does not accumulate inside the diamond.

To grow such a diamond film, a high temperature of about 900°C is usually required, which unfortunately destroys the GaN HEMT underlying the diamond growth. When a diamond film is grown at low temperature (~650°C, at which the GaN HEMT is not destroyed), the resulting reduction in thermal energy given to the methane gas used to create the diamond means that growth of the diamond is incomplete. Using the low-temperature method, it is only possible to grow microscopic diamond particles (or nano-diamonds) of several hundred nanometers or less. Furthermore, each particle becomes an aggregate of crystals facing different directions, which inhibits efficient heat transfer between particles (Figure 1).

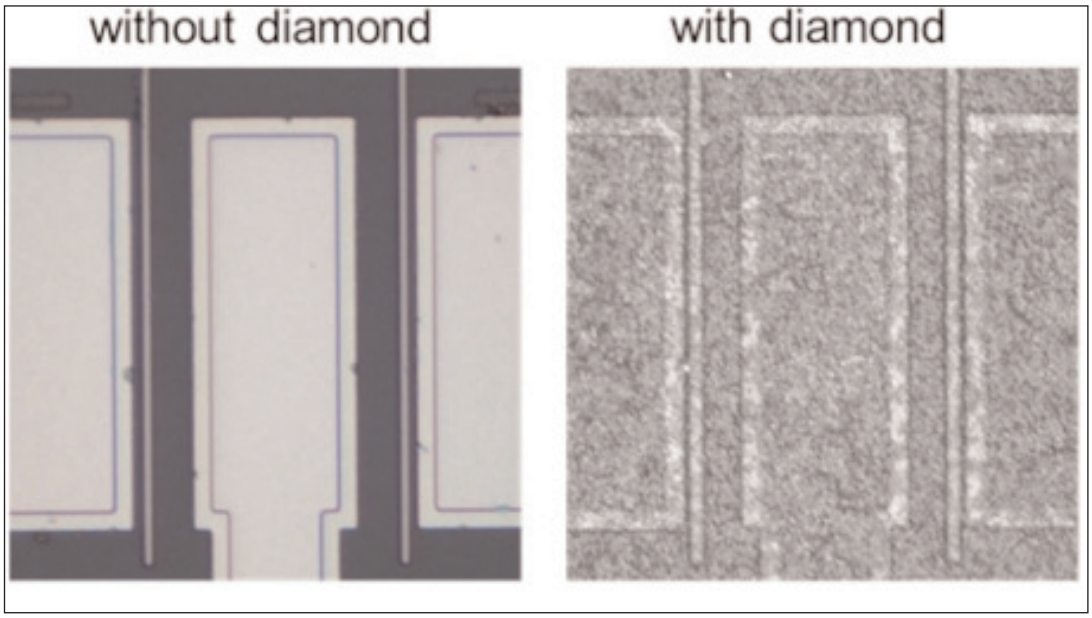
Newly developed technology

To address this challenge, Fujitsu has developed a technology for growing a highly heat-spreading diamond film at low temperatures (about 650°C) where transistors are not destroyed and, in what's claimed to be a world first, succeeded in demonstrating the operation of a GaN HEMT with a highly heat-spreading diamond film on its surface.

To grow the diamond film with this method, nano-diamond particles with a diameter of several nanometers are placed on the entire surface of the device. The nanodiamond particles are then exposed to methane

gas with high thermal energy to convert the carbon contained in the methane gas into diamond, which can then be incorporated into the particles. Carbon, with its high energy, is selectively incorporated into diamonds that point in a particular direction, allowing diamonds that point in the same direction to bond together and grow.

Focusing on the fact that the thermal energy given to methane varies depending on the pressure and the concentration of methane gas during diamond growth, Fujitsu discovered that nanodiamond particles oriented in a specific direction can be selectively enlarged at low temperatures. This makes it possible to convert a nanodiamond into a micron-sized diamond 1000 times larger (Figure 2). As a result, heat can easily pass through the diamond and the GaN HEMT can dissipate heat efficiently.



Outcome

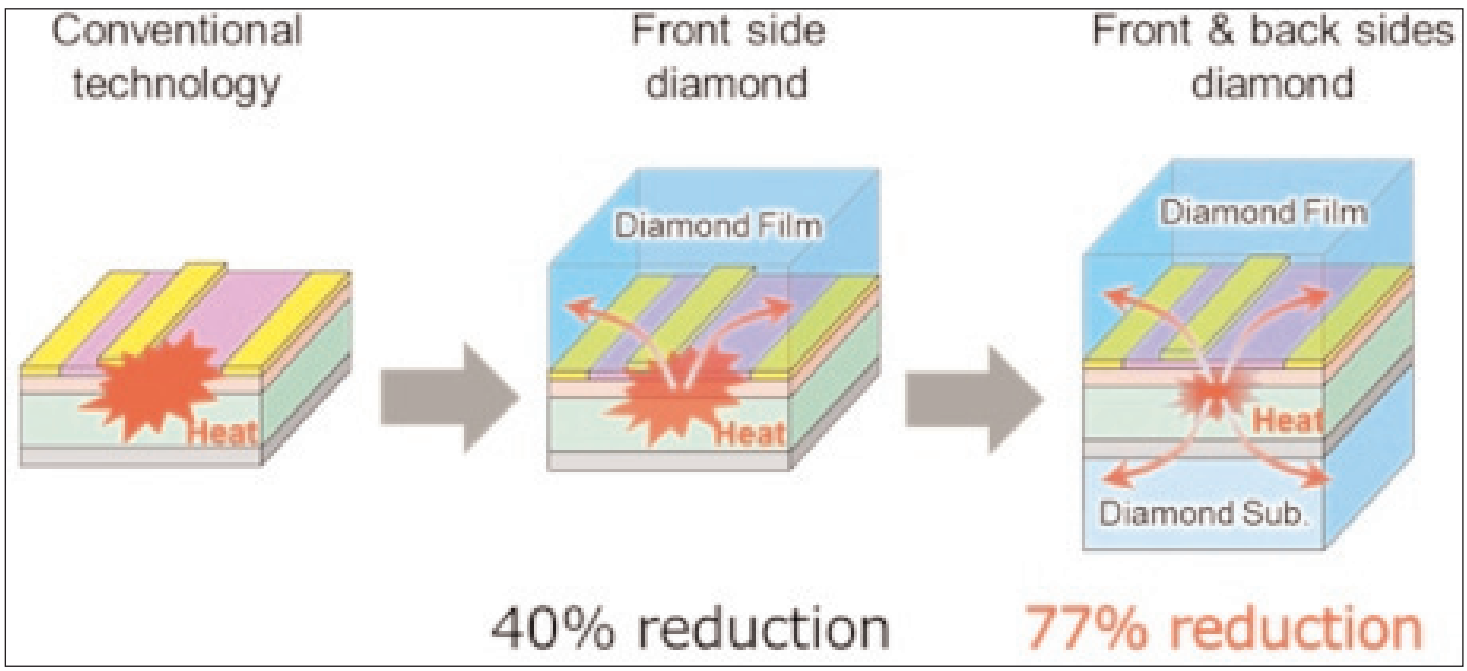
By using the newly developed technology, the amount of heat generated during GaN HEMT operation is reduced by about 40% compared to without diamond film, and the temperature can be lowered by 100°C or more. Furthermore, by combining heat dissipation from the backside of the GaN HEMTs with single-crystal diamond developed by Fujitsu and silicon carbide (SiC) bonding technology at room temperature, the front and back sides of the GaN HEMTs can be covered with a diamond film, which should reduce heat generation by about 77% (Figure 3).

This can enable the use of small cooling devices for high-performance radar systems that previously required large cooling devices, saving space and making it significantly easier to install the larger number of units needed for applications including improved weather forecasting and 5G communications, reckons Fujitsu.

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

Going forward, Fujitsu aims to commercialize its new high-heat-dissipation GaN HEMT amplifiers in fiscal 2022 for use in weather radar systems and next-generation wireless communication systems. ■

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



Hydrogen-terminated diamond transistors on gallium nitride/silicon

Complementary circuits based on diamond p-channel and gallium nitride n-channel transistors could lead to higher-power-density inverters and converters.

École polytechnique fédérale de Lausanne and Lake Diamond SA in Switzerland claim the first p-channel hydrogen-terminated diamond transistors (HTDTs) on gallium nitride (GaN) on silicon templates that demonstrate high-power device performance comparable with other HTDTs on polycrystalline and even monocrystalline diamond [Reza Soleimanzadeh et al, IEEE Electron Device Letters, published online 13 November 2019].

The researchers suggest that integration of p-channel HTDTs with n-channel GaN transistors opens "a pathway for future complementary power switch and logic applications". The diamond layer is also thermally conductive, allowing improved thermal management of GaN devices in high-power-density applications. The team sees potential for complementary logic operation, gate drivers and complementary power switches in integrated power inverters and converters.

The researchers used an aluminium gallium nitride barrier (AlGaN) GaN-on-silicon template, as used for the fabrication of n-channel high-electron-mobility transistors (HEMTs). The template was prepared for diamond deposition by applying layers of 30nm silicon nitride and 5nm silicon. These layers were designed to protect the template material from the harsh diamond deposition environment, along with enhancing adhesion and thermal conductivity between the materials.

The polycrystalline diamond deposition was seeded with 1–150μm nanoparticles applied in isopropanol solution. The main diamond deposition consisted of microwave-plasma chemical vapor deposition (MPCVD) at 800°C. The plasma power was 3.5kW. The carbon source was 5% methane at 140mbar pressure. Trace

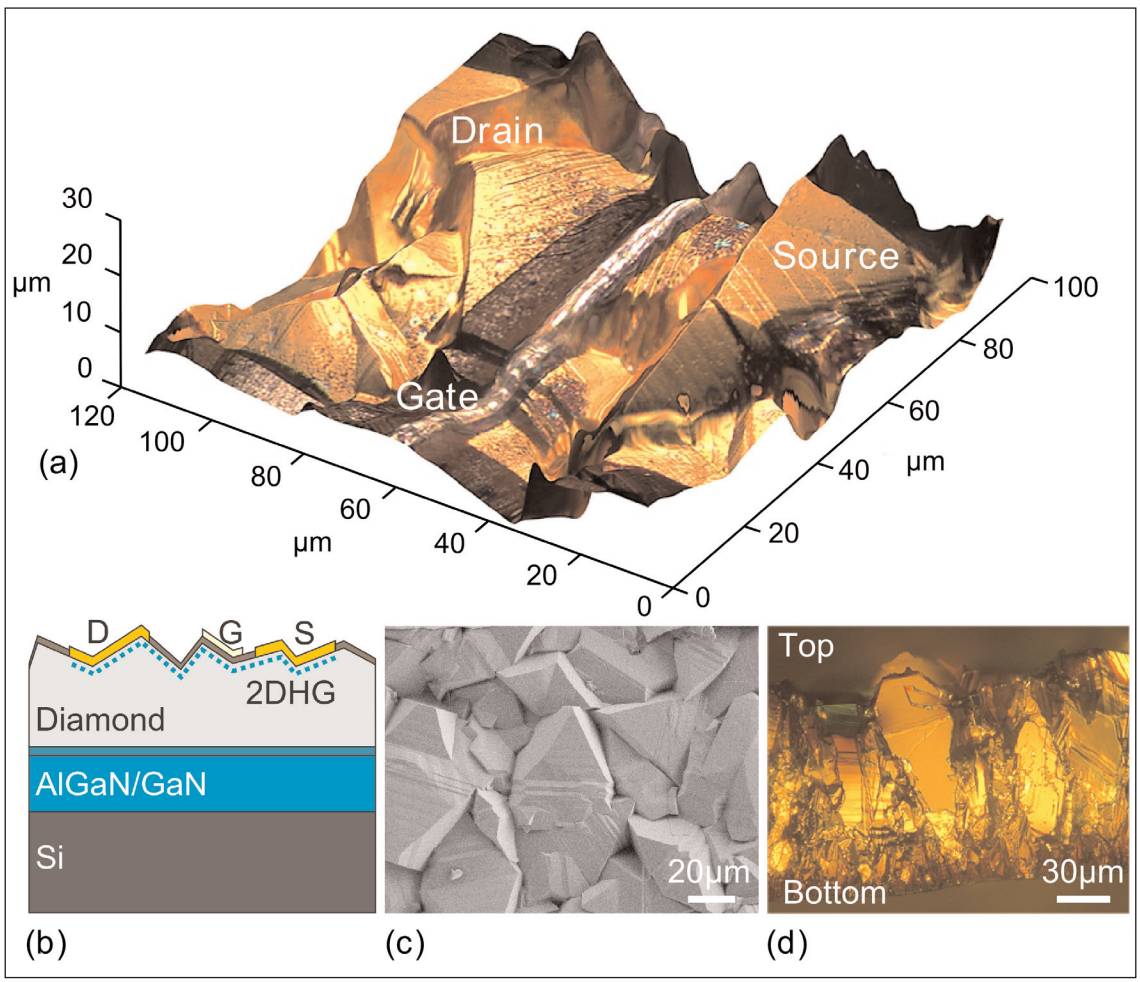


Figure 1. (a) Three-dimensional (3D) optical microscope image of fabricated HTDT, constructed using focus stacking. (b) Schematic of HTDTs. (c) Top-view SEM image of diamond surface. (d) Cross-sectional optical microscope image of diamond layer showing larger grain sizes at top.

quantities of nitrogen and argon were added to improve the growth rate. The carrier gas is not mentioned, but hydrogen is one gas that is used in such processes elsewhere.

Microscopic analysis of the diamond layer showed grains of average size 34μm, smaller than the 100μm grains often reported for the technique. The grains are smaller in the nucleation region, becoming larger at the surface of the 130μm-thick diamond layer.

Further transistor processing (Figure 1) consisted of surface hydrogenation with 650°C 2.8kW hydrogen plasma, deposition of 200nm-thick gold ohmic contacts, wet-etch gold removal from non-contact areas, 800W oxygen plasma treatment to isolate devices, 200°C atomic layer deposition (ALD) of 80nm aluminium oxide as gate oxide and surface termination, and deposition and plasma-etch patterning of 300nm-thick aluminium gate electrode.

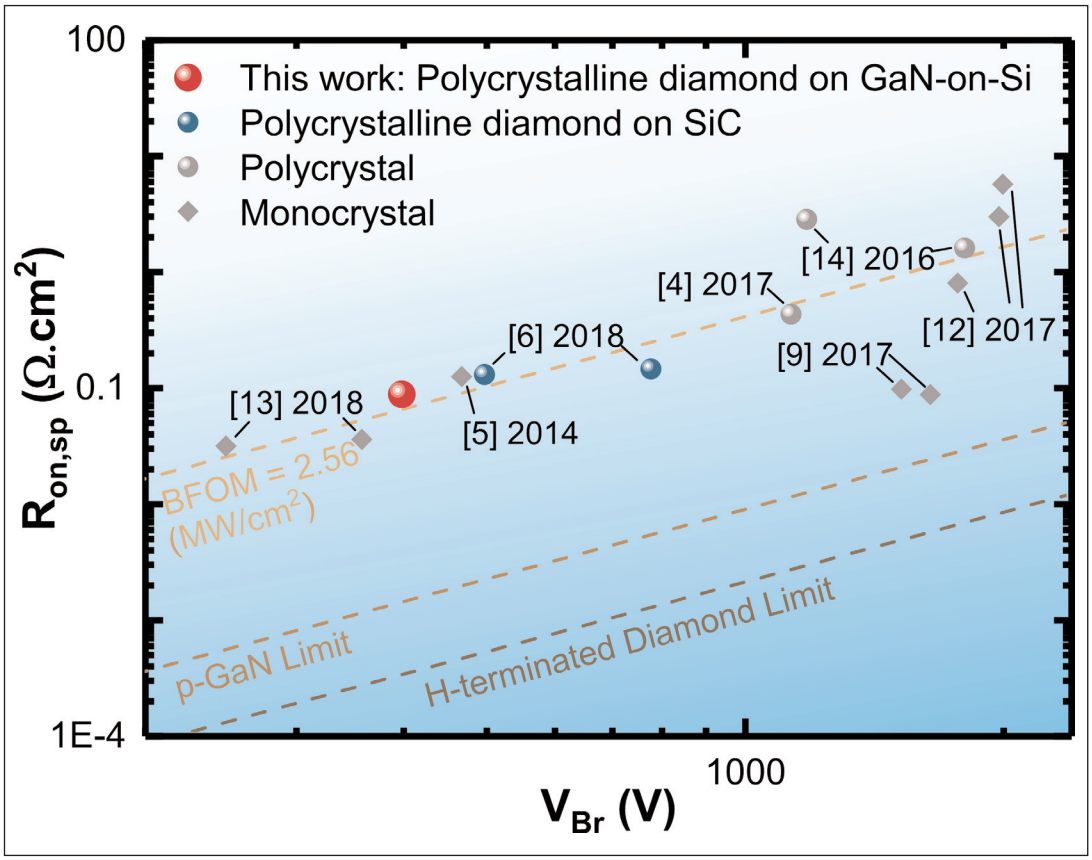


Figure 2. Benchmark of specific on-resistance ($R_{on,sp}$) and breakdown voltage (V_{Br}) of this work with heteroepitaxial material on silicon carbide (SiC), as well as polycrystalline and monocrystalline substrate HTDTs.

The hydrogenation resulted in a p-type conductivity with ~10^{14}/cm^2 hole density, according to Hall measurements. The 1.3cm^2/V-s mobility resulted in a sheet resistance of 50kΩ/square. The team comments: "The existence of many pits and edges in the unpolished diamond surface, serves as activation sites, resulting in a higher carrier density compared to the commonly reported values in the literature." The mobility was adversely affected by impurity scattering, the small grain sizes, and the rough surface — values of 3cm^2/V-s have been measured for holes in single-crystal diamond.

The fabricated transistor with 4μm gate length achieved an on/off current ratio of 10^9. Source–gate and gate–drain distances were 2μm and 8μm, respectively. The on-current reached –60mA/mm. The specific on-resistance of 84mΩ-cm^2 is described as "low". The leakage current was "very low" at less than 1μA/mm, even near breakdown.

The breakdown of the device occurred at –400V. The lateral critical field was estimated at 0.4MV/cm, according to studies using isolated contact pads separated by varying distances. The researchers report that monocrystalline diamond has achieved lateral breakdown fields of 1MV/cm.

The effective lateral conductivity came out at 900W/m-K in samples where the silicon substrate was removed from the backside of the diamond/GaN layers. The diamond grain size in the sample was 3μm on average.

The researchers comment: "Such excellent thermal conductivities can lead to very low thermal resistance and robust electrical performances in high-power-density applications. Moreover, this shows the potential of such high-quality CVD-deposited diamond layers for efficient thermal management of high-power GaN devices."

Comparing the performance with other polycrystalline and monocrystalline devices (Figure 2), the researchers observe that "there is still a gap between the performance of current HTDTs and their theoretical limits, which highlights the significant potential for improvement of this technology."

At the same time, the device exceeds the performance of GaN-based p-channel transistors in terms of "6 times higher current density, 4 orders of magnitude higher on-off ratio and more than 6-times higher thermal conductivity". The researchers trace the improvement to the higher theoretical Baliga figure of merit of the diamond HTDT structure, compared with p-channel GaN devices. ■

https://doi.org/10.1109/LED.2019.2953245

Author: Mike Cooke

Self-aligned-gate gallium oxide metal-oxide-semiconductor transistors

Researchers see such a process as being 'essential' for future devices with high performance and ultra-low power losses.

Researchers based in the USA and Germany claim the first demonstration of self-aligned gate (SAG) β-polytype gallium oxide (β-Ga_2O_3) metal-oxide-semiconductor field-effect transistors (MOSFETs) [Kyle J. Liddy et al, Appl. Phys. Express, vol12, p126501, 2019].

The researchers at KBR Inc and the Air Force Research Laboratory in the USA and Leibniz-Institut für Kristallzüchtung (IKZ) in Germany used a refractory metal gate-first design with silicon (Si) ion-implantation to eliminate source access resistance, giving some of the highest transconductance values reported so far for β-Ga_2O_3 MOSFETs. The US part of the team was sited at the Wright–Patterson Air-Force Base, Ohio.

The researchers see such a SAG process as being "essential for future β-Ga_2O_3 device engineering to achieve high-performance, ultra-low-power-loss devices".

It is only recently that β-Ga_2O_3 has been seriously considered as a semiconductor material for use in high-efficiency power applications, based on its ultra-wide bandgap (~4.8eV). The related high estimated critical field (~8MV/cm) is some 2–3x higher than for wide-bandgap materials such as gallium nitride or silicon carbide.

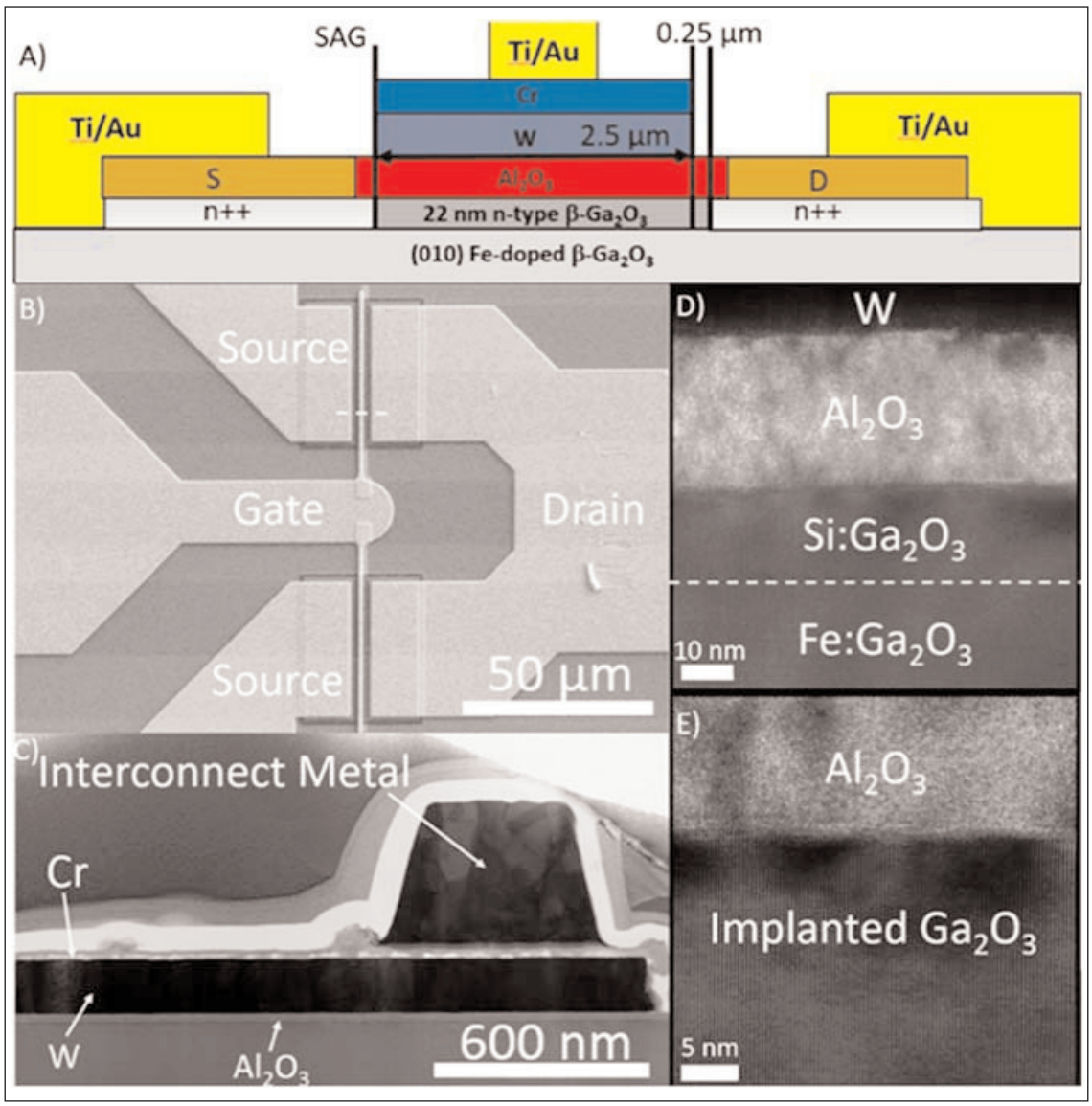


Figure 1. (a) Schematic of SAG β-Ga_2O_3 MOSFET, (b) top-down scanning electron microscope image of representative 2x50µm SAG MOSFET with dashed line indicating cross-sectioned region, (c) transmission electron microscope (TEM) image of gated region, and high-resolution TEM images of (d) W gate electrode, gate oxide and β-Ga_2O_3 substrate, and (e) gate oxide and implanted β-Ga_2O_3 channel.

The performance of reported β-Ga_2O_3 devices has been limited by parasitic resistance effects. Silicon ion implantation in SAG processes is a key technique for reducing access resistance in silicon and silicon carbide (SiC) transistors.

The team used a semi-insulating iron-doped β-Ga_2O_3 substrate to which a 22nm n-type channel layer of silicon-doped β-Ga_2O_3 was added through metal-organic chemical vapor deposition (MOCVD).

The formation of the gate stack consisted of 30nm aluminium oxide (Al_2O_3) dielectric atomic layer deposition (ALD), tungsten (W) sputtering, and patterning with a chromium (Cr) hard mask through reactive ion etch (Figure 1). The process avoided gold, since that metal would be damaged by later thermal annealing processes.

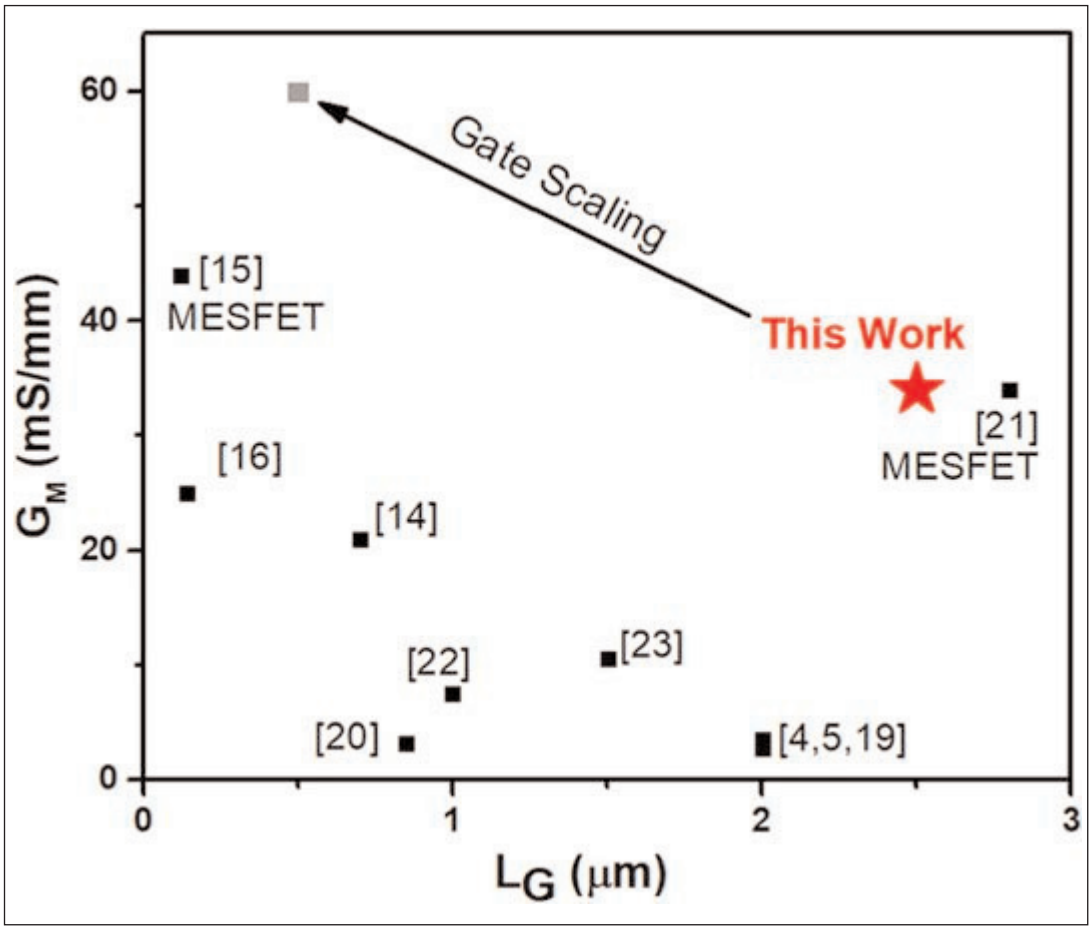


Figure 2. Peak transconductance (G_M) versus gate length (L_G) benchmarking of β-Ga_2O_3 FETs from this work (red), historical (black) and projection applying this process with sub-μm gate scaling (gray).

A silicon ion implant was made from the source side, giving a nominal gate–source distance (L_{GS}) of 0μm, while the gate–drain distance (L_{GD}) was 0.25μm due to shadowing effects. The Al_2O_3 gate dielectric layer also acted as an implant cap. The target doping of the implant region was $1x10^{20}/cm^3$.

Rapid thermal annealing at 900°C for 120s activated the silicon doping. High-resolution transmission electron microscopy (HR-TEM) studies of the final MOSFET showed no apparent damage to the interface between the W gate electrode and gate dielectric layer from the high-temperature annealing. There was also no sign of polycrystalline domains forming.

The device was completed with removal of Al_2O_3 from the source–drain regions with reactive-ion etch and the application of ohmic source–drain electrodes consisting of titanium/aluminium/nickel/gold (Ti/Al/Ni/Au) annealed at 470°C for 1 minute in nitrogen.

The devices were then electrically isolated from each other using plasma and reactive-ion etch. Interconnection for testing purposes consisted of Ti/Au metalization.

The researchers used Van der Pauw structures to extract a $4.96x10^{12}/cm^2$ carrier sheet density and a $48.4cm^2$/V-s mobility. The sheet resistance was $2.6x10^4\Omega$/square in the channel and $2.0x10^3\Omega$/square in the implanted regions. The contact resistance was 1.5Ω-mm.

Electrical characterization of a 2.5μm gate-length device had a peak transconductance of 35mS/mm with 10V drain bias. The maximum drain current reached 140mA/mm. The on/off current ratio was 10^8, indicating good pinch-off. The subthreshold swing was 121mV/decade, described by the researchers as "excellent". The on-resistance at small drain bias was 30Ω-mm with the gate at 4V.

Using a model based on the results, the researchers project that a 0.5μm gate device could achieve 0.6mS/mm transconductance, 350mA/mm drain current, and 17Ω-mm on-resistance. This performance would require suitable thermal management or pulsed operation to avoid self-heating.

The team compared their work with that of others (Figure 2), commenting: "With the exception of vertically scaled delta-doped β-Ga_2O_3 MESFETs, the G_M [peak transconductance] results are state-of-the-art and achieved with a large gate length." ■

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Author: Mike Cooke

Trends toward low-cost, high-power, high-frequency devices on silicon and more

Mike Cooke reports on contributions to December's International Electron Devices Meeting in San Francisco.

The most recent International Electron Devices Meeting (IEDM 2019) in San Francisco, CA, USA in December continued the trend of researchers reporting the development of III–V compound semiconductor devices using a silicon (Si) substrate, aiming at significant reductions in production and deployment costs. The work is targeted at both power and radio frequency (RF) electronics. For the generation of wireless signals, one often wants both high power output and high frequency.

Up to now, gallium nitride (GaN)-channel devices on silicon have tended to be for the lower-frequency switching capabilities used in power conversion and management. This is because growing GaN and other III–nitride materials on silicon is difficult to achieve with high crystal quality. However, the work reported at the latest IEDM suggests that researchers are expanding the capabilities, looking to the exacting requirements needed for fifth-generation (5G)-and-beyond wireless communications technology.

Another interesting development for GaN was some inklings for ways to achieve decent p-channel transistors using III–nitride materials. Here, we look in greater detail at these developments and more.

Compound semiconductors on silicon

Power and high-frequency moves

IMEC and KU Leuven in Belgium reported co-integration of GaN power integrated circuits on 200mm-diameter silicon-on-insulator (SOI) substrates [session 4.4]. The use of SOI substrates avoids back-gating effects seen in silicon, providing the necessary electrical isolation of the devices.

Among the components deployed were 200V high-electron-mobility transistors (HEMTs), metal–insulator–metal (MIM) capacitors, Schottky barrier diodes (SBDs), and two-dimensional electron gas (2DEG) resistors (Figure 1). Resistor-transistor logic (RTL) was used to compensate for the lack of an effective p-channel field-effect transistor (FET) solution in GaN. A 48V-to-1V single-stage buck converter combined a GaN half-bridge and on-chip driver circuitry. The metal-organic chemical vapor deposition (MOCVD) epitaxial structure included a p-GaN top layer, providing a p-GaN gate, allowing enhancement-mode devices to be achieved.

IMEC/KU Leuven also joined with Taiwan's National Chiao Tung University, Vanderbilt University in the USA and Belgium's Vrije Universiteit Brussel (VUB) to present a complementary metal-oxide-semiconductor (CMOS)-compatible, gold-free process for aluminium gallium indium nitride (AlGaInN) HEMTs, metal–insulator–semiconductor HEMTs (MISHEMTs) and MOSFETs on 200mm silicon [session 17.2]. The devices were targeted 20GHz RF operation with low 0.15dB/mm transmission loss, along with low contact resistance of 0.14Ω-mm. The vertical breakdown voltage (V_{BR}) was more than 300V. The field-effect mobility of the MISHEMTs exceeded 2000cm^2/V-s.

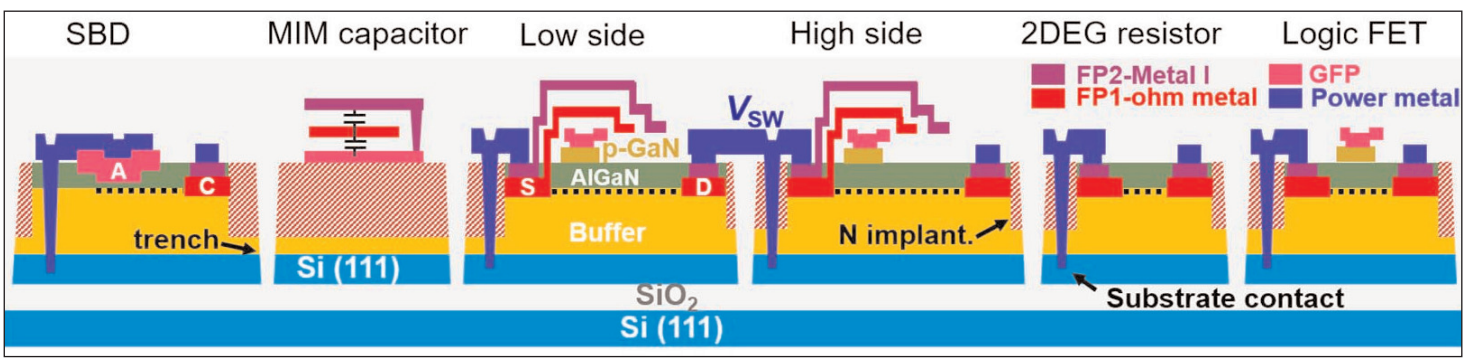

Figure 1. Schematic process cross-sections of GaN integrated circuit components on GaN-on-SOI substrate.

Such devices are sought for power amplification of radio signals for use in radar, satellite communication and wireless communication. The researchers comment: "Migrating to a 200mm silicon platform and manufacturing devices using standardized CMOS fab tools are critical steps toward the uptake of GaN devices for RF and mm-wave applications."

The ohmic contacts consisted of Si/Ti/Al/Ti/TiN recessed through the AlGaN/AlN barrier layers. The gate metal was titanium nitride (TiN). The MISHEMTs and MOSFETs used 10nm and 25nm aluminium oxide (Al_2O_3) dielectric, respectively. Devices with AlInN barrier layers showed reduced on-resistance (R_{on}) and increased transconductance and on-current.

IMEC, KULeuven and VUB also reported the 'first' demonstration of III–V heterojunction bipolar transistors (HBTs) on 300mm-diameter silicon substrates [session 9.1]. The current gain was 112 and the breakdown voltage (BV_{CBO}) was 10V. The researchers see "potential for enabling a hybrid III–V/CMOS technology for 5G and mm-wave applications". The devices used a gallium arsenide/indium gallium phosphide (GaAs/InGaP) heterostructure.

The integration of III–V material used a selective nano-ridge aspect-ratio trapping process. The defects from GaAs heterointegration on silicon were trapped by high-aspect-ratio trenches, resulting in high-crystal-quality ridges. Further epitaxial layers were added using metal-organic vapor phase epitaxy.

The team comments: "HBTs fabricated on this stack show an electrical performance considerably better than GaAs(P) devices fabricated on a silicon substrate with SRB [strain-relaxed buffer] layers, without any need to grow thick (>1–10μm) buffer layers."

Multi-channel boost

École polytechnique fédérale de Lausanne (EPFL) in Switzerland and Enkris Semiconductor Inc in China reported on multi-channel AlGaN/GaN MOSHEMTs on silicon that showed reduced specific on-resistance $R_{on,sp}$ of 0.47Ω-cm^2 while maintaining a high V_{BR} [session 4.1]. The performance was achieved using slanted tri-gates, rather than field plates, to enhance V_{BR} (Figure 2).

The team comments: "Firstly, the multi-channel devices broke the limit in R_{on} for lateral GaN power devices, greatly reducing the R_{on} from ~7Ω-mm in 600/650V single-channel devices to 2.8Ω-mm, while keeping a high V_{BR} of 1230V. In addition, the multi-channel devices yielded a record figure-of-merit of 3.2GW/cm^2 that is substantially improved from single-channel devices."

The researchers used a stack of four 2DEG channels to reduce R_{on}. The team also developed an enhancement-mode device with a threshold voltage (V_{th}) of +0.9V for 1μA/mm drain current. The researchers comment: "These results significantly outperform conventional single-channel devices and demonstrate the enormous potential of multi-channel power devices."

The channel stack used $Al_{0.25}Ga_{0.75}$ barrier layers to achieve the 4x 2DEG structure. The bottom barrier was 10nm thick, while the top three were 20nm. The barriers were silicon-doped. The bottom layer was thinner and incorporated less doping with a view to improving electrostatic control, avoiding punch-through in the off state.

The structure achieved a sheet resistance of 80Ω/square. The carrier sheet concentration and mobility were 5.6x10^{13}/cm^2 and 1407cm^2/V-s, respectively. The researchers claim a record effective resistivity of 1.1mΩ-mm for the 140nm-thick structure.

The fin structures of the wrap-around tri-gate were continued into the source-drain region to allow easy low-resistance contact with all the 2DEG channels. The gate stack consisted of atomic layer deposition (ALD) silicon dioxide, and nickel/gold electrodes. The slanted gate fin widths were 50nm for 300nm, then increasing to 100nm for another 300nm. The gate region was 1.5μm long in total, 700nm of which was covered in the gate stack. The enhancement-mode device used a fin as narrow as 20nm to increase the V_{th}. The leakage

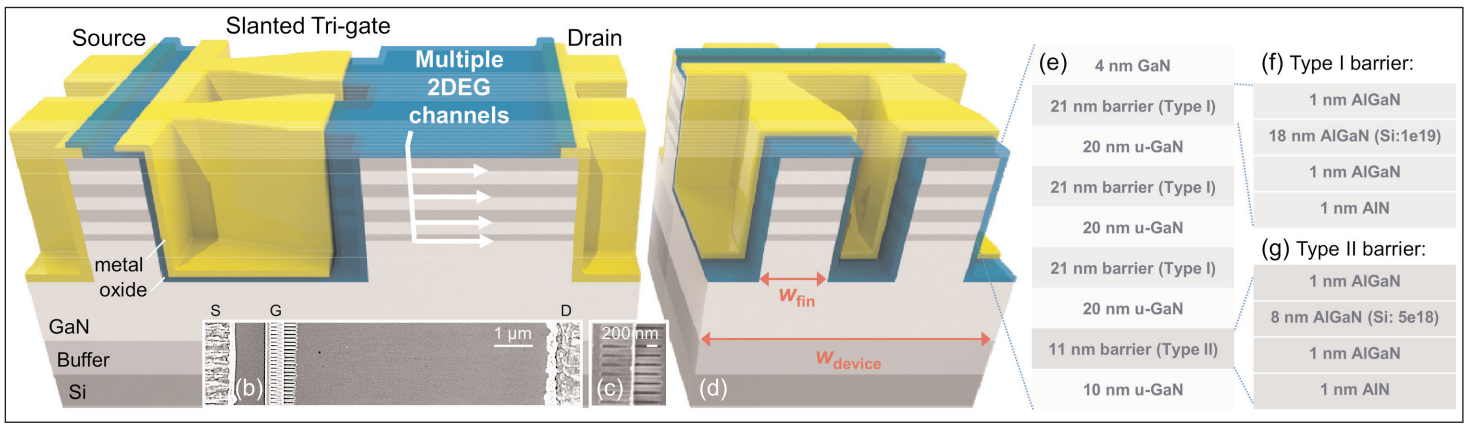

Figure 2. (a) Schematic of multi-channel slanted tri-gate MOSHEMTs. (b) Top-view, (c) zoomed scanning electron microscope images, and (d) cross-sectional schematic. (e)–(g) Schematics of the multi-channel structure with four parallel 2DEG channels.

of the normally-off transistor was 0.3nA/mm at 0V gate potential.

IBM Research Zurich and EPFL in Switzerland also reported on III–V heterojunction tunnel FETs integrated on 4-inch-diameter Si(100) substrates [session 37.1]. The devices feature InGaAs channels, heavily p-doped gallium arsenide antimonide (p^+-GaAsSb) raised source contacts, and an n^+-InGaAs drain. The team used a self-aligned CMOS-compatible process to create the transistors. The subthreshold swing was as low as 47mV/decade – so-called subthermionic behavior, since traditional transistors are usually limited by a temperature-dependent lower limit, 60mV/decade at 300K (a typical 'room temperature').

The researchers comment: "This is the first demonstration of sub-60mV/decade switching in heterostructure TFETs on Si(100), showing the strong promise of the technology for future advanced logic nodes aiming at low-power applications." A low swing allows lower supply voltage, reducing power consumption. The III–V materials were transferred to the silicon substrate by direct wafer bonding. The III–V drain and source materials were regrown using MOCVD.

5G and beyond

P-channel complement

Intel Corp in the USA reported the first heterogeneous integration of GaN NMOS and Si PMOS devices on 300mm-diameter high-resistivity silicon, targeting energy-efficient and compact power delivery, RF (5G and beyond) and system-on-chip applications [session 17.3]. The enhancement-mode NMOS transistors achieved 1.5mA/μm on-current, and off-currents as low as 100pA/μm. The f_T/f_{max} cut-off frequencies were 190/300GHz, respectively. Power amplification circuits achieved power-added efficiencies of 56% at 28GHz and 70% at 5GHz.

The GaN transistors were created by MOCVD on Si(111). The Si PMOS integration used 3D layer transfer from another 300mm wafer (Figure 3).

Cornell University and Intel have meanwhile been working to fill the p-channel III–N transistor gap with a GaN/AlN heterostructure FET (HFET) achieving more than 100mA/mm on-current [session 4.5]. The researchers claim this as "the strongest on-current performance of any significantly modulating p-channel transistor in the III–nitrides." Combined with the more advanced n-channel III–N transistors, the work could enable the use of more efficient complementary circuit designs, as seen with mainstream CMOS silicon electronics. An on-current of 300mA/mm was reached in cryogenic measurements at 77K. The researchers point out that their p-channel devices are "within striking distance" of reported high-voltage extended-drain 65nm silicon CMOS pFETs that generally achieve around 200mA/mm.

The GaN/AlN structure generates a two-dimensional hole gas (2DHG) channel through the discontinuity in charge polarization of the GaN and AlN chemical bonds. The heterostructure was grown by plasma-enhanced chemical vapor deposition (PECVD) on 2-inch-diameter AlN/sapphire templates. The templates were produced by MOCVD.

The fabricated transistors had palladium/nickel source-drain contacts deposited on a p-InGaN layer. The recessed Schottky gate was a molybdenum-based metal stack on the exposed GaN layer. The researchers comment that at present there is no suitable dielectric for MOS structures on p-channel devices. The fabrication avoided the use of gold with a view to facilities

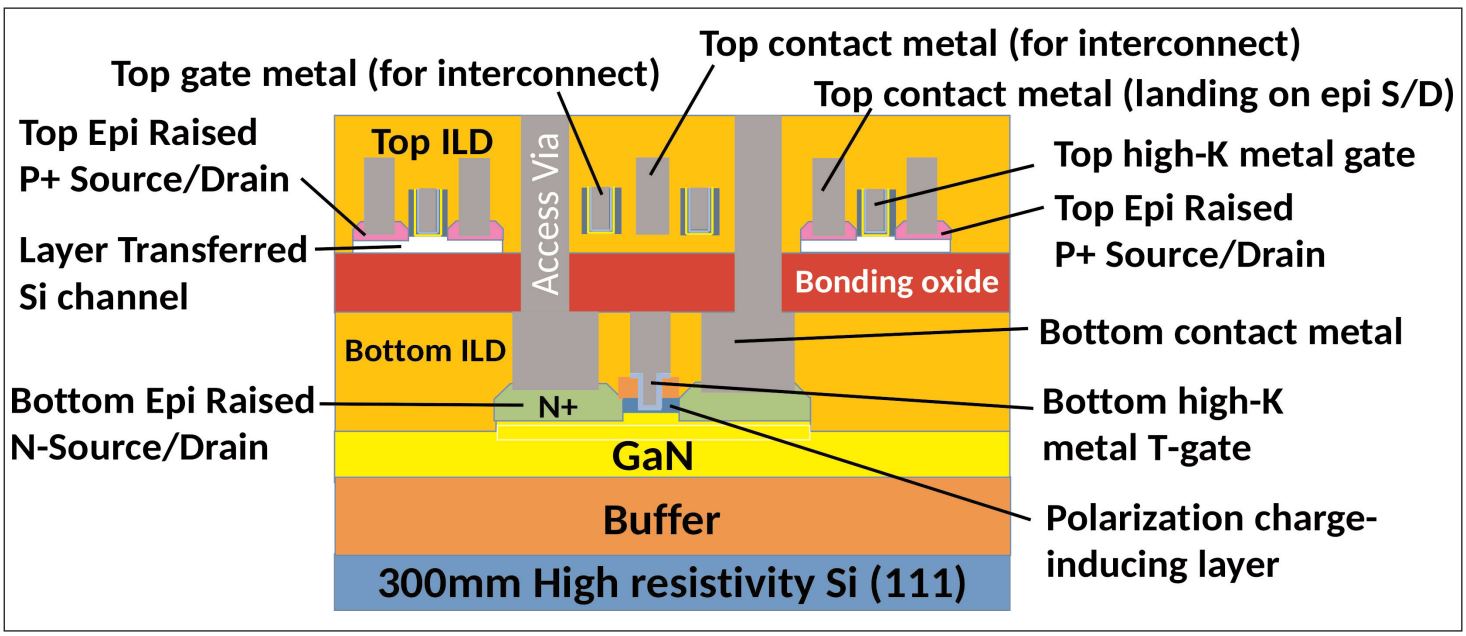

Figure 3. 3D heterogeneous integration of silicon PMOS transistors stacked on GaN NMOS transistor, enabled by 300mm GaN MOCVD epitaxy and 300mm 3D layer transfer.

where the metal is deprecated, such as in silicon wafer fabs.

Massachusetts Institute of Technology in the USA, Khalifa University in the United Arab Emirates (UAE), Enkris Semiconductor Inc in China and Intel in the USA reported on a self-aligned process for fabricating GaN pFETs [session 4.6]. The device used a $GaN/Al_{0.2}Ga_{0.8}N/GaN$ structure grown on silicon by MOCVD. The R_{on} of 400Ω-mm is claimed to be a record low. The on-current was 5mA/mm, and the on/off current ratio was $6x10^5$.

The threshold of −1V implies a normally-off enhancement-mode operation in p-channel devices; the opposite is true in n-channel transistors, where positive thresholds are needed. The researchers demonstrated the potential for complementary nFET and pFET circuits by monolithically integrating such devices on the platform.

The researchers see the use of silicon substrates as promising low cost and integration with high-performance logic and analog functionality. The self-aligned process compensates for low hole mobility by allowing aggressive device scaling, in this case by creating a 100nm-gate-length pFET.

The MOCVD was carried out by Enkris on 6-inch-diameter silicon substrates. The structure sequence was a 3.8μm buffer, 150nm unintentionally doped (UID) GaN, 20nm AlGaN, 20nm UID GaN, 50nm p-GaN, and 20nm p^+-GaN.

The self-aligned process created nickel/gold/nickel source–drain stacks that presented a mask for mesa etch and gate recessing down through the p-GaN layers to the top 20nm UID GaN layer. The gate dielectric was ALD Al_2O_3. The gate electrode was nickel/gold. The nFET used the p-type layers as a p-gate (Figure 4).

Pushing over 100GHz

NTT Device Technology Labs and Tokyo Institute of Technology in Japan presented a 300GHz wireless transceiver (TRx) aimed at 'beyond 5G' deployment (i.e. more than 10Gb/s data rate), based on indium phosphide HEMTs [session 9.2]. The channel material was high-mobility $In_{0.8}Ga_{0.2}As$ on lattice-matched $In_{0.53}Ga_{0.47}As$.

The device supported data rates of more than 100Gb/s. The transmission distance was 2.2m, increasing to 9.8m for 120Gb/s data with the aid of a high-linearity power amplifier. According to the team, these rates are the highest achieved so far for electronic-device-based 300GHz TRx.

The frequency range above 275GHz is attractive since it is presently unallocated and offers much higher bandwidth. Further, these frequencies have attenuation rates of less than 10db/km. Since the wavelength of the radiation was comparable to the size of the device, special measures in the monolithic microwave integrated circuit (MMIC) design had to be implemented, such as using a backside DC line, to give a low-loss connection with the waveguide portion of the device.

NXP Semiconductors [session 25.2] reports the first "3.3V/5V RF-LDMOS with a cutoff frequency beyond 100GHz, designed and fabricated without any additional dedicated mask in an advanced sub-28nm node FDSOI process."

The researchers — based in Belgium, The Nether-

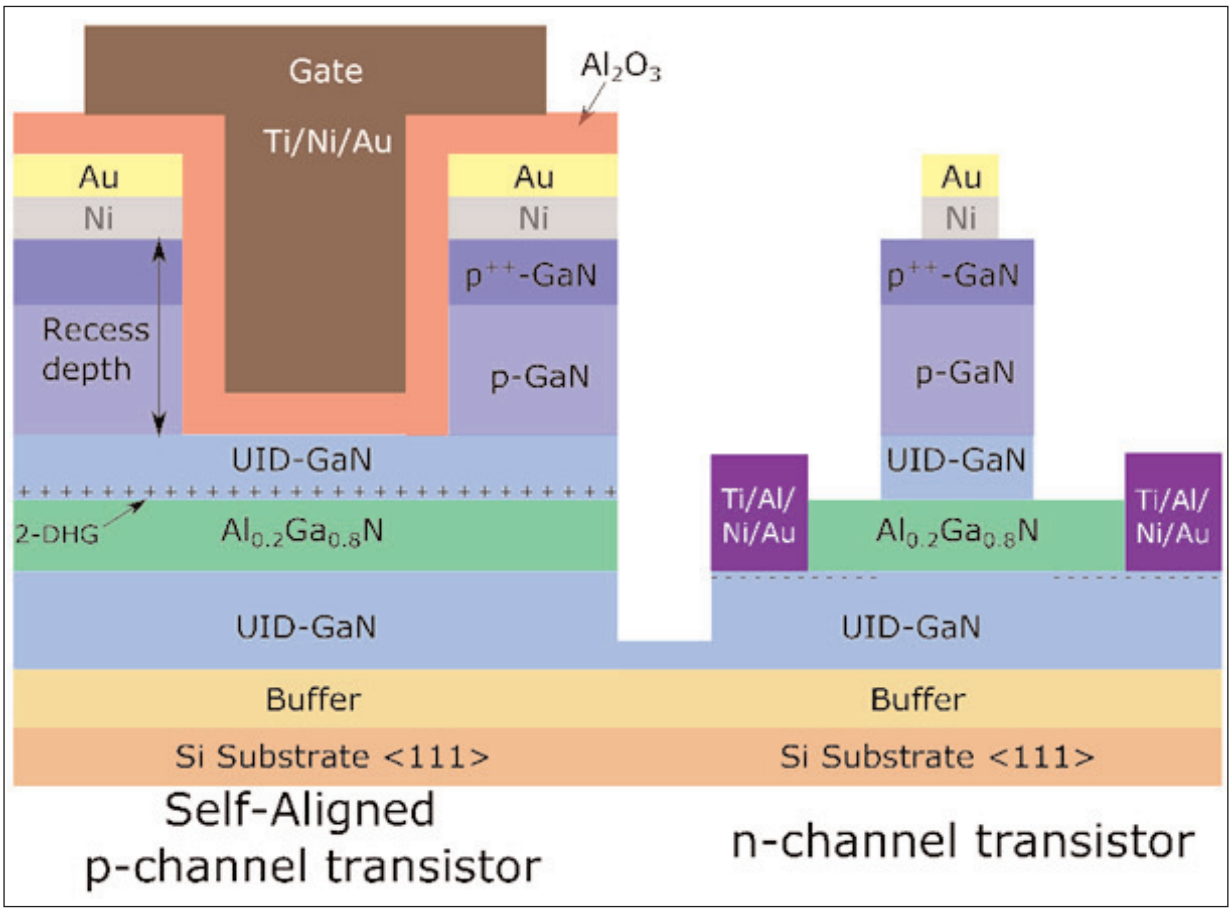

Figure 4. Monolithic integration of self-aligned p-FET and p-GaN gated n-FET.

lands, the USA and France — have also designed a series of passive devices for integration in the fully depleted SOI (FDSOI) process. They comment: "The RF performance of these high-voltage (HV)-capable devices is comparable to best-in-class devices in RF-HV-centric non-CMOS processes, e.g. SiGe and GaAs. This enables highly integrated cost-effective power amplifiers for both WiFi (5GHz) and 5G (28GHz) applications."

It is hoped that the device platform could find application in watt-level RF power amplifiers for WiFi, 5G, and beyond.

ETH-Zürich in Switzerland claims the first demonstration of "high-performance HEMTs combining InAs channel insets with InP sub-channels" [session 9.3]. The technique reduced the minimum noise figure to 0.65dB at 40GHz, compared with 1.15dB without an InP sub-channel. The inset in the 0.65dB case was 3nm and in the 1.15dB device it was 5nm. A 5nm inset with sub-channel achieved a 0.93dB minimum noise. The structure was designed to reduce noise from impact ionization. Applications of such devices presently center on radio-astronomy and deep-space communication. The f_T/f_{max} cut-off frequencies were 410GHz/660GHz, respectively.

Gallium oxide and silicon carbide

Substrate

Fraunhofer Institute for Applied Solid State Physics IAF in Germany claims the highest ever power-added efficiency for L-band (1–2GHz) performance of 77.3% at 1.0GHz [session 17.4].

The 0.5μm-gate transistor used an AlGaN/GaN structure on a 4-inch-diameter silicon carbide (SiC) substrate and was optimized for 100V load-pull operation. The maximum power density was more than 17W/mm with the drain biased at 100V. This increased to 20W/mm at 125V. The enhanced performance and power density was enabled by increasing the supply voltage to 100V, compared with the 28–50V used for mobile communications or civil and military radar.

To improve the high-voltage performance, the researchers optimized the extension of the source-terminated field plate (STFP) towards the drain contact, balancing the need for high V_{BR} against increased parasitic source-drain capacitance. The measured breakdown was more than 500V. The transistors also featured gate-terminated field plates.

The MOCVD epitaxial structure used a semi-insulating iron-doped GaN buffer on an AlN nucleation layer. The AlGaN barrier was capped with GaN.

The US Naval Research Laboratory reported integration of GaN HEMTs with a high overtone bulk acoustic resonator (HBAR) on SiC substrate [session 17.5]. The device achieved what is described as high values of quality factor (Q) and Q x frequency product at 295K of more than 10^4 and 10^{14}Hz, respectively

The combination of HBAR and HEMT is expected to lead to "building blocks for comb filters, circulators, and sparse spectrum front-ends". The superconducting nature of the niobium nitride (NbN) also suggests to the team that the structure has "enormous potential as an integrated quantum platform for computation, communications, sensing, and metrology". The Q-factor was more than 10^6 at 20K.

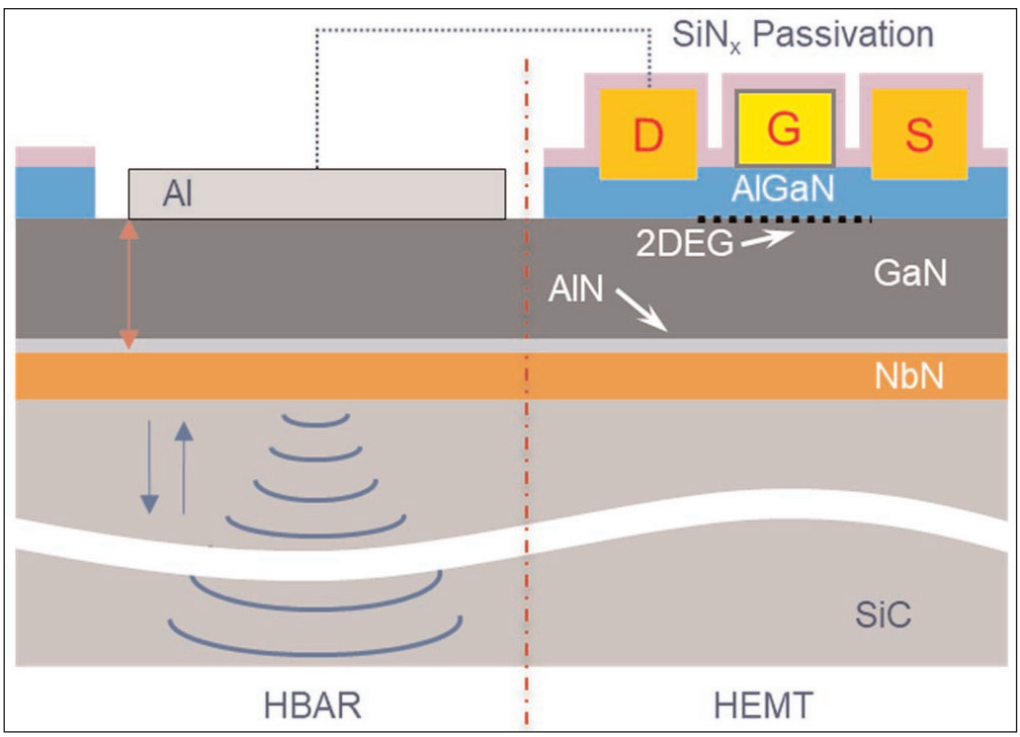

Figure 5. Cross-sectional schematic of HBAR+HEMT integrated on AlGaN/GaN/NbN heterostructure.

The molecular-beam epitaxy (MBE) structure consisted of a transition-metal nitride buried NbN electrode, and GaN buffer and AlGaN barrier layers (Figure 5). The acoustic waves were generated by piezoelectric stressing between an Al electrode and the buried NbN.

The combined structure demonstrated an on/off gain of 34dB (more than 10^3) in forward transmission (S_{21}) and a 16dB (factor of 40) directional contrast at 3GHz.

The researchers comment: "The amplified HBAR+HEMT pair can be used in a ladder configuration in order to generate exquisitely sharp RF comb filters, with zero loss, or net terminal gain. This configuration can be used to realize on-chip integrated oscillators

with low phase noise, or magnet-free frequency-selective integrated circulators operating beyond the X-band."

Vertical power

Researchers from the USA and Japan claimed record-high performance for normally-off single- and multi-fin gallium oxide (β-Ga_2O_3) vertical power transistors [session 12.4]. The team from Cornell and Hosei universities used an anneal process at 350ºC for 1 minute in nitrogen after the metal electrode deposition to increase channel mobility to ~130cm^2/V-s. With the fin width at 0.15μm, the V_{th} was more than +1.5V, giving true normally-off performance.

Multi-fin devices (Figure 6) managed to push breakdown voltages up to 2.66kV. The $R_{on,sp}$ was 25.2mΩ-cm^2, corresponding to a Baliga figure of merit of 280MW/cm^2. The figure of merit expresses the trade-off between V_{BR} and $R_{on,sp}$ as $V_{BR}^2/R_{on,sp}$. The researchers claim that the 280MW/cm^2 value is the highest reported for all Ga_2O_3 transistors (Figure 7).

The team also found that fins with approximately (100) sidewalls showed reduced interface trapping effects and higher current compared with other orientations relative to the crystal structure.

The Ga_2O_3 was deposited using halide vapor phase epitaxy (HVPE). The 10μm drift layer had a net n-type doping concentration of 2x10^{15}/cm^3, according to capacitance-voltage studies.

Researchers from China,

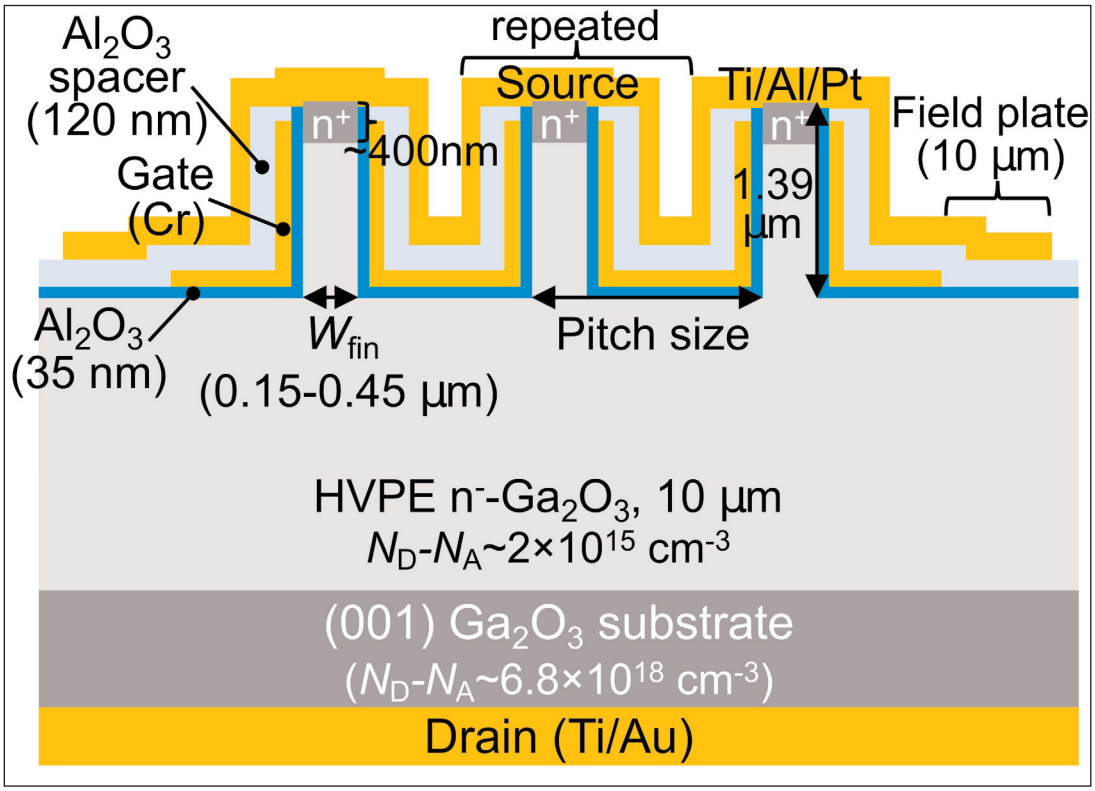

Figure 6. Schematic cross-section of Ga_2O_3 vertical fin transistors with multiple fins and source-connected field plate.

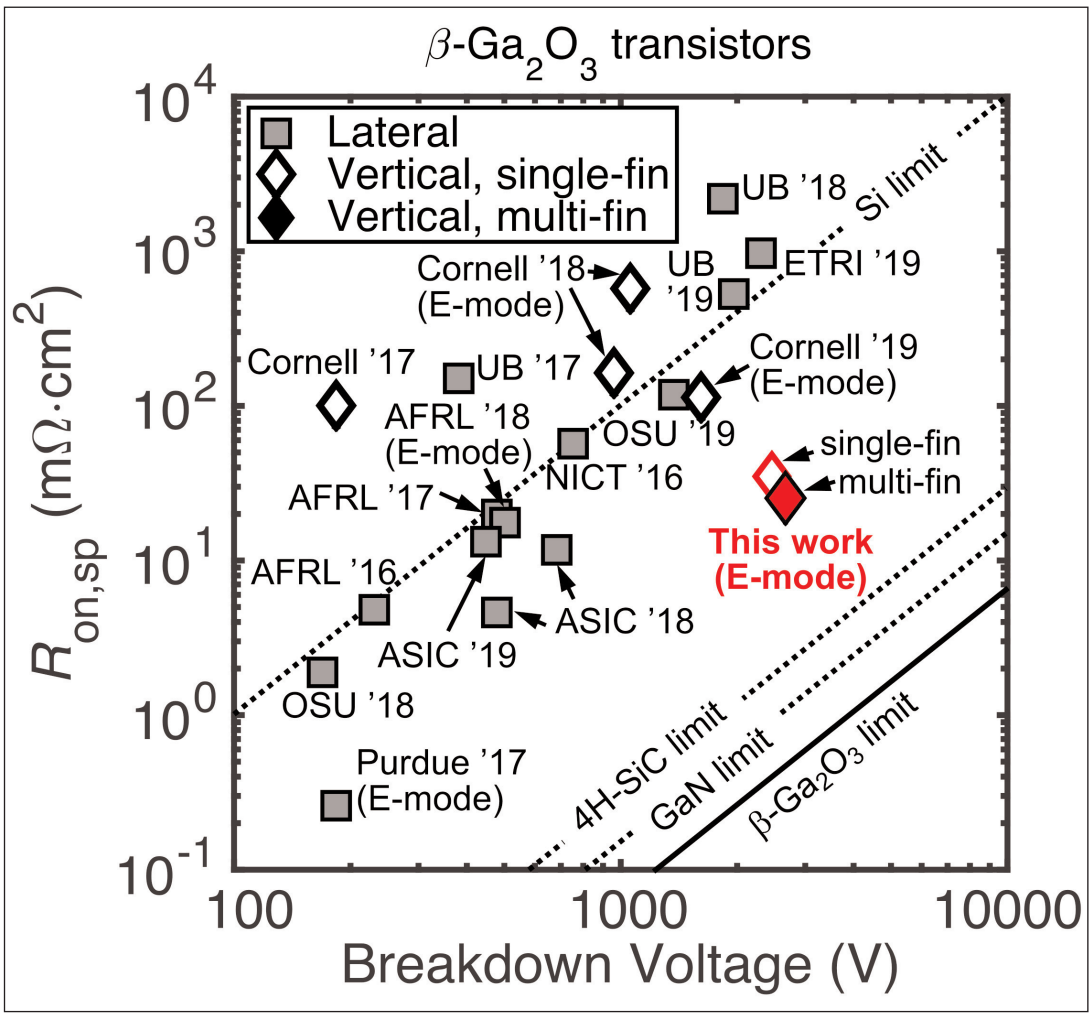

Figure 7. Benchmark plot of Ga_2O_3 transistors.

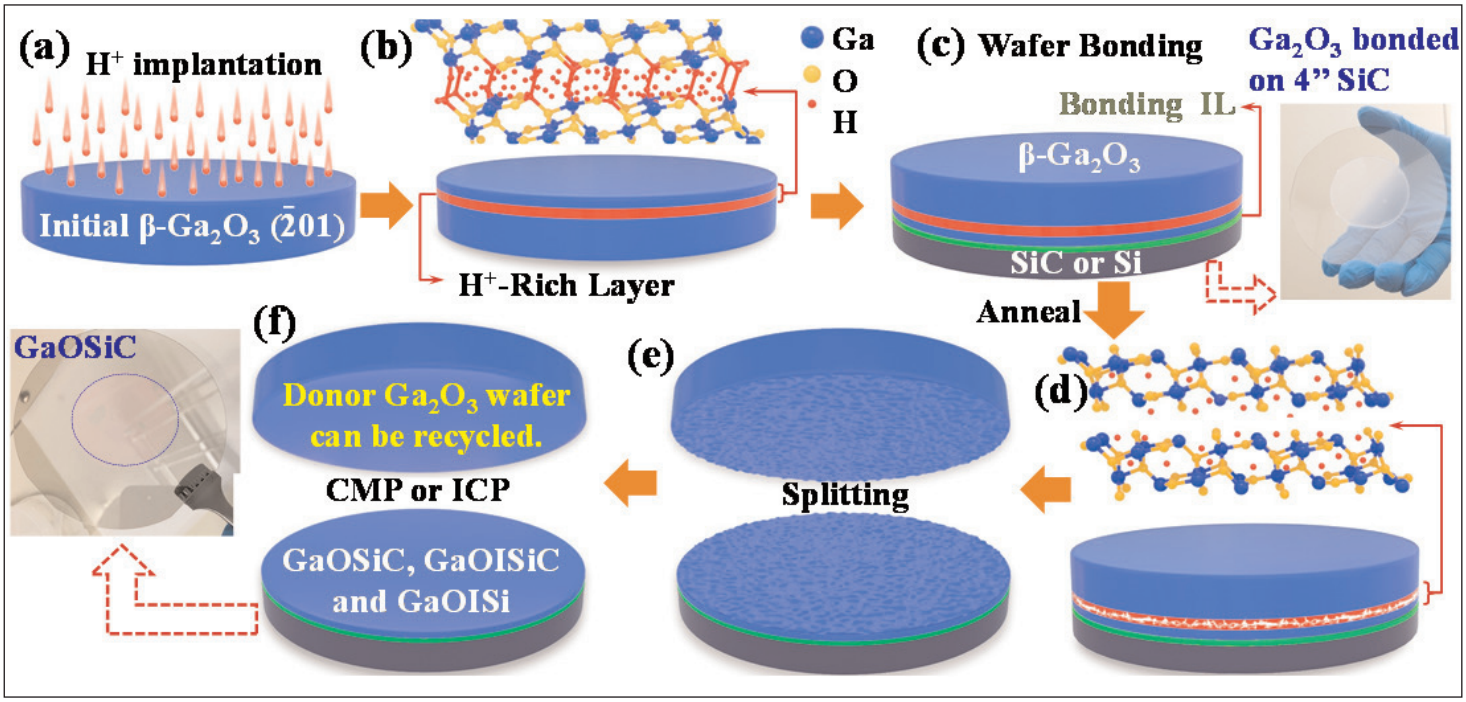

Figure 8. Process flow for transferring β-Ga_2O_3 thin film onto SiC (or Si) by ion-cutting. (a)-(b) Implanting H^+ into bulk β-Ga_2O_3 (c) Wafer bonding onto SiC (or Si), using amorphous or Al_2O_3 interlayers. (d) Forming plate-like defects by annealing. (e) Splitting. (f) Surface smoothing. Fabricated Ga_2O_3 on SiC wafer shown.

Japan and the USA say that they have demonstrated "for the first time" the transfer of 2-inch-diameter thin Ga_2O_3 layers to Si and SiC substrates using ion-cutting methods [session 12.5]. The team from Shanghai Institute of Microsystem and Information Technology and Xidian University in China, Meisei University in Japan, and Virginia Polytechnic Institute and State University in the USA also produced high performance enhancement-mode/depletion-mode normally-off/-on metal-oxide-semiconductor FETs on the material. They were also able to produce material with an insulating aluminium oxide interlayer.

A device operated at 500K maintained a V_{BR} above 600V. The researchers see the use of a thin Ga_2O_3 film as a means to overcome one of the drawbacks of the material — its low thermal conductivity compared with Si and SiC, enabling better thermal stability of devices.

The technique used for the transfer is related to the commercial SmartCut process trademarked to SOITEC (Figure 8).

The less than 400nm films demonstrated 0.5nm root mean square roughness and 130arcsec x-ray diffraction rocking curve full-width at half maximum (FWHM). Wafer-level Ga_2O_3t thickness non-uniformity was ±1.8%. The smooth surface was achieved after wafer bonding with inductively coupled plasma etch (2.0nm roughness) or chemical mechanical planarization (0.5nm roughness.)

Thyristor–IGBT combo

Japan's National Institute of Advanced Industrial Science and Technology (AIST) claims the first fabrication of a 17kV SiC MOS thyristor combined with insulated-gate bipolar transistor (IGBT) [session 20.2]. The on-voltage was 5V and the differential on-resistance was 15mΩ-cm^2 at 100A/cm^2 current density. An IGBT produced on the same process achieved 5.03V and 17ΩW-cm^2, respectively.

Mitsubishi Electric Corp and the University of Tokyo in Japan have been the first to use oxygen ion-implant doping in the channel of SiC MOSFETs

Raising the temperature to 423K did not degrade the MOS thyristor performance. The switching operation and speed were comparable to those of IGBTs in terms of turn-on and -off performance.

Mitsubishi Electric Corp and the University of Tokyo in Japan have been the first to use oxygen ion-implant doping in the channel of SiC MOSFETs [session 20.4]. The effect was to reduce channel resistance and increase the V_{th}. The oxygen doping creates deep-level donor states. Conventional SiC MOSFET doping involves sulfur. The team comments: "By applying this novel technique to vertical 4H-SiC MOSFETs, 32% reduction of specific on resistance (R_{on}) at a high V_{th} of 4.5V was achieved."

The device was also found to have improved negative bias temperature instability (NBTI) performance in terms of V_{th}. The use of ion-implant doping gave a higher concentration near the MOS interface compared with thermal oxidation doping processes. The gate oxide was produced by thermal oxidation, followed by nitridation using a diluted NO atmosphere. ■

Author: Mike Cooke

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www.fcm-germany.com

Kyma Technologies Inc
8829 Midway West Road,
Raleigh, NC, USA
Tel: +1 919 789 8880
Fax: +1 919 789 8881
www.kymatech.com

MARUWA CO LTD
3-83, Minamihonjigahara-cho,
Owariasahi, Aichi 488-0044,
Japan
Tel: +81 572 52 2317
www.maruwa-g.com/e/products/ceramic

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

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

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

Umicore Electro-Optic Materials
Watertorenstraat 33,
B-2250 Olen,
Belgium
Tel: +32-14 24 53 67
Fax: +32-14 24 58 00
www.substrates.umicore.com

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

4 Epiwafer foundry

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

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

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

IQE
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St Mellons, Cardiff
CF3 0EG,
UK
Tel: +44 29 2083 9400
Fax: +44 29 2083 9401
www.iqep.com
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OMMIC
2, Chemin du Moulin B.P. 11,
Limeil-Brevannes, 94453,
France
Tel: +33 1 45 10 67 31
Fax: +33 1 45 10 69 53
www.ommic.fr

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

5 Deposition materials

Akzo Nobel High Purity Metalorganics
www.akzonobel.com/hpmo
Asia Pacific:
Akzo Nobel (Asia) Co Ltd,
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
Dornkaulstr. 2,
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Germany
Tel: +49 2407 9030 0
Fax: +49 2407 9030 40
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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Fax: +1 925 449-4096
www.temescal.net

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Fax: +1 727 577 7035
www.plasmatherm.com

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31 rue Casimir Périer, BP 70083,
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
7620 Executive Drive,
Eden Prairie, MN 55344,
USA
Tel: +1 952 934 2100
Fax: +1 952 934 2737
www.svta.com

Veeco Instruments Inc
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7 Wafer processing materials

Air Products and Chemicals Inc
7201 Hamilton Blvd.,
Allentown, PA 18195, USA
Tel: +1 610 481 4911
www.airproducts.com/compound

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

Praxair Electronics
(see section 5 for full contact details)

8 Wafer processing equipment

EV Group
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,
USA
Tel: +1 800 223 2389
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E-mail: conax@conaxtechnologies.com

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k-Space Associates Inc
2182 Bishop Circle
East, Dexter, MI 48130,
USA
Tel: +1 734 426 7977
Fax: +1 734 426 7955
www.k-space.com

KLA-Tencor
One Technology Dr,
1-2221I, Milpitas,
CA 95035,
USA
Tel: +1 408 875 3000
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

1–6 February 2020
Photonics West 2020
The Moscone Center,
San Francisco, CA, USA
E-mail: customerservice@spie.org
https://spie.org/conferences-and-exhibitions/photonics-west

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

3 February 2020
EPIC World Photonics Technology Summit
St. Regis San Francisco Hotel,
San Francisco, CA, USA
E-mail: neringa.norbutaite@epic-assoc.com
www.epic-assoc.com/epic-world-photonics-technology-summit-2020

3 February 2020
ITF Photonics 2020
San Francisco, A, USA
www.futuresummits.com/itf-2020/itf-photonics

5–7 February 2020
SEMICON Korea 2020
COEX Convention & Exhibition Center, Seoul,
South Korea
E-mail: semiconkorea@semi.org
www.semiconkorea.org/en

11–13 February 2020
Strategies in Light
San Diego Convention Center, San Diego, CA, USA
E-mail: SIL@american-tradeshow.com
www.strategiesinlight.com

24–27 February 2020
GSMA Mobile World Congress (MWC Barcelona 2020)
Barcelona, Spain
E-mail: registration@mwcbarcelona.com
www.mwcbarcelona.com

8–12 March 2020
OFC: The Optical Networking and Communication Conference & Exhibition
San Diego Convention Center, San Diego, CA, USA
E-mail: OFC@compusystems.com
www.ofcconference.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

advertisers' index

E-mail: apec@apec-conf.org
www.apec-conf.org

15–17 April 2020
EPIC Annual General Meeting 2020
Radisson Blu Hotel Lietuva, Vilnius, Lithuania
E-mail: neringa.norbutaite@epic-assoc.com
www.epic-assoc.com/epic-annual-general-meeting-2020

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
E-mail: contact@iculta.com
www.ICULTA.com

4–6 May 2020
16th International Conference on Concentrator Photovoltaic Systems (CPV-16)
Golden, near Denver, CO, USA
E-mail: info@cpv-16.org
www.cpv-16.org

7–8 May 2020
EPIC Meeting on Nanophotonics for Communication, Sensing and Data Processing at Nanoscribe
Karlsruhe, Germany
E-mail: neringa.norbutaite@epic-assoc.com
www.epic-assoc.com/epic-events

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

11–14 May 2020
CS MANTECH: 2020 International Conference on Compound Semiconductor Manufacturing Technology
JW Marriott Starr Pass, Tucson, AZ, USA
E-mail: registration@csmantech.org
www.csmantech.org

17–21 May 2020
32nd International Symposium on Power Semiconductor Devices and ICs (ISPSD 2020)
Hofburg Palace, Vienna, Austria
E-mail: ispsd2020@guarant.cz
www.ispsd2020.com

21–26 June 2020
Microwave Week, including: IEEE MTT-S International Microwave Symposium (IMS 2020) Radio Frequency Integrated Circuits Symposium (RFIC 2020) Automatic Radio-Frequency Techniques Group Conference (ARFTG)
Los Angeles, CA, USA
E-mail: e.niehenke@ieee.org
www.ims-ieee.org

21–23 July 2020
SEMICON West 2020
Moscone Center, San Francisco, CA, USA
E-mail: semiconwest@semi.org
www.semiconwest.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

23–27 August 2020
SPIE Optics + Photonics 2020
San Diego Convention Center, San Diego, CA, USA
Abstract deadline: 12 February 2020
E-mail: customerservice@spie.org
https://spie.org/Optics_Photonics

23–28 August 2020
International Workshop on Nitride Semiconductors (IWN 2020)
Maritim Hotel Berlin, Germany
E-mail: iwn2020@conventus.de
www.iwn2020.org

23–28 August 2020
9th International Conference on Optical, Optoelectronic and Photonic Materials and Applications (ICOOPMA)
University of Pardubice, Czech Republic
E-mail: info@icoopma.com
www.icoopma.com

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