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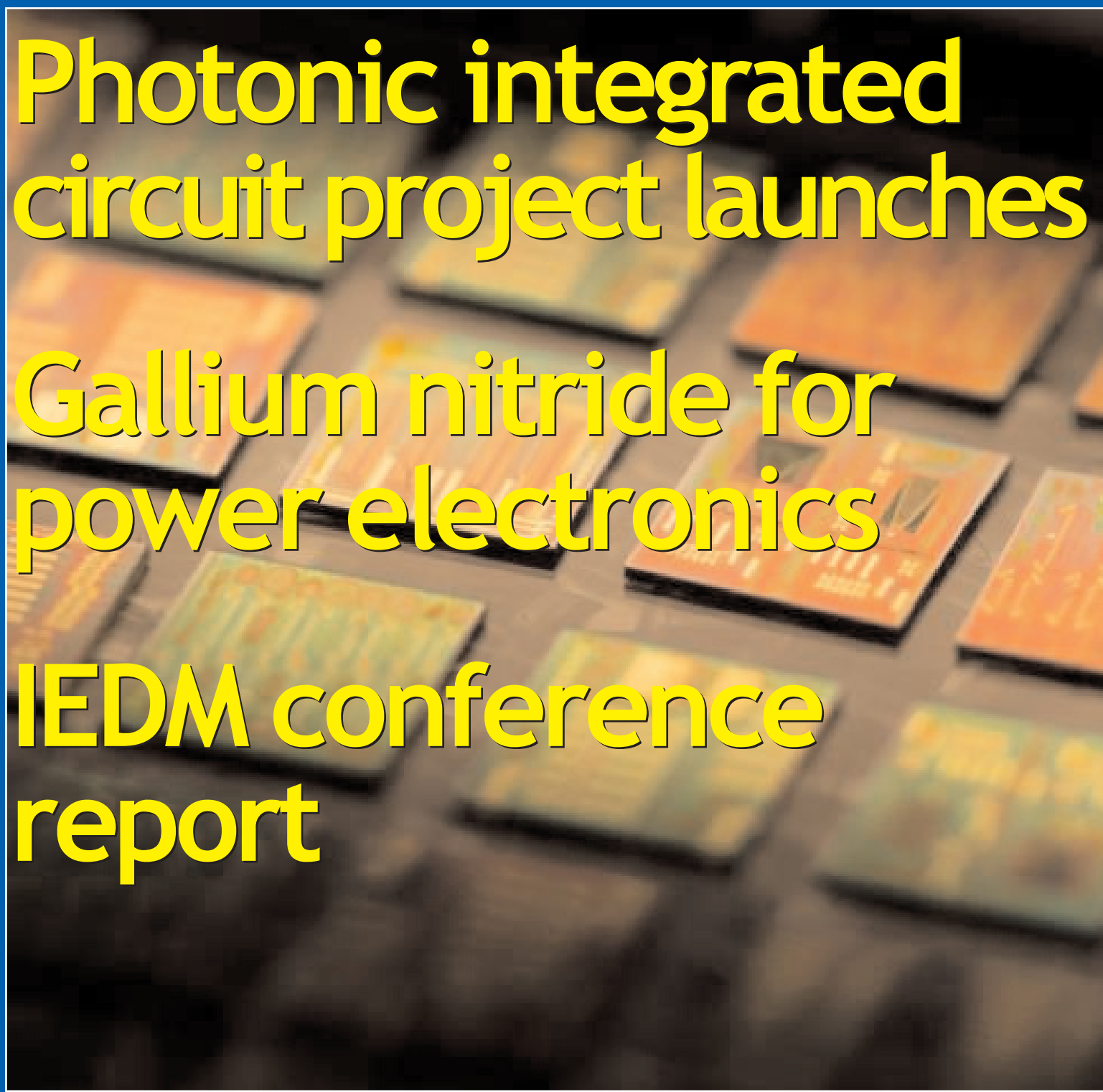


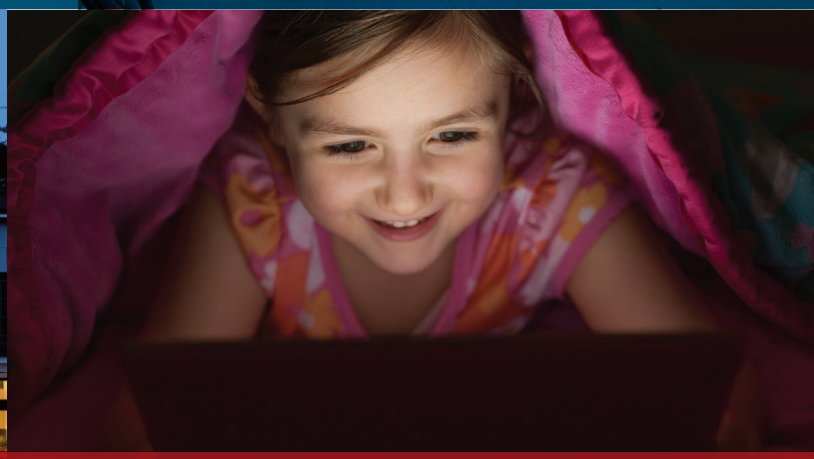
Photonic integrated circuit project launches

Gallium nitride for power electronics

IEDM conference report

Skyworks cuts guidance • Kaiam shutters Scotland plant
TRUMPF acquiring Philips Photonics • Cisco acquiring Luxtera

Lower Cost LEDs



Faster LED Adoption

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

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

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

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The advantage is not just big. It's EPIK.

Contact us at *www.veeco.com/EPIK700* to learn more.

Veeco's New TurboDisc EPIK700 GaN MOCVD System

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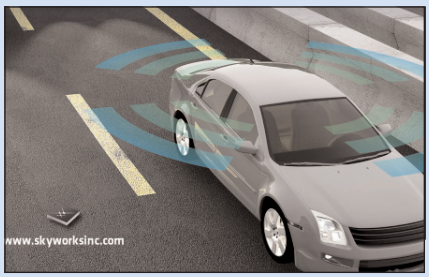
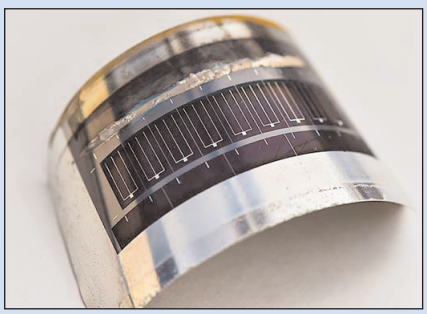
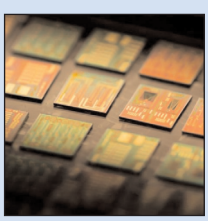


p9 Skyworks has launched its suite of SkyOne Ultra 3.0 devices for advanced automotive applications.

p55 Kaiam's plant in Livingston, Scotland, which is being sold after Kaiam Europe entered administration.



p68 Alta Devices has set an efficiency record for GaAs single-junction solar cells (for the seventh consecutive time since 2010) at 29.1% (up from its 28.9% record announced in July).



Cover: Supported by the European Commission together with Photonics21 and PhotonDelta, 16 European partners (led by Eindhoven University of Technology) have started project InPulse, which will offer new-entrant companies direct access to the manufacturing of photonic integrated circuits based on indium phosphide. **p61**

editorial

Wide-bandgap power sector growing despite end-product slowdown

After reporting last issue about Apple's poor iPhone sales growth and the reductions in December-quarter revenue guidance throughout the supply chain from device makers like Qorvo and Lumentum to epiwafer supplier IQE, on page 8 of this issue we report how Qorvo's rival Skyworks has also cut its December-quarter guidance due to weak sales for its largest smartphone customers (see page 8). Meanwhile, IQE has further reduced its full-year 2018 guidance due to "the sudden disruption in a significant supply chain and short-term demand for VCSEL laser wafers in November" (page 24). In addition, substrate maker AXT has just cut its December-quarter guidance due to a "significant slowdown during the last two months… The business climate grew increasingly cautious over the quarter" (see page 29).

Just before the end of January, Apple reported a 15% drop in iPhone sales last quarter (driving the firm's first year-on-year drop in overall quarterly revenue since 2016). It attributes this to the economic slowdown in China, as well as the strong dollar (leading it to consider reducing iPhone pricing in emerging markets). However, in addition to the global smartphone market falling by 5% over the last year, Apple has lost market share to Chinese rivals Huawei and Oppo (probably exacerbated by the US–China trade war, especially as China becomes more capable in domestic production, and as domestic purchases are increasingly favored). This has led to Apple's quarterly revenue in the Greater China region falling by more than 25% year-on-year.

Similarly, Germany's Osram expects December-quarter revenue to be down 15% year-on-year, due to an "accelerated market decline, especially in December". Particularly affected were the firm's core markets of Automotive (especially in China), General Lighting, and Mobile Devices (a slump at smartphone makers Apple and Samsung), blaming primarily the ongoing trade conflicts (between the USA and China), weak growth in China, and general political uncertainties. A revenue drop of 16.9% for the Osram Opto Semiconductors business unit in particular has led the firm to cut 300 of the 2800 jobs at the Regensburg plant by the end of this September (with 240 temporary workers also to go).

However, even if end-product markets are slowing, for compound semiconductors in particular there is still scope for significant growth through penetration into existing markets (in place of incumbent silicon technology) as well as adoption for new applications.

For example, Technvio expects the market for wide-bandgap power semiconductor devices — silicon carbide (SiC) and gallium nitride (GaN) — to rise at a compound annual growth rate (CAGR) of nearly 39% to $2.19bn in 2023, driven by use in power supply systems, photovoltaic inverters and electric & hybrid electric vehicles (EVs/HEVs) — see page 6. The GaN power device market in particular is estimated by Yole Développement to be growing between 2017 and 2023 at a CAGR of 55% in a 'base case' scenario (driven by the power supply segment) or 93% in a 'bull case' scenario (if GaN is adopted by leading consumer electronics manufacturers, including Apple, for wireless charging) — see pages 84–86. So, even if end-product markets slow, markets for 'new' technology can still thrive.

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

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

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Wide-bandgap power semiconductor device market growing at 39% CAGR to 2023, driven by rising implementation of signal processing applications

UPS & PS systems held 41% market share in 2018 and to remain dominant

The market for wide-bandgap (WBG) power semiconductor devices will rise at a compound annual growth rate (CAGR) of nearly 39% to $2.19bn in 2023, forecasts Technavio in its report 'Global Wide-Bandgap (WBG) Power Semiconductor Devices Market 2019–2023'.

A key driver is the increasing demand for high-power-density devices, including in uninterruptible power supply (UPS) and power supply (PS) systems, photovoltaic (PV) inverters and electric and hybrid electric vehicles (EVs/HEVs), where there is an increasing focus on achieving higher efficiency in power systems. The UPS and PS systems application segment held the largest share of the wide-bandgap power semiconductor devices market in 2018 (at about 41%), and is expected to dominate throughout 2019–2023. The Asia Pacific (APAC) region held more than 43% market share in 2018, followed by Europe, the Middle East & Africa (EMEA) and the Americas, respectively. APAC is expected to dominate the market throughout 2019–2023.

As power electronics offer benefits such as light weight, easy maintenance, better control and fault-detection intelligence, demand is particularly high in the aerospace & defense sector. In particular, intensive signal processing applications such as radio detection and ranging (radar), unmanned aerial vehicles (UAVs), unmanned underwater vehicles (UUVs) and sound navigation and ranging (sonar) use processing power that generates a tremendous amount of heat. So, durable and high-performance electronics are required so that products such as missile systems (which can be stored for as long as 10 years) function effectively when deployed for mission-critical applications. Aircraft and military manufacturers have hence been developing power electronic systems incorporating the WBG materials silicon carbide (SiC) and gallium nitride (GaN) to withstand high voltages and deliver high output.

The Asia Pacific (APAC) region held more than 43% market share in 2018, followed by Europe, the Middle East & Africa (EMEA) and the Americas

"The latest trend gaining momentum in the market is the growing implementation of signal processing applications including underwater communications, naval mine detection, offshore oil & gas exploration, and search & discovery missions," comments Technavio.

With broad applications of high-power density devices in different end-user industries, various power semiconductor device manufacturers are investing in R&D on WBG power semiconductor materials. For example, in June Cree subsidiary Wolfspeed announced the development of its third-generation 1200V SiC MOSFET for boosting drivetrain efficiency in EVs/HEVs. As well as Cree, the report also includes analysis of companies such as Infineon Technologies, ROHM Semiconductor, STMicroelectronics and Transphorm.

www.technavio.com/report/global-wide-bandgap-wbg-power-semiconductor-devices-market-industry-analysis

Optical transceiver market grows 8% year-on-year in Q3/2018 despite localized headwinds

II–VI, Accelink, Innolight, Lumentum, Neophotonics and Sumitomo growing strongly, while Acacia and Oclaro still recovering from ZTE shutdown

The market for optical transceivers eked out respectable year-on-year growth (+8%) in Q3/2018 despite headwinds faced by several vendors, according to LightCounting's Quarterly Market Update. Strong year-on-year sales growth was reported by II–VI (+20%), Accelink (+18%), Innolight (+18%), Lumentum (+49%), Neophotonics (+15) and Sumitomo (+12%), while quality issues at Applied Optoelectronics Inc (down 36% year-on-year), and incomplete recoveries from ZTE's Q2/2018 shutdown at Acacia (down 10% year-on-year, despite being up 46% versus Q2) and Oclaro (down 15% year-on-year, while up 9% sequentially) suppressed the market average.

This 'ying and yang' market dynamic was also present in company guidance for Q4/2018, which ranged from strong growth to seriously disappointing. II–VI continues to benefit from strong demand for reconfigurable optical add/drop multiplexers (ROADMs) and 980nm pump lasers, and guided for 20% year-on-year growth. Acacia and Neophotonics guided for mid-teens growth in sales on the back of new CFP2 and 600G products (Acacia) and increased sales to Huawei (NeoPhotonics).

Lumentum had guided for 14% growth, but had to revise that to –15% after a 'large consumer electronics customer' (Apple) said it wouldn't need as many VCSEL arrays in Q4/2018 as it first thought. Also, AOI is still struggling with a quality issue that is limiting its ability to ship everything that customers want.

The fundamental drivers of growth in the optical components data-center segment remain strong, says LightCounting. Internet content providers (ICPs) spent 66% more on property plant and equipment in the first three quarters of 2018 than in the same period in 2017. Data-center storage, server and switch makers benefited from this largess, growing sales 14% year-on-year through September, despite the continuing migration towards open systems and white-box manufacturing. And while sales for datacom equipment vendors as a group were down 3% sequentially in third-quarter 2018, seven — Arista, Dell, Extreme, Inspur, Lenovo, Mellanox and NetApp — reported double-digit sales growth compared with Q3/2017. Sequential growth was more mixed, indicating that, although ICPs are spending at a new higher level in 2018, they are not increasing spending through the year.

Communications service providers (CSPs) held capital expenditure (CapEx) flat in the first three quarters of 2018 on a year-on-year basis. While commercial 5G services were launched in September by Verizon, its four-city rollout and other operators' equally small initial deployments are not yet of a scale to require an appreciable increase in capex. China's 5G rollout is about a year behind Verizon's. Publicly reported sales from telecom equipment makers were down 2% year-on-year through September, partly because of ZTE's forced shutdown in Q2/2018. However, like the optical component market, the average belies a wide range of performance. Ciena and Infinera both reported double-digit year-on-year sales growth for 2018 through the end of September, while ZTE was down 20%, and Ericsson and Fujitsu sales were also lower this year compared with 2017.

DWDM port shipments (a more direct indicator of optical component demand in the communications service provider segment) rose 48% year-on-year in 100G port-equivalents. While 100G ports only grew by single digits, 200G-capable ports rose by 189%, and 400G-capable shipments — though still small — increased by 272% compared with Q3/2017.

The outlook for 2019 is for continued growth, with the occasional pothole. LightCounting's recent five-year market forecast forecasts double-digit growth in revenues for the Ethernet, WDM and wireless transceiver segments, as well as in active optical cables (AOCs). The need for speed continues to drive the adoption of higher-priced modules in all three segments. Products that are expected to have particularly strong growth in 2019 include 100GbE Ethernet transceivers in several flavors: 200G DWDM (CFP2 ACO, CFP2 DCO), and 25G SFPs for 5G fronthaul.

Near term, the biggest threat to growth in 2019 is the deteriorating US–China trade relationship, strained by the recent arrest of Huawei's chief financial officer. If Huawei gets hit with a sales ban like ZTE, the impact could be as bad or even worse than the ZTE shutdown. More generally, trade tariffs — or just the threat of tariffs — could disrupt existing supply-chain relationships, as companies move manufacturing or change suppliers from one country to another to eliminate tariff costs. LightCounting's forecast assumes that the industry can weather this storm without suffering a significant impact, but some potholes are unavoidable, the firm adds.

www.lightcounting.com/marketupdate.cfm

Skyworks cuts December-quarter revenue and earnings guidance

Impact driven by unit weakness across largest smartphone customers

Skyworks Solutions Inc of Woburn, MA, USA (which manufactures analog and mixed-signal semiconductors) has reduced its revenue guidance for fiscal first-quarter 2019 (ended 28 December 2018) from $1bn–1.02bn (given on 8 November) to about $970m (down on the prior quarter's $1.008bn and $1.052bn a year ago). The firm has also reduced its guidance for non-GAAP diluted earnings per share from $1.91 to $1.81-1.84 (down on the prior quarter's $1.94 and $2.00 a year ago).

"First fiscal quarter results were impacted by unit weakness across our largest smartphone customers," says president & CEO Liam K. Griffin.

This follows similar December-quarter guidance cuts from rival Qorvo in November, as well as Lumentum and IQE (also in the Apple iPhone supply chain), and specifically follows Apple issuing a profit warning in early January.

Broad markets business tracked in-line with our prior outlook. Cash flow generation continued to be strong, allowing us to return cash to shareholders through share repurchases and dividends

"Despite these near-term challenges, our broad markets business tracked in-line with our prior outlook," he adds. "In addition, cash flow generation continued to be strong, allowing us to return cash to shareholders through share repurchases and dividends."

www.skyworksinc.com

Skyworks powers next-generation 4G/5G mobile hotspots

Skyworks says that its SkyOne Ultra 3.0 portfolio is being leveraged by Inseego, a pioneer in 5G and intelligent Internet of Things (IoT) device-to-cloud solutions, for their next-generation mobile hotspot.

Given the significant growth in mobile subscribers and densification of data traffic — which will intensify with 5G — demand for portable, reliable, anytime connectivity is rapidly increasing. Skyworks' compact, highly integrated front-end system is being utilized in combination with Qualcomm's LTE X20 modem to power Inseego's MiFi 8800L device, which is claimed to be the first commercially available gigabit LTE platform for Cat 18.

The complete global solution covers more than 23 bands and provides ultra-fast user experiences with enterprise-grade security.

"Leveraging decades of expertise, Skyworks' innovative cellular solutions are enabling a growing number of diverse applications," says Carlos Bori, senior VP of sales and marketing. "Mobile hotspots and IoT enterprise devices represent yet another burgeoning market where Skyworks' advanced wireless architectures are facilitating broad coverage and premium performance," he adds.

"As we accelerate towards 5G, Skyworks is the ideal partner to provide next-level performance across consumer, enterprise and IoT use cases," comments Ashish Sharma, chief marketing officer & executive VP of IoT and mobile solutions at Inseego. "Skyworks' leading wireless engines seamlessly interface with our robust technologies to deliver unprecedented LTE speeds and highly reliable connections in dense traffic areas, a forerunner to what 5G networks will offer."

According to Zion Market Research, the mobile hotspot router market is expected to rise at a compound annual growth rate (CAGR) of 20% from about $2bn in 2017 to more than $7bn by 2024.

www.skyworksinc.com/Products/622/SkyOne®_Modules

Skyworks launches high-efficiency power amplifier for cellular 4G and 5G infrastructure

Skyworks has unveiled its latest cellular infrastructure product, a wide instantaneous bandwidth power amplifier for FDD/TDD 4G LTE and 5G applications.

The SKY66313-11 can be used in small-cell and massive MIMO base stations to deliver higher data rates and enhanced network efficiency that result in improved carrier capacity and greater coverage for data-intensive, multimedia and Internet of Things (IoT) devices.

The amplifier's highly efficient design has fully matched input/output and high gain. With an integrated on-chip active bias circuit, the device provides what is claimed to be excellent performance over temperature, voltage and process variations and facilitates faster design cycles.

www.skyworksinc.com/Product/4113/SKY66313-11

Skyworks unveils SkyOne Ultra 3.0 devices for automotive connectivity

Skyworks Solutions Inc of Woburn, MA, USA (which makes analog and mixed-signal semiconductors) has introduced its suite of next-generation SkyOne Ultra 3.0 devices, designed specifically for advanced automotive applications.

The latest wireless solutions are derivatives of the SkyOne cellular platform, delivering robust, low-latency, high-bandwidth LTE connectivity in addition to extended operating temperature ranges and production lifetimes.

SkyOne Ultra 3.0 incorporates the key analog and RF functionality in both transmit and receive paths of LTE communications. Transmit devices contain power amplifier modules with SkyBlue technology for improved efficiency, as well as integrated duplexers (PAMiDs), low-noise amplifiers (LNAs) and antenna switches. Diversity receive (DRx) modules combine the necessary components within the LTE receive path including LNAs, filters and antenna switches.

Specifically, the suite comprises:

- SKYA230xx — front-end modules with SkyBlue enabling technology, LNAs and integrated duplexers;
- SKYA220xx — suite of power amplifiers;
- SKYA250xx — DRx and MIMO modules; and
- SKYA21xxx — discrete switches and LNA products.

The complete cellular solution is contained in a package of less than 40mm x 40mm, a critical element

in meeting automotive-qualified network attached device (NAD) reliability requirements. Further, the connectivity engines can be regionally optimized for North American, European, Chinese and other SKUs to achieve additional cost savings.

The portfolio exceeds LTE CAT 16 requirements, is scalable to 5G new radio standards and supports all global cellular bands. Given their compatibility with all leading chipset providers and a simplified compliance process, the highly integrated architectures are being adopted by customers to reduce design complexity as well as time to market, says the firm.

"With the introduction of SkyOne Ultra 3.0 for automotive, Skyworks is enabling the full benefit of high-speed data and real-time communication in the connected car," says Joel King, senior VP & general manager of mobile solutions for Skyworks. "At a higher level, in-vehicle technologies and rapidly changing standards are being adopted at a pace previously unheard of in the automotive industry — particularly with the advent of 5G and the move toward autonomous driving. Our differentiated portfolio takes seamless connectivity to the next level, making the driving experience increasingly smarter and safer."

Embedded navigation systems, diagnostic capabilities, personalization services and other smart features are fueling consumer demand for connected cars. IHS Markit forecasts that worldwide sales will rise from 24 million units in 2015 to more than 72 million by 2023. Placing this growth in perspective, in eight years nearly 70% of the passenger vehicles sold will be transmitting data with external sources, bringing new services and business models to automotive markets.

www.skyworksinc.com/Products_SkyOne_Ultra_3_0_for_Automotive.aspx

Skyworks launches high-power switches for wireless infrastructure

As data-intensive multimedia and Internet of Things (IoT) applications continue to proliferate, cellular infrastructure solutions are becoming more robust to meet increasing network demand.

Skyworks says that its newest family of high-power SPDT switches, the SKY12241-492LF, SKY12242-492LF and SKY12245-492LF, deliver leading performance and efficiency in an extremely compact package, enabling high data rates with low power consumption for next-generation wireless devices. Specifically designed for TDD 2G/3G/4G micro- and macro-cell base stations, the SKY1224x suite offers excellent low transmit/receive insertion loss as well as high transmit-to-receive isolation, facilitating optimal system performance. A single 5V DC supply also simplifies design and implementation.

www.skyworksinc.com/Products/507/High_Power_SPDT_and_SPST_PIN_Diode_Switches

SkyWater launches direct MPW FastShuttle program

SkyWater Technology Foundry of Bloomington, MN, USA — a solely US-owned Trusted Foundry that manufactures differentiated integrated circuits in markets including consumer, industrial, aerospace & defense, automotive, and the Internet of Things (IoT) — has announced its multi-project wafer (MPW) FastShuttle program offering what is said to be quick and low-cost prototyping and design enablement with access to high-performance processes and regularly scheduled launch dates. The program provides a vehicle to develop new application-specific integrated circuit (ASIC) and custom designs, meeting customers' evolving requirements to bring products to market quickly.

The MPW FastShuttle program now supports rapid prototyping activities on SkyWater's 90nm and 130nm technology nodes for applications ranging from commercially focused mixed-signal to specialized aerospace & defense. Volume manufacturing is supported at SkyWater's ISO 9001- and ITAR (International Traffic in Arms Regulations)-compliant production facility.

"SkyWater's MPW program is an extremely valuable service which directly meets our critical needs," comments Mike Ward, CEO of Linear ASICs. "Working with SkyWater gives Linear the advantage of high-performance fab operations, but it is also the right size to be flexible and support us with the services we need to be responsive to our customers," he adds.

The direct MPW program reduces prototyping cost for commercial and government customers by grouping IC designs and sharing mask costs among MPW program participants. In addition, production rebates effectively bring the cost of participating in the program to zero, says SkyWater.

The FastShuttle MPW program "enables our customers to achieve product prototyping, device characterization, and IP validation quickly and cost-effectively," says SkyWater's president Thomas Sonderman. "We look forward to continuing to provide the reliability, IP security and high-quality manufacturing that is crucial for both military and commercial applications."

www.skywatertechnology.com/mpw-fastshuttle

Teledyne e2v HiRel extends space-qualified InGaP gain blocks to X-band

Teledyne e2v HiRel Electronics 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) has announced availability of the new 14GHz family of RF gain blocks, spearheaded by an 18.4dB amplifier (TDGB014-003). The gain blocks are based on an indium gallium phosphide (InGaP) technology that is suitable for aerospace & defense applications because of its ceramic packaging and space qualification.

The gain blocks also come in gain configurations of 13.6dB and 16.5dB, allowing design engineers to exactly configure the signal gain without incurring unwanted parasitic effects.

Teledyne e2v HiRel says that, with its new family of X-band gain blocks, customers now have a standard amplifier solution that covers L-band through X-band. The standard amplifier enables a reduction in the number of new qualified components required for flight programs, simplifying the component procurement process.

The TDGB014-003 50Ω gain block utilizes a mature and reliable heterojunction bipolar transistor (HBT) InGaP process and incorporates proprietary monolithic microwave integrated circuit (MMIC) design techniques. The process has space-flight heritage and has shown to be radiation tolerant to 100krad, making it a viable choice for satellites and other high-altitude applications.

"Teledyne e2v HiRel has developed a broad portfolio of analog, digital, power and RF semiconductors targeted at aerospace & defense applications," says Mont Taylor, VP of business development. "We're pleased to be able to incorporate InGaP technology into our current A&D product offerings. Additionally, we are excited to provide a growing portfolio of standard RF building blocks such as amplifiers, LNAs, PAs, DSAs, limiters, mixers, pre-scalers, phase-locked loops (PLLs), switches and more to help customers design RF signal chains that meet the high-reliability requirements of defense and space."

Teledyne e2v's Hi-Rel X-band gain blocks offer what's said to be high gain flatness and P1dB (output power at 1dB gain compression point). The gain block family is available now, packaged in a 2-lead, ultra-small, hermetic gullwing package. Both the wafer process technology and the package have space-flight heritage.

www.teledyne-e2v.com/products/semiconductors/peregrine

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MACOM launches first product in range of wideband, ultra-low-phase-noise amplifier

MACOM Technology Solutions Inc (which makes semiconductors, components and subassemblies for RF, microwave, millimeter-wave and lightwave applications) has unveiled the first entries in its new portfolio of wideband, ultra-low-phase-noise amplifiers.

Available in 2.8mm x 1.73mm x 0.1mm bare-die and 5mm x 5mm, 32-lead AQFN-packaged formats, the MAAL-011151 is suitable for use as a low-phase-noise amplifier stage for signal generation applications spanning system designs targeting test & measurement (T&M), electronic warfare (EW), electronic counter-measures (ECM) and radar.

Phase noise is a critical specification in defining the frequency stability of a signal source, with significant implications for receiver sensitivity performance. The MAAL-011151 minimizes phase-noise contribution in providing LO signal gain, enhancing spectral integrity for T&M and communications systems, target acquisition for radar, and aerospace & defense (A&D) applications.

The MAAL-011151 provides 16dB of linear gain across the 2–18GHz frequency band, and 17.5dBm of output power at 1dB gain compression point (P1dB) and 5dB of noise figure at 10GHz with input and outputs that are fully matched to 50Ω and DC blocked. Amplifier control is available through the use of a control circuit or by direct bias injection. The MAAL-011151 is fabricated using a low-phase-noise heterojunction bipolar transistor (HBT) process that features full passivation for enhanced reliability.

"With the introduction of MACOM's new MAAL-011151 ultra-low-phase-noise amplifiers, we're investing in a growing portfolio of signal-generation components that encompasses high-performance comb generators, mixers and more," says Graham Board, senior director of product marketing. "As we expand this portfolio to include additional discrete amplifiers covering additional frequencies, and integrated low-phase-noise LO modules, system designers will benefit from seamless device compatibility and exceptional performance across the signal chain," he adds.

MAAL-011151 ultra-low-phase-noise amplifiers are now sampling to customers in bare-die and packaged formats.

www.macom.com/products/product-detail/MAAL-011151

Qorvo launches first 28GHz GaN front-end module, targeting 5G fixed wireless access base stations

Qorvo Inc of Greensboro, NC, USA (which provides core technologies and RF solutions for mobile, infrastructure and defense applications) has expanded its offering for 5G applications with what is claimed to be the first 28GHz gallium nitride (GaN) front-end module (FEM). The new single-channel FEM is said to reduce overall system costs for base-station equipment manufacturers as they expand into 5G.

According to SNS Telecom & IT, the 28GHz frequency band is widely preferred for early 5G-based fixed wireless access (FWA) deployments, enabling operators to meet the speed, latency, reliability and capacity requirements of 5G.

Operating at frequencies of 26–30GHz, the QPF4001 FEM integrates a high-linearity three-stage low-noise amplifier (LNA), a low-loss transmit/ receive (T/R) switch and a high-gain, high-efficiency three-stage power amplifier (PA) in a single monolithic microwave integrated circuit (MMIC). The compact 5mm x 4mm air-cavity laminate surface-mount package is optimized for the phased-array element spacing at 28GHz for 5G base-station architectures.

The new GaN FEM enables smaller, more powerful and efficient millimeter-wave phased-array systems, which will steer signals to areas of greater bandwidth demand. Qorvo says that using its 0.15μm GaN-on-SiC technology in this application allows the user to more efficiently achieve higher levels of EIRP (equivalent isotropically radiated power) while minimizing array size and power dissipation, resulting in a lower-cost system.

Using 0.15mm GaN-on-SiC technology in this application allows the user to more efficiently achieve higher levels of EIRP

"Thirty years of solving the power, size and efficiency challenges of integrated circuits for the point-to-point, satellite communications and defense industries are now shaping Qorvo's 5G innovations," says James Klein, president, Infrastructure and Defense Products. "Our GaN technology is used in dozens of 5G field trials, and this new module will enable further reductions in size and power consumption, which are essential for the very small arrays critical to mmW frequencies."

Complementing Qorvo's portfolio of 5G products (including the 39GHz FEMs for 5G, announced in June 2017), engineering samples of the QPF4001 FEM are available now to qualified customers.

www.qorvo.com/products/p/QPF4001

Anokiwave's founder & CTO named IEEE Fellow

Anokiwave Inc of San Diego, CA, USA — which provides highly integrated silicon core chips and III-V front-end integrated circuits for millimeter-wave (mmW) markets and active antenna-based solutions — says its founder & chief technology officer Dr Nitin Jain has been named a Fellow of the Institute of Electrical and Electronics Engineers (IEEE) for leadership in the development of physics-based models for mmWave system-on-chip ICs.

The grade of Fellow is conferred at the initiative of the IEEE board of directors (following a nomination and evaluation process) in recognition of unusual and outstanding professional distinction. Individuals receiving this distinction have demonstrated extraordinary contributions to one or more fields of electrical engineering, or related sciences.

Anokiwave says that, under Jain's leadership, its portfolio of highly integrated silicon ICs has seen a high percentage of first-pass design success, showing his attention to detail, his EM simulation ability, and the integrity of his modeling of the

mmWave, RF, analog and digital circuits.

"Nitin, the co-founder of Anokiwave with his wife Deepti, has had a long history of creative and innovative work and is one of the best engineers with whom I have had the pleasure of working during my career," comments CEO Robert S Donahue. "He is skilled at all levels of engineering from the transistor level to the microwave system engineering level," he adds.

Jain earned his B.Tech degree (in Electronics) from the Indian Institute of Technology, Madras, India in 1986, and his MS and Ph.D. in Electrical Engineering from the Rensselaer Polytechnic Institute, Troy, NY, USA in 1989 and 1991, respectively. He has over 37 publications in international conferences and journals, and more than 35 granted and pending US patents.

www.ieee.org

VP of sales made VP of business development

Anokiwave has appointed Gary St. Onge (most recently its VP of sales, responsible for growing worldwide business) as VP of business development. He will take on additional business leadership responsibilities in the San Diego office, increase the firm's business footprint in the western USA, and provide strategic customer support to key accounts.

Over his career, St. Onge has a proven track record in leadership roles in sales, marketing and engineering. Prior to joining Anokiwave in April 2014, he was director for new product engineering at MACOM, where he led an international team of 25 people bringing new products to market. Prior to that, he was senior VP of international sales at WIN Semiconductors Corp, responsible for substantial sales growth year-on-year.

"Gary brings outstanding entrepreneurial business skills to his new role at Anokiwave," comments CEO Robert S Donahue. "I have had the pleasure of working with Gary at several companies, and he brings experience, a proven track record of success, and drive to everything he sets out to accomplish."

St. Onge has a B.S.E.E. from the University of Massachusetts at Amherst, an M.S.E.E. from Northeastern University, and he is a graduate of Philips Andover Academy.

www.anokiwave.com

IN BRIEF

10W broadband, multi-stage GaN-on-Si PA module with flexible mounting

MACOM has expanded its gallium nitride on silicon (GaN-on-Si) power amplifier portfolio by launching the MAMG-100227-010 broadband PA module optimized for use in land mobile radio (LMR) systems, wireless public safety communications, and military tactical communications and electronic countermeasures (ECM).

Combing the design efficiencies of a fully matched (50Ω), two-stage PA architecture with top-and bottom-side mounting configurability, the MAMG-100227-010 can enable design flexibility for radios balancing stringent size, weight and power (SWaP) specifications.

The MAMG-100227-010 leverages GaN-on-Si to achieve a very wide frequency bandwidth of 225–2600MHz, with 10W CW output power, 40% typical power added efficiency over the band, 22dB typical power gain, and up to 36V operation (28V typical). Supplied in a compact 14mm x 18mm air-cavity laminate package with integrated gold-plated copper heatsink, it can eliminate the need for additional componentry and PCB space required for unmatched PA architectures, with top and bottom accessibility for improved mounting and heat-sinking agility.

"The MAMG-100227-010 builds on MACOM's rich legacy of providing high-performance GaN-on-Si solutions with field-proven reliability," says Mark Murphy, senior director of marketing, RF Power and Basestation. "For customers seeking exceptional design flexibility, the MAMG-100227-010 exemplifies the design and application expertise that MACOM provides across a wide range of broadband frequencies and power levels."

www.macom.com

Sanan IC announces commercial release of 6" SiC wafer foundry process

650V, 1200V and higher Schottky diodes to be followed by MOSFETs for 900V, 1200V and beyond

Sanan Integrated Circuit Co Ltd (Sanan IC) of Xiamen City, Fujian province (China's first 6-inch pure-play compound semiconductor wafer foundry) has added to its foundry services portfolio after achieving full process qualification for the commercial release of 6-inch silicon carbide technology, which has emerged as the most mature wide-bandgap (WBG) semiconductor for power electronics circuit designs.

Founded in 2014 as a subsidiary of Sanan Optoelectronics Co Ltd (China's largest LED epiwafer and chip maker, based on GaN and GaAs technologies), the firm now provides dedicated capacity for its 6-inch SiC wafer processing services in addition to its III-V gallium arsenide (GaAs), gallium nitride (GaN) and indium phosphide (InP) compound semiconductor manufacturing.

"We see tremendous business opportunities in serving the high-growth power electronics market with SiC displacing silicon solutions due to its higher efficiency, higher switching frequency and higher-temperature characteristics," says Sanan IC's CEO Raymond Cai. "The enormous growth of the automotive, big data, renewable clean energy and power utility industries has created opportunities for us to offer SiC foundry services to the global market," he adds.

Sanan IC's SiC process technology offers device structures for 650V, 1200V and higher-rated Schottky barrier diodes (SBD), to be followed soon by a SiC MOSFET process for 900V, 1200V and higher. Due to their higher performance, SiC SBDs and MOSFETs are emerging for power conversion applications starting from 650V. Given the superior properties of SiC over silicon in terms of higher efficiency, increased power density, higher switching frequency, higher temperature, higher breakdown strength, and more compact and lighter system design, several applications have started to embrace this technology, says the firm.

The adoption of SiC has accelerated into multiple markets such as in photovoltaic solar cells, industrial motor drives, power factor correction (PFC) for enterprise server, and telecom base-station power supplies. In electric and hybrid electric vehicles (EV/HEV), SiC is widely used in the on-board charger (OBC), power train inverters and DC/DC converters. According to the 'Power SiC 2018: Materials, Devices, and Applications Report' by market research firm Yole Développement, the SiC power device semiconductor market is rising at a compound annual growth rate (CAGR) of 31% from 2017 to over $1.5bn in 2023.

www.sanan-ic.com

Cree and ST sign multi-year SiC wafer supply agreement

Deal to boost commercial expansion of SiC in automotive and industrial applications

Cree Inc of Durham, NC, USA has signed a multi-year agreement to produce and supply its Wolfspeed silicon carbide (SiC) wafers to STMicroelectronics of Geneva, Switzerland. Enabling silicon carbide applications in the broad automotive and industrial markets, the agreement governs the supply of a quarter billion dollars of Cree's 150mm silicon carbide bare and epitaxial wafers to STMicroelectronics during the current period of growth and demand for silicon carbide power devices.

"ST is the only semiconductor company with automotive-grade silicon carbide in mass production today, and we want to press forward to grow our SiC business both in terms of volume and breadth of applications served, targeting leadership in a market estimated at more than $3bn in 2025," says STMicroelectronics' president & CEO Jean-Marc Chery. "This agreement with Cree will improve our flexibility, sustain our ambition and plans, and contribute to boosting the pervasion of SiC in automotive and industrial applications," he reckons.

ST is the only semiconductor company with automotive-grade silicon carbide in mass production today, and we want to press forward to grow our silicon carbide business

"We remain focused on increasing the adoption of silicon carbide-based solutions, and this agreement is a testament to our mission," says Cree's CEO Gregg Lowe. "This is the third multi-year agreement that we have signed this past year in support of the industry's transition from silicon to silicon carbide," he adds. "As the world leader in silicon carbide, Cree continues to expand capacity to meet the growing market needs, particularly in industrial and automotive applications."

www.wolfspeed.com
www.st.com

Wolfspeed launches fifth-generation 1700V SiC Schottky diode for renewable energy, EV applications

Wolfspeed of Durham, NC, USA — a Cree Company that makes silicon carbide (SiC) power products and gallium nitride on silicon carbide (GaN-on-SiC) high-electron-mobility transistors (HEMTs) and monolithic microwave integrated circuits (MMICs) — has introduced the fifth-generation (C5D) 1700V SiC Schottky diode, which is optimized for renewable energy, industrial power and electric vehicle charging applications including solar power and wind turbine inverters, off-board chargers and uninterruptible power supply (UPS).

The 1700V C5D is commercially available in both bare die and package formats, providing designers with a versatile portfolio that can be utilized in diverse settings. It joins the firm's existing line of 1700V MOSFETs, which feature an optimized TO-247-4 Plus package that provides extra electrical isolation suitable for high-pollution environments.

Wolfspeed says that its new Schottky diodes feature essentially no switching losses due to nearly zero reverse recovery and what is claimed to be the industry's lowest forward voltage drop. This generates higher efficiencies and systems that are smaller, cooler, faster and lower cost than possible with silicon bipolar devices, it adds. The C5D product family combines these features with the new TO-247-2 package option, making it suitable for high-pollution environments such as off-board battery chargers and solar inverters that require high power and voltage.

The C5D is a direct drop-in replacement of Wolfspeed's third-generation 1700V product. In addition, the family offers what is reckoned to be the industry's largest range of current ratings at this voltage (5A, 10A, 25A, 50A), giving designers maximum flexibility in incorporating the C5D series into their designs.

"Our goal is to enable our customers to create innovative and ground-breaking designs that are enabled by silicon carbide," says Jay Cameron, general manager of Wolfspeed's power business. "The launch of the C5D offers our customers the ability to achieve higher efficiency and better overall system performance."

www.wolfspeed.com/power/products

Transphorm ships over a quarter of a million GaN power devices, reaffirms high-volume scalability

Transphorm Inc of Goleta, near Santa Barbara, CA, USA — which designs and manufactures JEDEC- and AEC-Q101-qualified high-voltage (HV) gallium nitride (GaN) field-effect transistors (FETs) for high-voltage power conversion applications — says it has shipped more than 250,000 high-voltage GaN FETs, manufactured at its wafer foundry in Aizu, Japan for mass-production applications.

Transphorm also says that the wafer foundry's annual installed capacity base of 15 million parts of its 50mΩ product equivalent can easily scale to address 2–5x the volume. Further, when demand warrants it, the technology and manufacturing process can be structured to scale from the current 6-inch to 8-inch or potentially higher wafer diameters.

"2018 has been a game-changing year for high-voltage GaN," says Transphorm's co-founder & chief operating officer Primit Parikh. "More than 250,000 650V GaN FETs from Transphorm are deployed in our customers' mass-production, high-performance power converter and inverter products. These products are available through various channels. Even Amazon," he adds. "With our production volumes to date, we're able to conservatively estimate more than 1.3 billion field hours of operation with a field FIT [failure in time] rate in the low single digits as well as over a billion hours of mean time before failure (MTBF) at operating conditions from an extensive suite of operating and accelerated reliability testing."

Transphorm claims to be the first high-voltage GaN FET supplier to show field failure data from devices shipped. This data is used to calculate the field failure rate in parts per million (ppm) and failure in time (FIT), which shows the technology's reliability. Availability of field data is an important new phase for high-voltage GaN in power systems, as it indicates a maturing technology, says the firm.

Market research and strategy consulting firm Yole Développement forecasts (in an aggressive scenario) in its report 'Power GaN 2018: Epitaxy, Devices, Applications and Technology Trends' that the power GaN market will rise at a compound annual growth rate (CAGR) of 91% to $408m in 2023. The high-voltage applications slated to drive that growth include fast chargers, data centers and other high-end power supplies.

Supporting that research, Transphorm's in-production customers cross the Yole-referenced growth segments and others, including PC gaming power supplies (CORSAIR), server power supplies (Bel Power, Delta), servo drives (Yaskawa), and portable power (Inergy/Telcodium). Also, notably, 2018 saw major steps forward in GaN's commercialization with Nexperia's plans to release 600V+ GaN FETs and Infineon's introduction of its 600V portfolio.

"The pivotal benchmarks of any new technology's market acceptance are adoption by leading customers in key market segments and the emergence of multiple, strong suppliers capable of supporting ensuing high-volume ramps," says Transphorm's CEO Mario Rivas. "While we are very pleased with what Transphorm has achieved in partnership with our customers, we are even more excited to see high-voltage power semiconductor leaders like Nexperia and Infineon join the GaN revolution," he adds. "Customers can now reap the benefits of energy-saving GaN with increased confidence in its suppliers."

www.transphormusa.com

Saab receives Swedish defense order for GaN-based radar

Sweden-based defence and security firm Saab AB has received an order from the Swedish Defence Materiel Administration (FMV) to develop and maintain the Armed Forces' artillery- and weapon-locating capability. The order includes Saab's Giraffe 4A multi-function radar and life extension of the artillery-locating system Arthur.

Giraffe 4A is a multi-function radar with a range of capabilities, including a gallium nitride (GaN)-based digital multi-channel system featuring active electronically scanned array (AESA) technology that can be used for air surveillance and air defence as well as warning and artillery locating tasks.

Deliveries of the ground-based multi-function system Giraffe 4A and life extension of Arthur will create conditions for the Armed Forces' long-range surveillance capability in the long term and give the defence new possibilities for handling existing and future threats. Work will take place at Saab in Gothenburg, with deliveries from 2019.

"Our ground-based radar Giraffe 4A strengthens our customers' capability to detect incoming threats including tactical ballistic missiles," says Anders Carp, head of Saab's business area Surveillance. "The system gives our customers a world-class multi-function capability that helps to protect their interests," he adds.

www.saab.com
www.saabgroup.com

Portable solar generator uses Transphorm's GaN

Transphorm's high-voltage GaN is being used in the Kodiak Extreme portable power generator of Inergy of Pocatello, ID, USA (which makes portable plug-and-play energy storage, aided by power supply design partner Telcodium Inc of Boucherville, QC, Canada).

The Kodiak Extreme uses a photovoltaic inverter and battery charger that both integrate Transphorm's JEDEC-qualified GaN platform. These power systems result in a generator that is said to be more powerful, lighter and quicker to charge than competing products. Also, given that GaN runs cooler than similar silicon devices, the Kodiak Extreme does not need an internal cooling fan, yielding one of the first truly water-resistant and dustproof solar power generators for consumers.

With a 110/120V_{ac} 2kW output, the Kodiak Extreme solar generator targets consumers and professionals (construction, emergency services, industrial etc) by providing reliable off-grid AC power. Its PV inverter and battery converter use Transphorm's TP65H050WS 50mΩ TO-247 FET and TPH3206LDGB 150mΩ PQFN devices, respectively. They serve as close replacements for the silicon IGBTs and MOSFETs used in prior Kodiak models given their standard packaging, making them easy to design in and heat-sink.

Transphorm says that its high-reliability GaN semiconductors can increase power density up to 40% and decrease heat losses through traditional heat-sinking methods while switching 2–3 times faster than silicon transistors. The Gen III devices also offer ±20V gate robustness and a 4V threshold, decreasing the need for additional circuitry and controls to ensure reliability.

Compared with currently available competing products, the Kodiak Extreme is claimed to demonstrate the following advantages:

- 33% more power output;
- minimum 98% inverter efficiency from light load to full load;
- charging over four times faster;
- fanless for harsh environments; and
- roughly half the weight.

"We've been interested in GaN power systems for some time, having first been introduced to it observing the Google Little Box Challenge," says Inergy's chief technology officer James Brainard. "The technology's capabilities would allow us to create a highly ruggedized and efficient portable generator capable of bringing affordable solar energy to the masses. Superior durability, high clean power output, light weight — these are all the attributes that our customers want. Working with Transphorm and Telcodium to develop the GaN platform for our system enables us to achieve that vision."

The Kodiak Extreme was unveiled at Power-Gen International 2018 in Orlando (4–6 December), prior to its launch in first-quarter 2019.

www.power-gen.com
www.telcodium.com

Military-grade high-frequency power supply gains from HV GaN FETs

Aerospace & defense supplier Marotta Controls' new power supply unit (PSU) replaces silicon MOSFETs with Transphorm's high-voltage GaN PQFN devices.

The new design operates at high frequency in a conduction-cooled mechanically constrained envelope. Its topology features hard switching and an automatic transformer RESET capability where transistor voltage stresses are clamped to the input voltage. The GaN devices increase the PSU's efficiency and alleviate a complex thermal design in the small-form-factor package.

"The demand on our power supplies and expectation of performance is high," says Marotta Controls' principal engineer Mike Scruggs. "This particular complex PSU needed to reliably convert and distribute power in a small envelope. The system design had to work considerably higher than 100kHz to reduce the power component's size, but our engineering team met challenges with heat dissipation and component temperatures under peak load conditions."

After testing Si-based prototypes, Marotta vetted the TPH3208LD PQFN package, which reached the desired switching speeds with much reduced losses. Compared with the Si MOSFETs', dissipation fell, yielding lower board component temperatures and hence a simpler viable thermal design and packaging concept for the overall system.

"We initially selected Transphorm's transistors for the reputable reliability, and our experience has since exceeded our expectations," comments Steve Fox, Marotta's VP of engineering and program management & chief technology officer. "Transphorm's GaN enabled us to not only gain high power efficiency and thermal performance but also generated power savings in the drive and control circuitry — additional benefits that will provide opportunities in future designs. Transphorm's ability to align with our vision of providing advanced, next-generation technologies — combined with their exceptional level of technical support and dependability — are the exact characteristics we look for in our growing supplier base," he adds.

Marotta's design success "indicates yet another hard-switched topology type that can effectively leverage high-voltage GaN,"says Philip Zuk, Transphorm's VP of worldwide technical marketing. "Marotta completed its design with minimal assistance from Transphorm's application support team."

Launch of the high-frequency PSU marks the aerospace & defense industry's first publicly recognized high-voltage GaN power supply.

Further EPC eGaN FETs now AEC-qualified for automotive power systems

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 — has announced AEC Q101 qualification of two additional eGaN devices, addressing a range of applications in the automotive industry and other harsh environments. The new products EPC2206 and EPC2212 are both discrete transistors in wafer-level chip-scale packaging (WLCS) with 80V_{DS} and 100V_{DS} ratings, respectively.

eGaN technology has been in mass production for over eight years, accumulating billions of hours of field experience in automotive applications, such as light detection and ranging (lidar) and radar for autonomous cars, 48V–12V DC–DC converters used in data-center computers, ultra-high-fidelity infotainment systems, and high-intensity headlamps for trucks. These new devices have completed rigorous automotive AEC Q101 qualification testing and will be followed with several more discrete transistors and integrated circuits designed for the harsh automotive environment.

The EPC2206 is an 80V, 2.2mΩ enhancement-mode FET with a pulsed current rating of 390A in a 6.1mm x 2.3mm chip-scale package. The EPC2212 is a 100V, 13.5mΩ component with a pulsed current rating of 75A in a 2.1mm x 1.6mm chip-scale package. These eGaN FETs are said to be many times smaller and achieve switching speeds 10–100 times faster than their silicon MOSFET counterparts.

The EPC2206 is suitable for vehicles using 48V bus power distribution to manage the power-hungry electronically driven functions and features appearing on the latest cars, such as electric start-stop, electric steering, electronic suspension and variable-speed air conditioning. Now, with the emergence of self-driving vehicles, additional demands from systems such as lidar, radar, camera and ultrasonic sensors are placed upon the power distribution system, accelerating the need for automobiles to move to a 48V bus system. For 48V bus systems, GaN devices like the EPC2206 increase efficiency, shrink size and weight, and reduce system cost.

The EPC2212 is suited to use for firing the lasers in lidar systems because the FET can be triggered to create high current with extremely short pulse widths. The short pulse width leads to higher resolution, and the higher pulse current allows the lidar system to discern objects at greater distances. These two characteristics, along with their tiny size and low cost, make eGaN FETs ideal for radar and ultrasonic sensors in addition to lidar in demanding automotive applications.

"These two automotive products are the next in what will be a constant stream of transistors and integrated circuits designed to enable autonomous driving and improve fuel economy and safety," says CEO & co-founder Alex Lidow. "Our eGaN technology is faster, smaller, more efficient, lower cost and more reliable than the aging silicon power MOSFET used in today's vehicles."

www.epc-co.com/epc/Products/eGaNFETsandICs/EPC2206.aspx

EPC displays GaN-enabled wirelessly powered systems for the home and high-resolution LiDAR for AVs at CES

At the 2019 Consumer Electronics Show (CES) in Las Vegas (8–11 January), EPC demonstrated the power of eGaN technology to enhance two game-changing consumer applications: wirelessly powered systems for the home and LiDAR systems for self-driving autonomous vehicles.

In the EPC Palazzo hospitality suite at The Venetian hotel, EPC had multiple wirelessly powered surfaces on display to demonstrate consumer applications 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. A wirelessly powered robotic digital assistant will also be on display.

Also shown in the suite were multiple eGaN FET-based LiDAR systems. LiDAR technology is emerging as the leading technology to act as the 'eyes' for self-driving cars, and increasingly finding new applications in warehouse automation, augmented reality, and drones.

www.ces.tech

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Akash granted FCC approval for satellite launch of GaN-on-diamond power amplifier

Akash Systems Inc of San Francisco, CA, USA — which was founded in 2016 by Felix Ejeckam and Ty Mitchell and is focused on developing and supplying small satellites (CubeSats) and the RF power amplifiers that power them — has been granted an Experimental Special Temporary Authority (STA) license from the US Federal Communications Commission (FCC) for a satellite launch featuring its proprietary gallium nitride (GaN)-on-diamond transmitter technology, which will be integrated into a Ka-band (17.2–20.2GHz) 3U radio transmitter and launched in a 12U CubeSat allowing for new levels of data transmission for customers to increase capacity and reduce end-user costs.

"This demo will showcase the use of our proprietary GaN-on-diamond RF amplifier technology," says co-founder, CEO & GaN-on-diamond inventor Felix Ejeckam. "Beyond the capability to handle the increasing demands of today's extreme data throughput, we are confident future adoption of the system will drive down end-user costs to levels never before seen."

The satellite launch will demonstrate the transmitter's capability to handle more than 5Gbps+ downlink speeds from a 10W 3U radio transmitter. Tentatively slated for early 2020, the launch will validate the data rates, reliability and space-qualification readiness of the GaN-on-diamond transmitter technology. The new technology enables a smaller, lighter and higher-performing satellite that will pave the way to lower launch costs, reduced cost-per-bit, more launch cycles, and increased communications access around the earth.

"Anyone buying our solid-state power amplifiers (SSPAs) to transmit data to or from space will be interested in the space worthiness and reliability of our SSPA products," says Jeanette Quinlan, director of space systems. "This launch helps us capture that worthiness and reliability data for them."

Akash says that it will continue to focus on scaling up and qualifying its GaN-on-diamond power amplifier product line, offering products with higher frequencies that will be announced in the months ahead.

www.AkashSystemsInc.com

GaN Systems exhibits GaN-based power systems

At the Consumer Electronics Show (CES) in Las Vegas (8–11 January), GaN Systems Inc of Ottawa, Ontario, Canada exhibited the latest GaN-powered developments from firms targeting automobiles, energy storage systems, wireless charging solutions, and consumer electronics.

The rollout of new electronics and data-intensive technologies increasingly demands significant amounts of power, notes the firm. Central to 2019 trends is the need for new ways of thinking about and addressing the power needs of the diverse technology surrounding us, it adds. As we evolve globally, power cannot be taken for granted and simply viewed as an endless resource.

Using GaN power semiconductors will usher in new energy-efficient systems and products, including lighter and longer-range electric cars, better navigation and sensing in autonomous vehicles, devices without power cords, and more affordable and improved energy storage systems, says GaN Systems.

As a building block for such systems, GaN is enabling the creation of new energy-efficient systems and products that are 4x smaller, 4x lighter and exhibit 4x less energy loss.

GaN Systems' power semiconductors are used in a wide range of applications. Demonstrations at CES by customers and partners Eggtronic, Osram and PowerSphyr included:

- a 4-channel, high-power LiDAR system;
- power supplies with 150% output power and no increase in size;
- multi-device wireless power charging;
- free-positioning capacitive wireless TV and laptops; and
- a portable energy storage and generation system.

"GaN technology is becoming the standard building block for product innovation by enabling new power system design approaches that meet size, power, efficiency and system cost requirements," says CEO Jim Witham.

"Power is a critical piece in any consumer and B2B electronic product design," notes Enrico Dente, chief technology officer & chief information officer of Eggtronic. "Using GaN power transistors as a basis for power systems opens the door for improving and creating new opportunities such as smaller power adapters to efficient high-power wireless charging," he adds.

"Osram enables LiDAR technology for autonomous vehicles by not only developing high-power, multi-channel SMT lasers that meet automotive quality standards but also working with eco-system partners like GaN Systems to address the technological barriers that arise," says Rajeev Thakur, senior marketing manager at Osram Opto Semiconductors.

"GaN is a critical partner in our ability to deliver our SkyCurrent III dual-mode wireless charging solution," says Neil Ganz, CEO & chairman of PowerSphyr. "GaN Systems is also a critical component across our entire suite of wireless charging solutions, allowing us to remove limitations of distance and wirelessly charge power hungry devices up to 500W."

www.gansystems.com

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The PCS100 AVC 40 designed for sag correction in large commercial and industrial applications. Available in ratings from 150 kVA to 3600 kVA, the PCS100 AVC-40 offers continuous protection from the most common utility voltage problems found in modern power networks. Failsafe worry free operation even in harsh electrical environments and a faster return on investment due to low operation costs will ensure your business is protected from power quality events. **abb.com/ups**

Compound Semiconductor Centre's vertical GaN project wins Welsh Government funding via SMARTCymru scheme

Project to develop manufacturing of voltage-scalable E-mode GaN trench FETs within UK

Through the SMARTCymru (SMART Wales) scheme via the European Regional Development Fund (ERDF), the Compound Semiconductor Centre Ltd (CSC) — a joint venture founded in 2015 between Cardiff University and epiwafer foundry and substrate maker IQE plc of Cardiff, Wales, UK — has been awarded Welsh Government funding to support a technical and commercial feasibility study for its 'VeGaN' project to develop a vertical gallium nitride device manufacturing capability within the UK.

According to a report from industry analyst Yole Développement in January, the GaN power market will grow at up to 55% per annum over the next five years, driven by the power supply segment, or 93% if adopted for wireless charging in consumer electronics, so there is great opportunity for innovative epitaxial products to unlock this growth potential.

The 2018 roadmap report from the UK Automotive Council and Advanced Propulsion Centre (APC) identifies vertical GaN as a more suitable technology for lower-voltage, lower-power automotive applications. These include on-board charging (OBC), DC–DC conversion and additional applications where the higher switching speed of gallium nitride is desirable.

The project will leverage epitaxial growth methods developed by CSC and the device manufacturing expertise of its Compound Semiconductor Cluster partners to develop a voltage-scalable process (200–1200V) where the electric field is supported vertically across a GaN drift layer.

Power transistors using silicon and silicon carbide (SiC) in vertical process architectures such as trench field-effect transistors (FETs) and insulated-gate bipolar transistors (IGBTs) offer improved performance and power density compared with lateral devices. The same benefits would also apply to GaN. The VeGaN project aims to develop enhancement-mode (normally-off) GaN trench FET devices built on thick, low-defect epitaxial GaN layers. This is a cross-cutting technology that addresses emerging automotive markets, ITAR-free defense and space applications as well as broader high-temperature, harsh-environment opportunities.

www.compoundsemiconductorcentre.com

CSC to participate in UK Industrial Strategy Challenge Fund program KAIROS to develop and commercialize quantum technologies

Teledyne e2v-led consortium to develop pre-production prototype of miniature atomic clock

CSC is to participate in an Industrial Strategy Challenge Fund project (delivered by Innovate UK, as part of UK Research and Innovation) to develop and commercialize a quantum miniature atomic clock that will power future 5G networks.

Led by Teledyne e2v with partners CSC, the National Physical Laboratory (NPL), Leonardo, Altran, ICS, HCD Research, Optocap, University of York and Cardiff University, the KAIROS consortium aims to develop a pre-production prototype of a miniature atomic clock for providing precise timing to critical infrastructure services such as reliable energy supply, safe transport links, mobile communications data networks and electronic financial transactions.

The precise measurement of time is fundamental to the effective functioning of these services, which currently rely on Global Navigation Satellite Systems (GNSS) for a timing signal. However, GNSS signals are easily disrupted either accidentally or maliciously and, in prolonged GNSS unavailability, these critical services stop functioning.

The reliance on GNSS for precision timing and the consequent vulnerability of essential services prompted InnovateUK to commission a report published by London Economics in June 2017. It estimated the impact on the UK economy of a five-day GNSS outage at £5.2bn. That message is becoming widely understood and is creating demand for timing solutions that are not GNSS dependent.

The next-generation miniature atomic clock arising from this project fulfills this need and is expected to find widespread application in precision timing for mobile base-stations network servers for financial services data centers, national power distribution networks and air traffic control systems.

Further applications arise in areas where an independent timing reference is needed on mobile platforms and especially in areas where no GNSS signal is available. It is reckoned that a high-performance compact clock would benefit a range of useful capabilities addressing civil and military applications, bringing both technical and economic gains for the UK.

www.ukri.org/innovation/industrial-strategy-challenge-fund/quantum-technologies

EC approves €1.75bn funding for IPCEI research and innovation project focused on microelectronics

Approval expected to open up extra €6bn in private investment

The European Commission has approved a plan, spearheaded by Wales, that identifies compound semiconductors as an important sector. Approval means that member states can provide up to €1.75bn of funding for research activities and first deployment. This is expected to open doors to an additional €6bn in private investment, and ultimately help to bring new technology innovations to market.

The project is the first integrated research, development and innovation program stemming from the Strategic Forum for Important Projects of Common European Interest (IPCEI) to be approved by the Commission, highlighting the importance of microelectronics and compound semiconductors for the European economy. The overall objective of IPCEI is to deliver an integrated and collaborative approach to research and innovation to develop innovative components and technologies for use in applications including 5G communications, connected autonomous vehicles, and other next-generation commercial and industrial devices.

The project is expected to benefit both the Welsh and the wider UK economy by establishing South East Wales as the leading center of compound semiconductor expertise.

The UK element of the pan-European joint microelectronics research and innovation project was driven by the Welsh Government and involves three Welsh companies: IQE, Newport Wafer Fab and SPTS Technologies (an Orbotech company), along with Manchester-based ICS Ltd.

"Wales' semiconductor cluster and its contribution to many of the technologies that are so prevalent in our modern everyday lives is a real source of pride, and I am delighted Wales has taken the lead on behalf of the UK in co-ordinating this project that will drive vital research and accelerate innovation work across Europe," states Wales' Economy Minister Ken Skates. "The EU's decision to approve the plan is huge news for the sector and of course for Wales' wider economy, paving the way for up to £6bn of private investment throughout Europe and enabling our own semiconductor companies to work alongside international giants in their field," he adds.

"Every connected device, every modern machine, all our digital services depend on microelectronic components that become smaller and faster with time. If we don't want to depend on others for such essential technology, for example for security or performance reasons, we have to be able to design and produce them ourselves," says Commissioner Mariya Gabriel, in charge of Digital Economy and Society. "The decision to approve the project is a result of enhanced cooperation and shared European vision."

The UK is already home to a number of businesses and research facilities in the compound semiconductor space, with a particular concentration in Wales. The South Wales semiconductor cluster — branded CSconnected — is a center for enabling technologies powered by compound semiconductors. It is further supported by the surrounding region, which has a range of facilities and businesses that support high-tech supply chains, from R&D through to innovative solutions.

www.clustercollaboration.eu/tags/ipcei

IQE reduces 2018 guidance for revenue from £160m to £156m and for adjusted EBITDA from £31m to £27.5m

Firm secures $35m credit facility

In a post-close trading update for 2018, epiwafer foundry and substrate maker IQE plc of Cardiff, Wales, UK says that it expects to deliver revenue of not less than £156m, up slightly on 2017's £154.5m but reduced from the revised guidance of about £160m given in mid-November. Adjusted EBITDA (earnings before interest, taxes, depreciation and amortization) should be at least £27.5m, down from £37m in 2017 and reduced from mid-November's guidance of about £31m.

"It is of course very disappointing that a substantial inventory correction in the first half of 2018 and the sudden disruption in a significant supply chain and short-term demand for VCSEL (vertical-cavity surface-emitting laser) wafers in November materially impacted our expected 2018 revenues and profitability," comments chief executive Dr Drew Nelson.

Net cash has fallen from £45.6m at the end of 2017 to £20.8m at the end of 2018. On 24 January, the firm agreed a new $35m multi-currency revolving credit facility (provided by HSBC Bank and secured over the assets of IQE) with a three-year term and an interest rate margin of 1.45–1.95% per annum over LIBOR on any drawn balances. The facility is undrawn.

As previously announced, IQE is closing its facility in New Jersey in order to consolidate its US-based gallium nitride (GaN) manufacturing capacity in its existing Massachusetts facility. The cost of the NJ closure (as an exceptional charge in the 2018 accounts) is estimated to be £3.35m (£1.2m in cash costs of severance and reactor decommissioning, and £2.15m in non-cash impairments). Following the closure, IQE expects to achieve annual operating cost savings of about £3m per annum.

IQE also expects to incur an additional exceptional charge of about £4.5m relating to an onerous lease accounting provision, for the period through to the end of the lease in second-quarter 2022, for the unused and unlet space in its Singapore facility. This exceptional provision has no cash impact.

"The position and prospects of IQE will not be defined by our 2018 financial results, which were delivered with none of the benefits of the investment programs which are now nearing completion," says Nelson.

"By the end of first-half 2019 we will have completed a significant two-year investment program across our global operations, commissioning our new mega-foundry in Newport [Wales] which is dedicated to photonics, installing additional wireless capacity in Taiwan, expanding our GaN capacity in Massachusetts and Infrared capacity in Milton Keynes [UK]. In addition, we have made a considerable investment in engaging with more than 25 VCSEL chip companies, underscoring IQE's exceptional leadership position in the emerging VCSEL supply chains based on our technical excellence, proven ability to ramp and dedicated commitment to install capacity. We will bring additional photonics capacity into production in Phase 1 (the first 10 reactors) in the new Newport foundry during first-half 2019, with 12 companies already actively qualifying the new facility," Nelson continues.

"The investment we have made in rationalization, capacity and new products and the opportunity that this has created will deliver strong performance across our wireless, photonics and infrared business units in the key sector areas of sensing, connectivity and energy, leading to margin expansion, increasing free cash flow and profitability in 2019 and beyond," believes Nelson.

IQE hence reiterates its 2019 and longer-term guidance. It will issue its full year-end results on 20 March.

www.iqep.com

IQE participating in Challenge Fund program to develop and commercialize quantum technologies

IQE plc is participating in an Innovate UK industry Challenge Fund quantum technology project to address the increased vulnerability to cyber-security threats brought about by quantum computing capabilities.

The Agile Quantum Safe Communications (AQuaSec) project will develop technologies for 'quantum-safe' communications that will combine efficient implementations of new quantum-resistant algorithms and techniques from quantum cryptography which are immune to all advances in computing including quantum computing.

The project will build prototypes that test their security and demonstrate their benefits to end users. Led by Toshiba Research Europe Ltd, other project partners are Bay Photonics Ltd, BP plc, BT Ltd, Dashboard Ltd, Heriot-Watt University, KETS Quantum Security Ltd, NPL Management Ltd, Queen's University (Belfast), Radianz Ltd, Royal Holloway University (London), Tethered Drone Systems Ltd, University of Cambridge, University of Glasgow and University of Sheffield.

www.iqep.com

CS Applications Catapult appoints chief technology officer

The Compound Semiconductor Applications (CSA) Catapult has appointed Martin McHugh as chief technology officer.

The CSA Catapult is a not-for-profit organization (headquartered in South Wales) focused on accelerating the adoption of compound semiconductors and on bringing applications to life. It works across the UK within a range of industry sectors from automotive to medical, and from digital communications to aerospace.

From January, McHugh will lead the strategic and technical direction of the CSA Catapult's four key technology areas of power electronics, RF & microwave, photonics and advanced packaging. As CTO, he will support the overall strategy of the organization, leading its technology teams.

McHugh's experience includes working in technical and commercial roles, with responsibilities covering the UK, Europe and North America. Most recently, he headed up business and technology development for of the advanced packaging business Microchip (previously Microsemi Corp) where, during his 20-year tenure, he played a key role in transforming the firm's focus from analog telecoms to wireless digital communications.

McHugh has also worked on over 30 Innovate UK- and EU-funded collaborations worth a total of £50m over a period of 15 years. He also sits on the Industrial Advisory Board of the School of Engineering at Cardiff University.

"I am excited to be joining the CSA Catapult at such a key point in its development. At just over a year old, it is the right time for it to fully develop its technical expertise and equipment to enable it to provide a center of excellence to further the adoption of compound semiconductors," says McHugh. "One of my first priorities will be to drive forward the development of our evaluation modules that will enable

companies to assess their new applications and bring them to market faster."

With analysts predicting that the global compound semiconductor market will rise from $74bn to over $300bn by 2030 (according to estimates by Allied Analytics, BCC Research, and CSA Catapult), the Catapult says it is essential that the UK plays a substantial part in that growth. The CSA Catapult is set to create about 100 new jobs internally and by 2023 it aims to have helped to create 1000 new high-tech jobs within the businesses it has supported around the whole of the UK.

"Martin's role is pivotal in ensuring that the Catapult's offer to businesses is informed by the highest standards and latest technology developments in compound semiconductors," says Catapult CEO Stephen Doran. "His experience in the sector and collaborative approach will ensure that the Catapult delivers on its promise to bring all sectors of the supply chain together to further the adoption of compound semiconductors into applications," he adds.

"The remit for the Catapult is to provide world-class engineering and consultative expertise coupled with state-of-the-art design and test facilities to advance the UK's compound semiconductor industry," notes Kevin Crofton, chairman of the board at CSA Catapult. "As CTO, Martin will ensure that the Catapult offers the right core capabilities in design, simulation and test protocols necessary to augment our growth in the compound semiconductor space," he adds. "Martin has a successful track record of working in collaborative environments — a skill that will benefit the Catapult and our industry partners."

www.csa.catapult.org.uk

Reedholm Systems launches wide-bandgap HTOL-HTRB reliability test system

Reedholm Systems of Georgetown, near Austin, TX, USA (which provides parametric and reliability test systems, including those for high-power wide-bandgap requirements) has launched the RS-100 test system to meet the unique needs and challenges of stress, test and measurement of wide-bandgap devices (WBG). The stress/measurement needs for these devices stretches the limits of conventional parametric measurement tools, says Reedholm. WBG materials challenges and applications are driving divergent needs from those of traditional silicon, so the firm tailors its measurement instrumentation and long-term reliability stress capabilities specifically for the gallium nitride (GaN), silicon carbide (SiC), GaN-on-Si and other WBG devices and materials.

The RS-100 WBG reliability test system delivers two fundamental capabilities:

- First is the capacity to deliver statistically significant sample sizes needed for reliability testing. The base system offers 15 DUT (device under test) per experiment stress condition and up to six simultaneous experiments for a capacity of 90 DUT, with expansions to 270 DUT and 18 simultaneous experiments.
- When paired with a fully integrated Reedholm parametric analyzer, it gives the ability to test both to pass AND to learn. Each experiment is independent of the others, and it is straightforward to switch-in parametric instrumentation for periodic user-defined measurements tests and cycles.

Reedholm's RS-100 WBG reliability test system.

A key principal in the design and execution of the systems is the intent for customization to meet stress and test requirements. The challenges of the devices and technologies being analyzed means that there is no single solution for all applications. Therefore the tools are architected to be readily customized for stress and measurement requirements defined by the customer. This is what allows for a single tailored system that can be used for both high-temperature reverse bias (HTRB) and high-temperature operation lifetime (HTOL) reliability requirements, whereby specific stress requirements for each application are factored into the hardware and software.

The RS-100 is available now, with lead times of 4–5 months customized to WBG requirements.

www.reedholmsystems.com

Linton developing software update to enhance automated melt gap management

Linton Crystal Technologies (LCT) of Rochester, NY, USA has performed the first live test of software that will enhance automated melt gap management in the crystal growing process. Being released in early 2019, this is the first of several planned enhancements to its Kayex Intelligent Crystal Control System (KICCS). KICCS provides hardware and software process control for the Czochralski (CZ) process crystal growers that Linton manufactures.

The ability to consistently maintain the melt gap is critical to growing a quality crystal. Although a laser-based system for measuring the melt gap was standard in the past, the technology is outdated, says LCT.

"The laser system lost its effectiveness when heat shields were introduced to growers," says senior software engineer Jeromy Tompkins. "Because all our grower models incorporate heat shield technology, a replacement for the laser technology has been needed," he adds. "Our new software uses multiple techniques and more robust data, gathered from a high-resolution camera and other machine parameters, to automate the management of the melt gap during a single crystal-growing cycle as well as across subsequent cycles."

LCT recently conducted the first live test of this software, where it was used during multiple crystal-growth cycles, each placing different demands on the melt gap control system. "It was very successful at managing the gap," says Tompkins. "The test demonstrated the software's functionality."

The software was able to control the measured melt gap to a precision of 0.5mm when holding it steady. Furthermore, equivalence between the techniques was maintained within 1mm throughout the range of crucible travel during the growth cycles.

LCT is continuing to fine-tune development, and is releasing the software during first-quarter 2019.

www.lintoncrystal.com/news/linton-crystal-technologies-

Disco launches high-precision fully automatic 8" wafer grinder for difficult-to-grind materials

At SEMICON Japan 2018 at Tokyo Big Sight (12–14 December), Tokyo-based equipment maker DISCO Corp — which makes manufacturing equipment including chemical mechanical polishing (CMP) systems and laser-based ingot slicing equipment and processes for silicon carbide (SiC) — exhibited the new DFG8640 (to be available in January), a fully automatic grinder compatible with 8"-diameter wafers suitable for a wide variety of materials including silicon (Si), lithium tantalate ($LiTaO_3$, or LT), lithium niobate ($LiNbO_3$, or LN) and silicon carbide.

Wafer-level thinning and grinding targeting low-height semiconductor memory and logic memory are essential for high functionality and high space efficiency of final products based on electronic components, notes DISCO. The gap between target thickness and actual thickness, as well as wafer thickness variation after grinding, may affect the characteristics of products such as power devices and some sensors, so a grinder capable of high-precision processing is needed, it adds.

In particular, demand for surface acoustic wave (SAW) devices (used in mobile communication devices including smartphones) continues to expand. Lithium tantalate and lithium niobate (the materials for those devices) are difficult to grind, and high-precision processing is required.

DISCO says that the DFG8640 fulfills these needs, and offers both a small footprint and further productivity improvement.

The DFG8640 achieves high-precision grinding through (1) optimizing the processing point layout (reducing the thickness variation both for individual wafers and between wafers); and (2) developing a new spindle (with high rigidity, low vibration and less rotation speed fluctuation) and a new small chuck table axis (with high rigidity, low vibration, low heat expansion and less rotation speed fluctuation) and improving the driving resolution of the axis (which moves the spindle up and down).

DISCO's new DFG8640 wafer grinding system.

Also, by reducing the cleaning mechanism operation time and redesigning the transferring arm, the wafer throughput of the DFG8640 is more than 1.2 times that of the DFG8540. In addition, system footprint has been reduced by about 13%.

The wafer throughput of the DFG8640 is more than 1.2 times that of the DFG8540. Footprint has been reduced by about 13%

Finally, the new equipment layout has taken accessibility into consideration, improving wheel replacement operability. In addition, a new graphical user interface (GUI) enables intuitive operation such as swiping.

www.disco.co.jp

ALLOS' customers confirm dynamic on-resistance of carbon-doping-free GaN-on-silicon

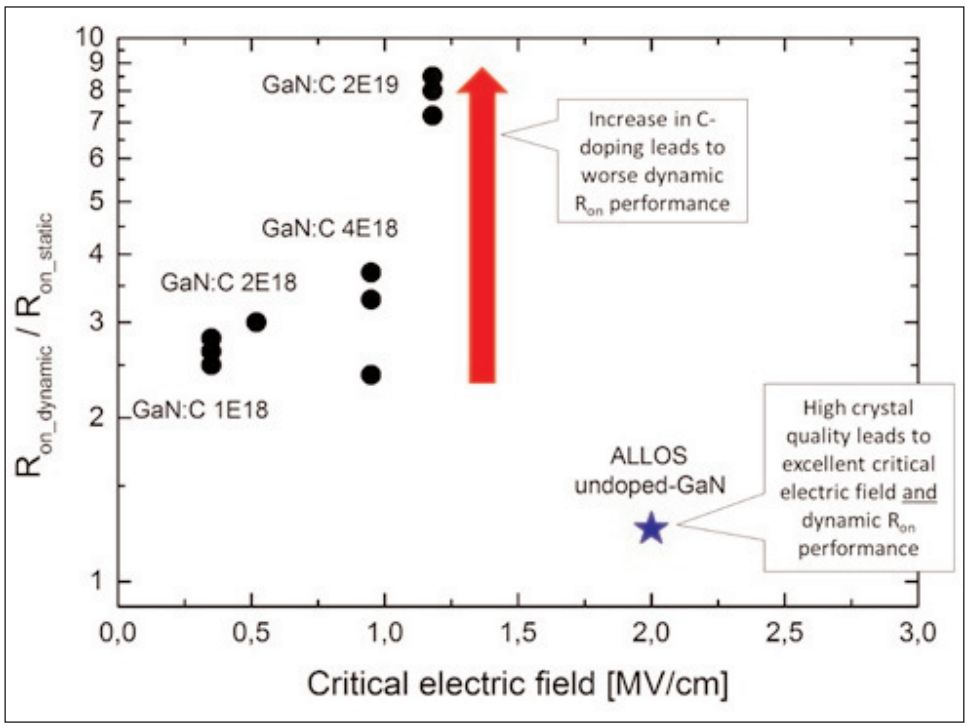
Good dynamic R_{on} achieved with good crystal quality and extremely low leakage

In an invited talk at the 2018 European Materials Research Society (E-MRS) Fall Meeting at Warsaw University of Technology, Poland (17–19 September), Dr Atsushi Nishikawa, the co-founder & chief technology officer of IP licensing & technology engineering firm ALLOS Semiconductors GmbH of Dresden, Germany, showed data from customers that confirms not only outstanding wafer-level data but also what is claimed to be excellent dynamic on-resistance (R_{on}) and high-temperature performance for its gallium nitride on silicon (GaN-on-Si) epitaxial material. Most importantly, carbon-doping (known for causing bad dynamic on-resistance) is uniquely avoided.

Being able to prove this is important for the high-power electronics (HPE) industry because it confirms the widespread belief that the absence of C-doping can help to reduce switching losses at high frequencies (dynamic R_{on}) by reducing electron-trapping effects, says ALLOS. Nevertheless, C-doping is usually unavoidable to achieve the required breakdown voltage but it causes lower crystal quality and, with that, more trapping and reliability issues.

ALLOS has therefore overcome this challenge of delivering other crucial performance parameters at the same time by showing — on the same epiwafer — not only good dynamic R_{on} but also the good crystal quality and extremely low leakage of ALLOS' material. "In epitaxy you often need to work with trade-offs between different criteria and thus it is really a big success to achieve all required specification parameters at the same time," says Nishikawa.

"It is ALLOS' value proposition to deliver a technology platform addressing all required spec parameters at the same time to enable our customers to make such epiwafers themselves after a technology transfer from us in only 12 weeks," notes co-founder & chief marketing officer Alexander Loesing.



Relationship of critical electric field and dynamic on-resistance (black data points are from Würfl et al., IEDM 13-144 (2013)).

In addition to excellent dynamic R_{on} and leakage performance, the 150mm and 200mm epiwafers have controlled and flat bow and — through availability in SEMI-standard thicknesses — the epiwafers are suitable for processing in high-volume CMOS lines.

In epitaxy you often need to work with trade-offs between different criteria. It is really a big success to achieve all required specification parameters at the same time

Based on its business model, ALLOS continues making its epiwafer technology available to high-power electronic companies that would like to enter the GaN-on-Si sector and avoid the cost, risk and uncertainty of starting their own epi development from scratch. "At the same time, also customers who already have an ongoing GaN-on-Si activity can benefit. In some cases they are not yet completely happy with their performance or want to increase the voltage range of their products to 1200V," says Loesing. He further cites that, in particular, wafer breakage is a key problem still faced by many. "And of course customers can test the technology easily by buying epiwafer samples from us," he adds, focusing on the low risk that ALLOS offers by guaranteeing the performance delivered in a technology transfer.

www.allos-semiconductors.com
www.european-mrs.com/meetings/

Riber reduces 2018 revenue guidance from €35m to €31m after deferral of two system deliveries to Q1/19

Operating income still positive

Following the deferral of deliveries for two systems to first-quarter 2019, Riber S.A. of Bezons, France — which manufactures molecular beam epitaxy (MBE) systems as well as evaporation sources and effusion cells — is reducing its revenue forecast for full-year 2018 from €35m to €31m (albeit still up on €30.6m for 2017).

Income from ordinary operations expected for 2018 will be affected by this deferral of revenue and the corresponding margin, as well as by an unexpected increase in costs, particularly for the firm's subsidiaries, including the creation of the Chinese subsidiary.

However, income from ordinary operations will continue to show a profit.

Riber says that this information does not change its strategy, backed by an order book of about €30m at the end of 2018.

www.riber.com

Riber receives European order for production MBE system

Riber has received an order from a European customer for a MBE 49 production system (for delivery in 2019).

The system will be used to increase the customer's opto-electronic component production capabilities.

Autonomous University of Madrid orders Riber research MBE system

Riber S.A. of Bezons, France — which manufactures molecular beam epitaxy (MBE) systems as well as evaporation sources and effusion cells — has received an order from the Autonomous University of Madrid for a Model Compact 21T research MBE system.

To be delivered in 2019, the system is intended to further strengthen the university's research capabilities for developing new electronic devices based on III-V materials on silicon substrate.

Riber says that the order reflects the commercial success of its Compact 21 range, which it claims is the world's best-selling research MBE system.

www.riber.com

IN BRIEF

AXT cuts Q4/2018 revenue guidance from $26.5–27.5m to $22–22.4m

For its fourth-quarter 2018 results (to be announced on 20 February) AXT Inc of Fremont, CA, USA — which makes gallium arsenide (GaAs), indium phosphide (InP) and germanium (Ge) substrates and raw materials in Beijing, China — has reduced its revenue expectation from previous guidance of $26.5–27.5m (provided on 31 October) to $22–22.4m (down from $26.3m in Q4/2017).

"AXT saw a significant slowdown during the last two months of the quarter," says CEO Morris Young. "The business climate grew increasingly cautious over the quarter and customers generally did not follow through with the level of orders they had previously forecasted. As a result, revenue for all our product lines came in below our expectations."

"We remain optimistic about the many drivers for our business growth, including data-center connectivity, PON, LED lighting, 3D sensing, 5G wireless, among others," Young adds. "Our new manufacturing facilities, technological proficiency and efficient cost-structure position us well to benefit when the demand environment strengthens."

AXT also says one of its partially owned supply chain companies was required to temporarily shut down during Q4/2018 to install manufacturing improvements mandated by a regional environmental agency. Under the equity method of accounting, the firm will incur a charge of $1.1m, which represents AXT's 25% ownership of the joint venture. The supply chain company resumed production and operations later in Q4.

www.axt.com

Aixtron's AIX G5+ C MOCVD system chosen for PlayNitride's micro-LED production

Joint collaboration agreement to accelerate technical and commercial breakthroughs of micro-LEDs

Deposition equipment maker Aixtron SE of Herzogenrath, near Aachen, Germany says that Taiwan-based PlayNitride Inc is to receive an AIX G5+ C metal-organic chemical vapor deposition (MOCVD) system for manufacturing of gallium nitride-based micro-LEDs.

PlayNitride was established in June 2014 to research and develop nitride-related materials and applications, and is now focused on GaN-based micro-LEDs, having recently demonstrated prototypes of its micro-LED display. In April 2018 Taiwan's Ministry of Science and Technology approved PlayNitride's application to set up a NT$500m (US$17m) facility in Hsinchu Science Park to produce micro-LEDs, display modules and panels (with the technology to be branded PixeLED displays). By signing a joint collaboration agreement, Aixtron and PlayNitride are joining forces in aiming to technically and commercially enable the step forward to unlock the potential markets.

Aixtron says that micro-LED technology is on the roadmap of all tier-one display manufacturers as a challenger to the existing display technology for next-generation consumer products. Displays made of micro-LEDs consist of micron-sized LED arrays forming individual sub-pixel elements. Compared with existing LCD and OLED technologies, micro-LED displays offer the lowest power consumption while exhibiting superior pixel density, contrast ratio and brightness, opening new horizons for consumer mobile products as well as premium TV displays.

In April 2018 Taiwan's Ministry of Science and Technology approved PlayNitride's application to set up a NT$500m facility in Hsinchu to produce micro-LEDs, display modules and panels

Aixtron says that its AIX G5+ C production tool offers market-leading wavelength uniformity to meet the tightened micro-LED market specifications in a batch reactor high-throughput environment. The system also allows for the low defect and particle levels due to an effective in-situ cleaning technology and a cassette-to-cassette handler (essential for high yields).

"Our AIX G5+ C platform perfectly backs PlayNitride's product strategy since it allows for outstanding performance in a high-volume manufacturing environment," believes Aixtron's president Dr Bernd Schulte.

www.playnitride.com
www.aixtron.com

San'an expands ROY LED production with Aixtron AIX 2800G4-TM MOCVD systems

Fine-pitch displays continue to raise demand for red LEDs

Deposition equipment maker Aixtron SE of Herzogenrath, near Aachen, Germany is to supply multiple AIX 2800G4-TM (IC2) cluster systems to Xiamen-based San'an Optoelectronics Co Ltd (China's largest producer of full-color ultra-high-brightness LED epiwafers and chips), supporting its long-term plan to address the rising market demand for fine-pitch displays, which requires a capacity increase in arsenide-phosphide-based red, orange and yellow LEDs (ROY LEDs). All AIX 2800G4-TM (IC2) tools will feature a 15x4"-wafer configuration and are scheduled for shipment between fourth-quarter 2018 and second-quarter 2019.

"Due to our long-standing cooperation, we are familiar with Aixtron's equipment technology," notes San'an Optoelectronics' general manager Simon Lin. "With respect to our long-term expansion plans for our LED business, we have a great deal of confidence in the outstanding quality of the latest AIX 2800G4-TM model, which has proven to be the best system currently available on the market," he comments. "Characterized by wafer homogeneity and efficiency in material consumption in combination with maximum flexibility and versatility in production, the AIX 2800G4-TM enables us to meet the demanding requirements of our customers," he adds.

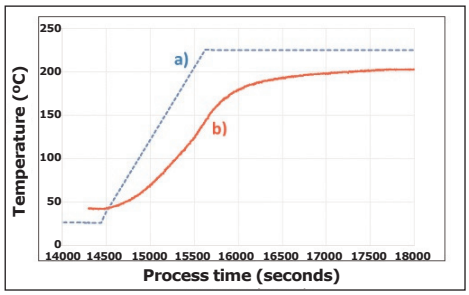
"San'an has once again selected our highly reliable AIX 2800G4-TM system for its capacity expansion," says Aixtron's president Dr Bernd Schulte. "Looking forward to the continuation of our long-standing collaboration with one of the global leading LED manufacturers, we will enable San'an to quickly commission the supplied systems for high-volume production."

www.sanan-e.com/en
www.aixtron.com

LayTec unveils EpiTT FaceT to boost yield of GaAs-based edge-emitting high-power infrared lasers

Precise control of laser facet temperature during facet passivation and coating of stacked GaAs-based laser bars in an MBE chamber is a challenge, notes LayTec. Until recently, the process temperature of laser facets was estimated only indirectly from the temperature of the heater, although it is a known fact that this method cannot provide the real temperature of the facet surface (see Figure). Consequently, deviations in this temperature significantly affect process quality (facet cleaning and facet passivation) and production yield.

As a solution to this problem, LayTec has developed the EpiTT FaceT, a new in-situ spectroscopic metrology tool that can measure the temperature of GaAs laser facets during cleaning and passivation (with an accuracy of ±1K from room temperature up to 400°C) in conjunction with real-time sensing of the zinc selenide (ZnSe) passivation layer thickness (0–50nm).



Temperature during plasma-assisted cleaning of laser facets in a stack of laser bars mounted at a platen in a MBE process chamber: (a) temperature of heater (as formerly used for process temperature control) and (b) true temperature of the laser facets as measured by EpiTT FaceT.

Two EpiTT FaceT systems, capable of monitoring the facet temperature in multi-stack configurations of laser bars at rotating platens in MBE, have already been installed at a customer site this year and a third is scheduled for shipment to a "leading industry customer" in Q1/2019.

www.laytec.de/VCSEL

LayTec ships new EpiTT Band Edge tool for MBE of VCSELs

LayTec has shipped its new metrology tool EpiTT Band Edge to the Walter Schottky Institute (WSI) in Munich. The tool is specially designed for molecular beam epitaxy (MBE) of indium phosphide (InP)- and gallium arsenide (GaAs)-based device structures.

Researchers in professor M.C. Amman's group at WSI are growing InP-based vertical-cavity edge-emitting lasers (VCSELs) in several MBE chambers in close collaboration with industrial partners so, unusually for a university institute, accurate chamber-to-chamber matching and extreme run-to-run reproducibility is a must.

Since September, after shipment and installation of the EpiTT Band Edge, all MBE systems at WSI are now equipped with EpiTTs for highly accurate growth-rate control during VCSEL epitaxy (utilizing automated pyrometric Fabry–Perot analysis) and Band Edge wafer temperature sensing. Accordingly, all MBE systems are always running at exactly the same absolute substrate temperature scale.

Band Edge temperature sensing is a new add-on option to the EpiTT and is designed for seamless integration into the EpiTT fiber-optic head technology. Using the substrate heater radiation as a light source, the optimum temperature range is 350–600°C for InP wafers, covering InP VCSEL growth conditions for ultrafast data communication and gas sensing applications.

ULVAC and OIPT collaborating to bring atomic-scale processing to Japanese power and RF markets

UK-based plasma etch and deposition processing system maker Oxford Instruments Plasma Technology (OIPT) and ULVAC Inc of Chigasaki, Kanagawa, Japan have announced a collaboration to bring leading-edge deposition and etch technology solutions to gallium nitride (GaN)- and silicon carbide (SiC)-based wide-bandgap production customers in Japan.

"Oxford Instruments Plasma Technology is excited to be collaborating with ULVAC in order to bring its proven process solutions to the Japanese power and RF markets," says OIPT's managing director Mike Gansser-Potts. "This relationship, which will begin with ULVAC as our channel partner in Japan, will allow local production customers access to Oxford Instruments' suite of

atomic-scale processing solutions," he adds.

"Our new collaborator, Oxford Instruments Plasma Technology, has critical process technology and know-how which complements our own capabilities," notes Tetsuya Shimada, general manager of ULVAC's Advanced Electronics Equipment Division. "Combined with our customer support infrastructure, this will allow us to provide a complete solution to our Japanese customers."

OIPT says that atomic layer deposition (ALD) and atomic layer etch (ALE) are critical process steps for GaN- and SiC-based devices to enable functionality and reliable device manufacturing. The firm reckons that, with its critical know-how and expertise gained over the last ten years in wide-bandgap applications, it is well placed to serve technology-leading Japanese production customers in these markets.

www.ulvac.co.jp
www.oxford-instruments.com/plasma

OIPT supplies plasma etch & dep systems to ITRI for micro-LED R&D

UK-based plasma etch and deposition processing system maker Oxford Instruments Plasma Technology (OIPT) says that Industrial Technology Research Institute (ITRI) of Hsin Chu, Taiwan has selected multiple PlasmaPro 100 systems (including both etch and deposition systems) for its micro-LED R&D program.

"ITRI has a close collaboration with Oxford Instruments due to their cutting-edge technology, but this is not the only reason we chose them to supply our latest system," comments Dr Fang, deputy division director, Electronics and Optoelectronics System Research Laboratories. "Their application solutions, unrivalled local process support and their capability to nurture laboratory developments into production standards with our industrial partners were key influences in our purchase decision."

The PlasmaPro 100 ICP process solutions are designed to support leading-edge device applications such as lasers, RF, power and advanced LEDs.

"ITRI has chosen to partner with OIPT in the next exciting phase of development of LEDs with this development program for micro-LEDs similar to those used to demonstrate Samsung's Wall TV," says OIPT's strategic marketing manager Robert Gunn. "ITRI is the latest to join many research institutes and start-up companies in adopting OIPT process solutions for this rapidly growing market."

https://plasma.oxinst.com/products/icp-etching/plasmapro-100-icp

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Rigaku Europe and Fraunhofer IISB partner on x-ray topography for substrate and epilayer characterization

Fraunhofer IISB to act as demo center for XRTmicron system in Europe

Analytical and industrial instrumentation technology Rigaku Europe SE of Neu-Isenburg and Fraunhofer IISB (Institute for Integrated Systems and Device Technology) in Erlangen, Germany have formed a strategic partnership focusing on the characterization of semiconductor materials by x-ray topography. Rigaku has hence installed its latest-generation x-ray topography tool, the XRTmicron imaging system, at Fraunhofer IISB. "We are proud to join forces with the highly experienced team at IISB for semiconductor substrate and epilayer characterization," comments Rigaku Europe's president Dr Michael Hippler.

Enabling the investigation of crystallographic defects with high speed and high resolution on the full wafer scale, the XRTmicron system is suitable for bare wafers, wafers with epilayer structures, partially processed wafers, and bonded wafers. The amount and different types of dislocations, slip lines, dislocation networks, (small-angle) grain boundaries, inclusions, precipitates, pits, scratches, stress level etc can be imaged and quantified on the samples.

Two different x-ray sources — a 40kV/30mA copper source and a 50kV/24 mA molybdenum source in combination with the application of a large-angle goniometer — accommodate a wide range of diffraction conditions. The XRTmicron system can therefore be applied to different kinds of materials including semiconductors (e.g. Si, Ge, diamond, SiC, GaN, AlN, GaAs, InP, CdTe, CdZnTe), oxides (e.g. sapphire, ruby, garnets, vanadates, niobates, quartz) and halides (e.g. fluorides, bromides).

The XRTmicron system can be operated in transmission as well as in reflection mode in order to detect defects in the volume of the sample or to quantify defects close to the surface. Furthermore, it is equipped with a standard and a high-resolution XTOP CCD-camera, yielding spatial resolution of 5.4µm and 2.4µm per pixel, respectively, for a single image size of 18mm x 13.5mm. Full wafer mappings and detailed defect imaging of regions of interest are possible under different diffraction conditions for sample sizes of up to 300mm in diameter. A measurement of a full 150mm SiC wafer under the high-resolution mode, for example, takes only 1 hour.

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Additionally, the XRTmicron system is equipped with a special slit-arrangement to perform cross-section topography measurements in high resolution. This gives detailed depth information through the whole thickness of the sample. For example, it is possible to investigate whether the glide plane formation in partly processed wafers starts on the front or back side of the wafer. Furthermore, the defect formation due to epilayer growth on top of a wafer can be quantified by this feature.

"The XRTmicron is the only tool available in Europe so far which fulfills the requirements of highest resolution for complete wafer mappings in shortest possible time scale to analyze single-crystalline materials," says Dr Christian Reimann, group manager Silicon at Fraunhofer IISB. "It is a revolution for crystallographic defect investigations compared to classical synchrotron-based topography measurements."

Fraunhofer IISB will act as a demonstration center for the XRTmicron system in Europe. "We already received numerous requests from the European semiconductor industry aiming to improve and better understand their product quality and yields," says Rigaku Europe's XRT product manager Uwe Preckwinkel. It is therefore planned to standardize the operation procedures for the different costumers due to their specific needs within the strategic collaboration between Rigaku and Fraunhofer IISB.

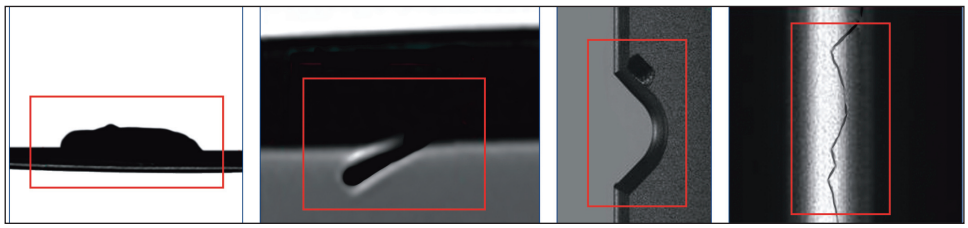
The XRTmicron system operated at Fraunhofer IISB is part of the 'Research Fab Microelectronics Germany (FMD)', which is funded by Germany's Federal Ministry of Education and Research (BMBF). Within this Research Fab Microelectronics Germany, the Fraunhofer Group for Microelectronics and two Leibniz institutes (FBH and IHP) are bundling their expertise in order to reach and expand on a new quality in research, development and (pilot) manufacturing of semiconductor-based microsystems and nanosystems.

www.iisb.fraunhofer.de
www.rigaku.com/en/products/xrm/xrtmicron

ISRA VISION launches wafer edge inspection system

ISRA VISION of Darmstadt, Germany has launched an inspection system that allows wafer edges to be monitored during the entire manufacturing process — both increasing yield and lowering costs, as the system prevents the processing of defective material. Also, because the sensor can be optionally integrated in existing process tools, it can be used in every production step.

Currently, the quality of wafers is often only checked at the start of production. However, the many processing steps put the material under great stress, particularly at the edge, and often cause quality issues. An efficient solution to this problem is high-speed surface inspection of the front, back and wafer edge. This is necessary as chips are becoming ever thinner for use in modern IT and consumer electronics products, making them more vulnerable. Devices such as smartphones are gaining ever more functions, yet the amount of space for the hardware is limited. To meet the simultaneously increasing quality requirements, continuous inspection is required as early as the wafer manufacturing process.



EdgeScan technology for edge inspection, from wafer processing to back end.

Customized deployment for critical process steps

Compatible with all common process tools and available as a retrofit solution for existing machines, the EdgeScan can be used as an OEM product throughout the entire process and for every type of wafer. Moreover, its connection and results output comply with the SEMI standard. The sensor unit can be deployed in an individual manner, depending on where in the process the components are under the most stress. During preadjustment, a line scan camera checks the edge of the wafer simultaneously from three sides. Its multi-view technology, in which a prism deflects the image by 45° and creates three views, making it possible to view the component from 360° even at cycle times of just a few seconds.

ISRA says this kind of inspection is a result of the new awareness that problems often begin at the edge, where defects can cause cracks and breaks. EdgeScan now allows the edge to be monitored throughout the entire production process. ISRA's solution complements conventional automated optical inspection (AOI) systems that use a matrix camera (which have a limited field of vision and only inspect the surface), enabling a complete inspection.

www.isravision.com

FBH orders three further ClassOne wet processing tools

ClassOne Technology of Kalispell, MT, USA (which manufactures electroplating and wet-chemical process systems for ≤200mm wafers) has sold three more tools to the Ferdinand-Braun-Institut, Leibniz-Institut für Höchstfrequenztechnik (FBH) in Berlin, Germany (which produces III-V compound semiconductors, including prototyping microwave and optoelectronic devices for communications, energy, health, mobility etc).

In October, FBH ordered ClassOne's 8-chamber Solstice S8 electroplating system. Now FBH is ordering three additional wet processing tools, including a refurbished Semitool Spray Solvent Tool (SST), a Semitool Spray Acid Tool (SAT) and a Trident Spin Rinse Dryer (SRD).

"We've put our trust in ClassOne for our entire wet processing line," states Olaf Krüger, head of FBH's Process Technology Department. "ClassOne provides state-of-the-art automated processing tools for 100mm and smaller wafers that allow for high process reproducibility during R&D of novel compound semiconductor devices and ensure compatibility to industrial standards. Plus, they've put together a support operation right here in Europe to provide us with everything we need," he comments.

"We see these follow-on orders from FBH as a real vote of confidence," says ClassOne's CEO Byron Exarcos. "Europe is an important market for us. Which is why we've invested heavily to build a world-class customer support structure here, including a strong, experienced process engineering team and a seasoned field service and support group that's able to cover everything our customers might need, up to and including an extensive inventory of spare parts. So, it's extremely gratifying to see our European customers really recognizing and making use of our local capabilities," he adds.

"The investment is also paying off in terms of the market share gains we're seeing," says Roland Seitz, director of ClassOne's European Operations. "European customers continue to tell me ClassOne has moved into leading-supplier position for plating and wet processing equipment for 200mm wafers and below. It's been the result of high-performance equipment combined with strong customer support and affordable price," he adds. "Going forward, the European sales of Solstice plating systems and associated tools are growing at a very rapid pace."

www.fbh-berlin.com
www.classone.com/products

UVFAB launches HELIOS-1200 300mm-wafer UV-ozone cleaning and surface treatment system

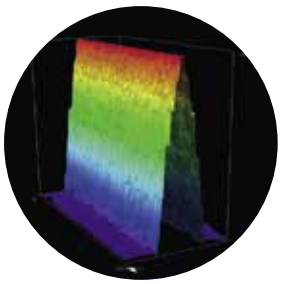
UVFAB Systems Inc of Walnut Creek, CA, USA, which manufactures ultraviolet (UV) and ozone surface treatment equipment, has launched the Model HELIOS-1200 as the second product in its HELIOS series of UV-ozone cleaning systems.

Designed to be very compact, lightweight and competitively priced, the HELIOS-1200 includes a high-intensity UV grid lamp for increased uniformity as well as a digital process timer that allows more accurate control over the process time. The drawer loading sample stage can accommodate up to 12"x12" substrates, one 300mm wafer, one 200mm wafer or four 100mm wafers using prefabricated substrate holders. For maintenance purposes, the system also comes with a built-in hour-counter to keep track of UV lamp life-time.

UV ozone cleaning is a photo-sensitized oxidation process in which the contaminant molecules of photo-resists, resins, human skin oil, cleaning solvent residues, silicone oils and flux are excited and/or dissociated by the absorption of short-wavelength UV radiation. Atomic oxygen is simultaneously generated when molecular oxygen and ozone are dissociated by 185nm and 254nm UV wavelengths, respectively. The 254nm UV radiation is absorbed by most hydrocarbons and also by ozone. The products of this excitation of contaminant molecules react with atomic oxygen to form simpler, volatile molecules, which desorbs from the surface. Therefore, when both UV wavelengths are present, atomic oxygen is continuously generated and ozone is continually formed and destroyed.

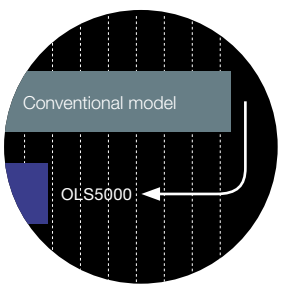
Using a UV-ozone cleaner, near atomically clean surfaces can be achieved in minutes without any damage to devices. This fast method of obtaining ultra-clean surfaces free of organic contaminants on most substrates — such as quartz, silicon, gold, nickel, aluminum, gallium arsenide (GaAs), alumina, glass slides, etc — can easily be achieved by utilizing a well-designed UV-ozone cleaning system, says UVFAB Systems.

www.uvfab.com



4K Scan Technology

Smart Scan



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EVG unveils BONDSCALE fusion wafer bonder for 'More Moore' scaling and front-end processing

EV Group of St Florian, Austria — a supplier of wafer bonding and lithography equipment for semiconductor, micro-electro-mechanical systems (MEMS) and nanotechnology applications — has introduced the all-new BONDSCALE automated production fusion bonding system, designed for a wide range of fusion/molecular wafer bonding applications, including engineered substrate manufacturing and 3D integration approaches that use layer-transfer processing, such as monolithic 3D (M3D).

The firm says that BONDSCALE brings wafer bonding to front-end semiconductor processing and helps to address long-term challenges for 'More Moore' logic device scaling identified in the International Roadmap for Devices and Systems (IRDS). Incorporating enhanced edge-alignment technology, BONDSCALE is claimed to provide a significant boost in wafer bond productivity and lower cost of ownership (CoO) compared with existing fusion bonding platforms.

Already being shipped to customers, BONDSCALE is being sold alongside EVG's GEMINI FB XT automated fusion bonding system, with each platform targeting different applications. While BONDSCALE will primarily focus on engineered substrate bonding and layer-transfer processing, the GEMINI FB XT will support applications requiring higher alignment accuracies, such as memory stacking, 3D systems on chip (SoC), backside illuminated CMOS image sensor stacking, and die partitioning.

BONDSCALE automated production fusion bonding system.

Direct wafer bonding key to driving semiconductor performance scaling

According to the IRDS Roadmap, parasitic scaling will become a dominant driver of logic device performance in the coming years, requiring new transistor architectures and materials. The roadmap also notes that new 3D integration approaches such as M3D will be necessary to support the long-term transition from 2D to 3D VLSI, including backside power distribution, N&P stacking, logic-on-memory, clustered functional stacks and beyond-CMOS adoption. Layer-transfer processes and engineered substrates are enabling technologies for logic scaling by helping to deliver significant improvements in device performance, functionality and power consumption. Direct wafer bonding with plasma activation is a proven solution for enabling heterogeneous integration of different materials, high-quality engineered substrates as well as thin-silicon-layer-transfer applications.

"Nearly 25 years ago, EVG introduced the industry's first silicon-on-insulator (SOI) wafer bonder to support the production of high-frequency and radiation-hard devices for niche applications," says executive technology director Paul Lindner. "Since then, we have continuously enhanced the performance and CoO of our direct bonding platforms to help our customers bring the benefits of engineered substrates to a wider range of applications," he adds. "Our new BONDSCALE solution takes this to the next level, boosting productivity to fulfill the growing need for engineered substrates and layer-transfer processing to enable continued performance, power and area scaling of next-generation logic and memory devices in the 'More Moore' era."

BONDSCALE is a high-volume production system for fusion/direct wafer bonding needed for front-end-of-line applications. Featuring EVG's LowTemp plasma activation technology, it combines all essential steps for fusion bonding — including cleaning, plasma activation, alignment, pre-bonding and IR inspection — in a single platform suitable for a wide range of fusion/molecular wafer bonding applications. Capable of processing both 200 and 300mm wafers, the system ensures a void-free, high-throughput and high-yield production process, says EVG.

BONDSCALE incorporates next-generation fusion/direct bonding modules, a new wafer handling system and optical edge alignment to provide higher throughput and productivity to support the ramp up of engineered substrate wafer production and M3D integration.

www.evgroup.com/en/products/bonding/integrated_bonding/bondscale

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BluGlass demonstrates functioning tunnel junctions, enabling cascaded LEDs

RPCVD used to create as-grown and activated p-GaN

BluGlass Ltd of Silverwater, Australia — which was spun off from the III-nitride department of Macquarie University in 2005 — says that, using its low-temperature remote-plasma chemical vapour deposition (RPCVD) manufacturing technique for its unique as-grown and activated p-GaN (AAG) technology, it has demonstrated functioning tunnel junctions to enable the fabrication of cascaded light-emitting diodes.

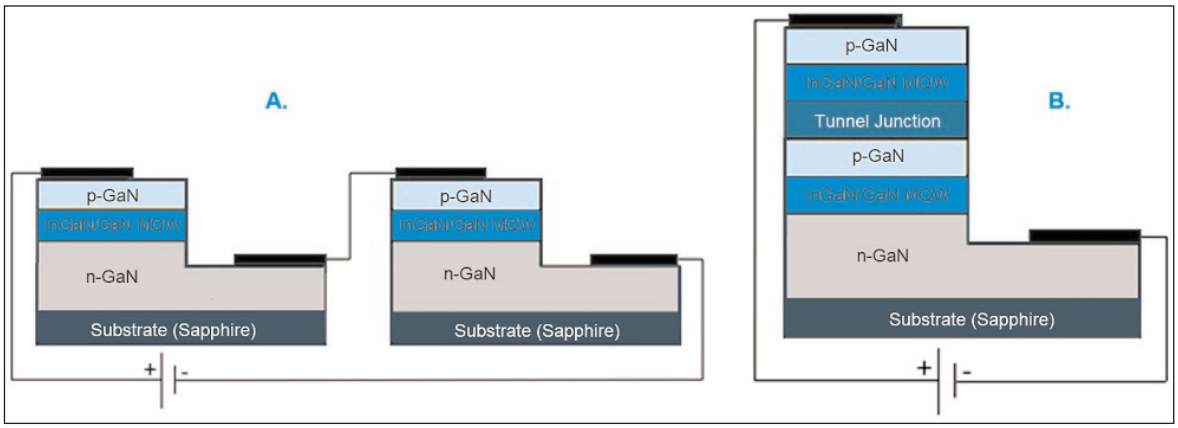


Figure 1: The different structure and physical arrangement between two laterally spaced and interconnected LEDs (A) versus a single vertical cascaded LED using a tunnel junction (B).

Cascaded LEDs can mitigate the efficiency droop seen in gallium nitride (GaN)-based LEDs, where light output efficiency drops as the driving current increases. For many applications (particularly lighting) LEDs are typically driven at high current to generate the maximum brightness - significantly higher than the point where the efficiency begins to drop, so devices are operating outside their peak efficiency range.

A simple solution is to replace a single LED with multiple LED chips, in which case the desired amount of light can be generated by driving each LED at a lower current that is matched to the individual chip's peak efficiency. However, this increases cost and the required real-estate.

A better solution is to use a single chip to grow LEDs in a continuous vertical stack using a tunnel junction to interconnect the multiple LEDs on a single chip. Such a vertically arranged multi-junction, cascaded LED benefits from reduced efficiency droop as emitted light power is increased by stacking voltage, rather than current, without increasing the required device real-estate (hence increasing the emitted light power density). For example, cascaded LEDs could be used in automotive headlights, where there are strict limitations on the lateral size of the devices, to achieve optimal performance. The vertical solution also increases the number of devices than can be made from a single wafer, reducing manufacturing costs.

Tunnel junctions are used in other semiconductor applications such as solar cells, but there are currently no GaN-based commercial products on the market that utilize them and hence, to date, cascaded LEDs have not been commercially available. This is because achieving working tunnel junctions in the GaN-based material system has proven very difficult to achieve using incumbent metal-organic chemical vapour deposition (MOCVD) manufacturing technology since the nitrogen source is ammonia (toxic and expensive), which requires high growth temperatures and results in significant quantities of hydrogen being incorporated in the epitaxial layers.

In contrast, BluGlass' RPCVD technology includes low-temperature deposition coupled with nitrogen plasma as the nitrogen source rather than ammonia (yielding little incorporated hydrogen), enabling the fabrication of practical GaN-based tunnel junction devices.

A key feature is the ability to achieve the required buried activated p-type gallium nitride (p-GaN) — critical for the function of the tunnel junction — without the need for the complicated and time-consuming ex-situ lateral activation methods employed by MOCVD. This unique 'as-grown and activated p-GaN' (AAG) technology for enabling a buried p-GaN layer to remain activated in various devices is a fundamental advantage of using RPCVD, says the firm.

BluGlass has been developing its tunnel-junction capabilities for several years, initially for triple-junction InGaN solar cells. The firm is now optimizing the RPCVD tunnel junctions for realizing cascaded LEDs with the performance required to address the stringent requirements of both brightness and small form factor for existing and emerging LED markets.

BluGlass claims that RPCVD-grown tunnel junctions could be commercially compelling for applications including not just high-performance LEDs (for automotive lighting) and high-efficiency multi-junction solar cells but also ultra-violet LEDs (for water purification) and high-power laser diodes (for industrial machining applications).

Chief operations & technology officer Dr Ian Mann is presenting a talk on RPCVD-grown tunnel junctions for cascaded LEDs at the Photonics West 2019 conference in San Francisco, CA, USA (2–7 February).

Facilities update

BluGlass's facility upgrade is approaching completion. The firm has taken delivery of an Aixtron AIX 2800 G4 commercial-scale MOCVD platform, to be retrofitted with RPCVD. A second system is arriving in January.

The upgrade will provide BluGlass with extra capacity for industry collaborations to demonstrate the key benefits of RPCVD platform technology for tunnel-junction-enabled cascaded LEDs, micro-LEDs and power electronics, among other applications.

Lumileds collaboration update

Further to its recent disclosure at its annual general meeting (AGM) on 19 November, BluGlass says that it remains in negotiations with LED maker Lumileds of San Jose, CA, USA to extend their existing collaboration agreement and potentially enter into a commercialization agreement. BluGlass is no longer bound by exclusivity arrangements with Lumileds in relation to the RPCVD field of use being developed by the parties.

www.bluglass.com.au

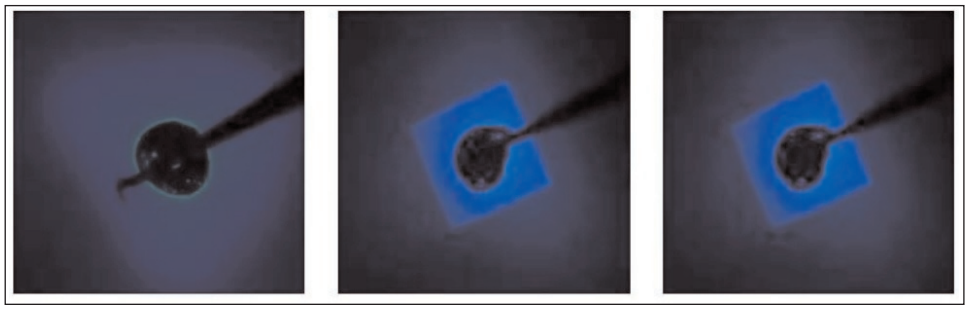


Figure 2: Bare wafer comparison. Optical micrographs of light distribution of non-processed LED wafers (characterized on wafer using BLG electroluminescence quick test, using indium dot contacts): (a) commercial MOCVD full blue LED without indium tin oxide (ITO), (b) commercial MOCVD full blue LED with indium tin oxide (ITO), and (c) RPCVD tunnel-junction overgrowth on commercial MOCVD partial blue LED without ITO.

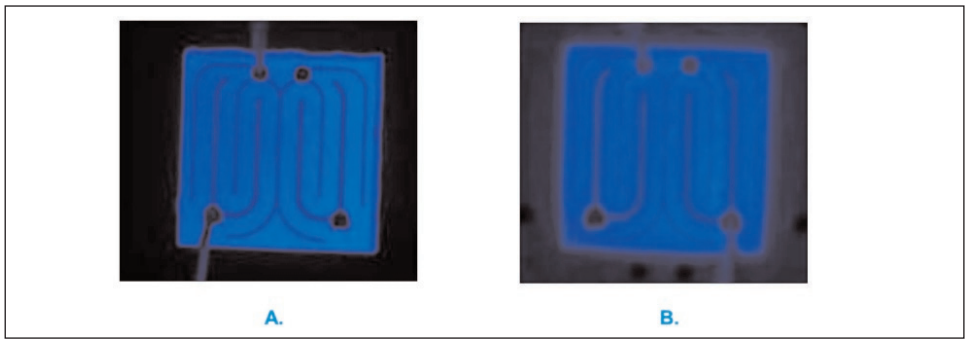


Figure 3: Fully processed wafer comparison. Optical micrographs of fully processed LED light distribution of (a) commercial MOCVD full blue LED with ITO and (b) RPCVD tunnel-junction overgrown on a commercial MOCVD partial blue LED without ITO.

BluGlass collaborating with Aixtron to scale RPCVD to mass production

Aixtron to explore potential of RPCVD for low-temperature deposition of nitride layers

BluGlass is collaborating with deposition equipment maker Aixtron SE of Herzogenrath, near Aachen, Germany to evaluate BluGlass' unique remote-plasma chemical vapor deposition (RPCVD) technology.

BluGlass has selected Aixtron's AIX 2800G4-HT system for scaling RPCVD to mass-production capacities. The semiconductor film uniformity of Aixtron's Planetary Reactor is attributed to its proprietary dual axis of wafer rotation during deposition. BluGlass' RPCVD technology enables low-temperature deposition of III–V nitride materials, which can potentially improve the performance of devices. The first integration of RPCVD onto the AIX 2800G4-HT will be conducted at BluGlass' Silverwater facility in Sydney.

"We are very pleased to have the support from Aixtron for this major scaling project of our technology," comments BluGlass' managing director Giles Bourne. "This is an important step towards demonstrating the commercial viability of RPCVD in large-scale manufacturing," he adds.

"At Aixtron, we are constantly striving to bring novel technologies onto our platforms in order to provide our customers with advanced capabilities," says Aixtron Group's innovation officer Dr Ken Teo. "We want to explore the potential of RPCVD technology for low-temperature deposition of nitride layers, which may open up new possibilities for opto/electronic devices; we look forward to working with BluGlass in integrating RPCVD and evaluating the technology".

www.aixtron.com

www.bluglass.com.au

Crystal IS' Klaran UVC LED water disinfection demonstrates legionella performance

Crystal IS Inc of Green Island, NY, USA, which makes proprietary ultraviolet light-emitting diodes (UVC LEDs), says independent testing by the University of Colorado Boulder shows that the Klaran AKR (an on-demand UVC LED-based water disinfection reactor designed by parent company Asahi Kasei Corp for consumer and commercial water purification) can provide a 99.998% reduction in legionella pneumophila at a flow rate of 2l/min.

Legionella is a new risk parameter for drinking water proposed under the revision of the European Union (EU) Drinking Water Directive. A vote in October on proposed water guidelines in Europe ruled in favor of more stringent quality standards for consumer drinking water, expanding monitoring and limits on certain pollutants, including legionella.

The revision notes that legionella causes the highest health burden of all waterborne pathogens in the EU and proposes to apply random monitoring at the tap to man-made water systems and subsequent remediation actions to improve water safety. Crystal IS says that the performance of the Klaran AKR (available now for design integration sampling) can provide a risk management solution for meeting the <1000 CFUs/liter assessment value.

"UVC LED technology enables water product manufacturers to differentiate their solution with point-of-dispense disinfection, supporting new and existing customers in mitigating the risk of legionella," says product manager James Peterson. "The Klaran Reactor series uses our UVC LEDs to provide maintenance-free disinfection that lasts longer and is more affordable than UV lamps or filtration cartridges. Along with its compact size, this makes the Klaran AKR an ideal method of worry-free legionella management."

Enforcing regular monitoring at the point of dispense would not only improve water hygiene from large and small utility systems, but also promote new risk identification mechanisms inside of building distribution systems and water holding appliances, says Crystal IS. In addition to potentially improving public health, raising consumer confidence and reducing cases of legionnaires' disease, this regulation would place increased accountability for water hygiene on building managers and water product designers in the EU, adds the firm.

While individual member states, system operators and building managers will need to interpret their risk reduction plans based on the final legislation, water purification and appliance manufacturers are acting on these future needs now to provide new solutions for this existing health concern and upcoming regulatory situation, says Crystal IS.

Lasting for years after installation rather than months, Klaran reactors provide effective water hygiene without maintenance schedules or burdens to owners and service providers, it is claimed. As both facilities and product designers face the task of identifying low-impact strategies to improve legionella management, Klaran UVC LED-based reactors can offer long-term and unobtrusive installation into water systems, while providing reliable performance claims backed by third-party validation, says the firm.

www.cisuvc.com/products/klaran

UVphotonics/FBH unveiling UVC LEDs at Photonics West

Together with Berlin's Ferdinand-Braun-Institut, Leibniz-Institut für Höchstfrequenztechnik (FBH) in the German Pavilion (booth 4545-50) at Photonics West 2019 in San Francisco, CA, USA (5–7 February), UVphotonics NT GmbH — a spin-off from FBH and Technische Universität Berlin (TU Berlin) that makes LEDs emitting in the UVB (280–320nm) and the UVC (230–280nm) wavelength regions — is showcasing its latest UV LED developments.

Due to their customizable wavelengths, low operation voltages, ability to be rapidly switched and dimmed along with their robustness, the compact devices are suited for a great variety of applications, says the firm. These include water purification, disinfection, medical diagnostics, phototherapy, plant growth lighting, UV curing, and sensing.

Featured products at Photonics West comprise 310nm UVB LEDs with up to 30mW output power at 350mA and 265nm UVC LEDs with >25mW at 350mA. Also, fully packaged UVC LEDs with a single emission peak at 233nm and an output power of 0.3mW at 100mA are being showcased.

In addition to these standard wavelengths, UVphotonics offers customizable LEDs tailoring the emission wavelength, emission area and spatial emission characteristics to meet specific requirements of the respective application.

"We stay at the forefront of UV LED technology due to our close collaboration with the FBH and the TU Berlin," says UVphotonics' CEO Dr Neysha Lobo Ploch. "FBH conducts R&D on (Ga,Al,In)N UV LEDs and performs all stages of device fabrication in-house, from design to epitaxial growth to chip processing, packaging and up to complete turnkey modules which are ready to use in applications," she adds.

Also at Photonics West, FBH is presenting its diode laser developments in the neighboring booth.

www.uvphotonics.de
www.fbh-berlin.com

OSA develops 4W UVC LED water disinfection module within the 'Advanced UV for Life' consortium

Collaboration with CiS, Fraunhofer IOSB and Xylem as part of 'Advanced UV for Life' consortium

OSA Opto Light GmbH of Berlin, Germany (which makes custom-designed LED chips, SMD LEDs and LED modules emitting at wavelengths ranging from UV 350–420nm to VIS 420–660nm and IR 660–1080nm) has developed a high-performance UVC LED radiation source, emitting 4W optical power at an emission wavelength 275–280nm.

The firm collaborated with CiS Forschungsinstitut für Mikrosensorik GmbH, the Advanced System Technology branch of the Fraunhofer-Institute für Optronik, Systemtechnik und Bildauswertung (IOSB, Fraunhofer Institute of , System Technologies and Image Exploitation) and Xylem Services GmbH, as part of the water disinfection activities within the 'Advanced UV for Life' consortium of more than 47 German industrial and academic partners, which work together on the development and application of UV LEDs within the framework of the 'Zwanzig20' initiative funded by the German Federal Ministry of Education and Research (BMBF).

Several key features were implemented in the new LED module:

- a unique aluminium parabolic array of reflectors emitting light at an angle of about 15°;
- new anti-reflection coating on the front window with a transmission value of about 97% for wavelengths of 270–280nm;
- reliable and efficient chip-mounting process;
- a new heat sink with a 40% lower thermal resistance compared with the old design, allowing low operation temperatures at power losses up to 400W;
- integrated electronic control unit with computer software enabling good monitoring of the operation state of the system, overheating protection, and a safety shutdown; and
- computer-independent operation mode with the last saved settings.

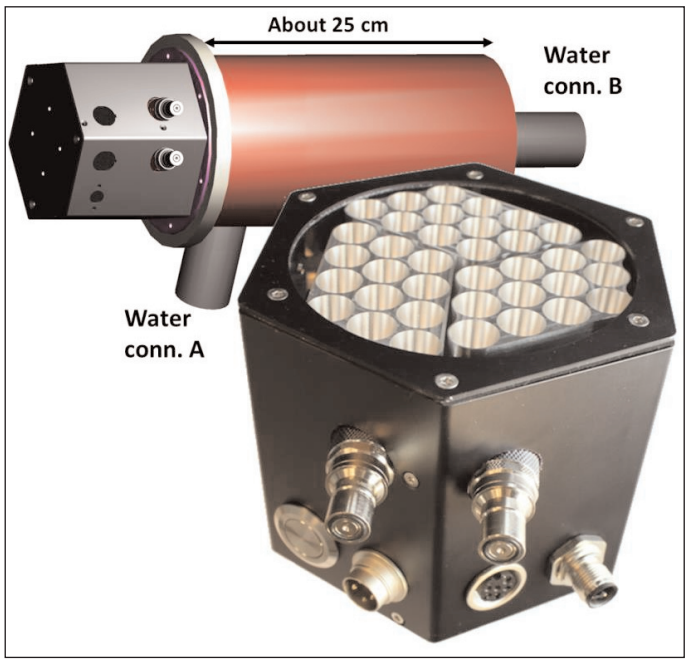


Figure 1. UVC LED module for water disinfection.

Figure 2 shows the distribution of irradiance at distances of 1, 10 and 30cm from the front window. The parabolic reflector arrays yields a maximum optical power density at a distance of 25cm of about 30mW/cm^2 (50% of the initial maximum optical power density). For comparison, the blue curve shows the Lambertian radiation of an LED module without a lens or parabolic reflectors.

www.advanced-uv.de
www.osa-opto.com

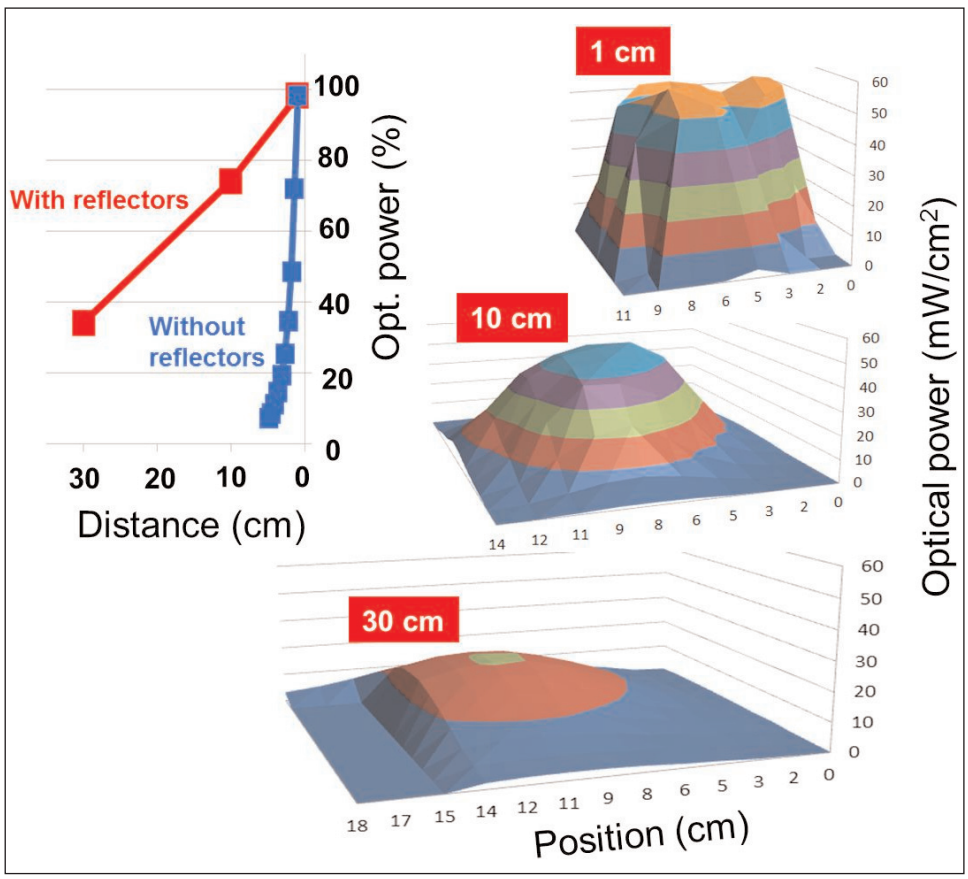


Figure 2. Irradiance distribution of 4W LED module.

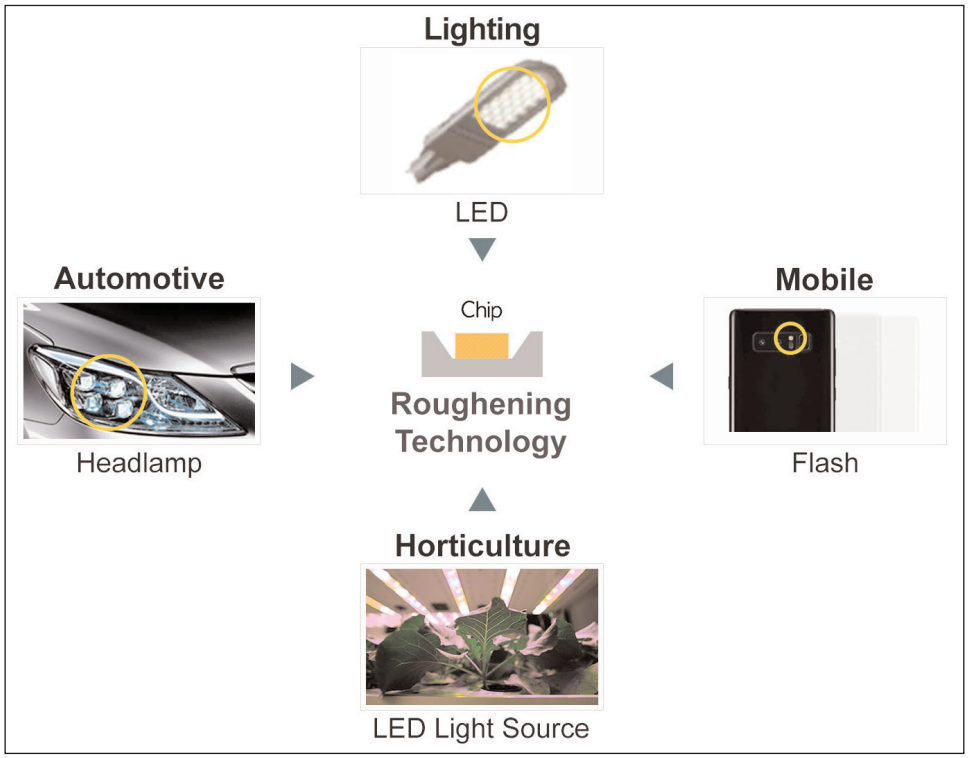
Seoul Semiconductor wins all five patent litigations against Everlight

South Korean LED maker Seoul Semiconductor Co Ltd has won a patent invalidity litigation that was filed against Everlight Electronics in the Korean Patent Court.

Everlight's patent was purchased from a US company in 2017. Previously, Seoul also filed patent invalidation litigation against this patent's Europe (UK) counterpart in the UK Patent Court. Following the UK challenge, Everlight voluntarily acknowledged that its patent is invalid, and the UK Patent Court ordered Everlight to pay about $1m in litigation costs to Seoul.

Despite the UK Court's declaration of invalidation, the Korean Patent Trial Board dismissed Seoul's invalidation challenge against Everlight's patent. However, the Korean Patent Court has now reversed this first-instance decision and declared the challenged claims of Everlight's patent to be invalid (consistent with the outcomes of the UK patent litigation). As a result, Seoul says that it has won all five patent litigations filed against Everlight.

In particular, a few weeks ago the German court rendered a judgment in favor of Seoul's patent infringement claims, including ordering a permanent injunction against sales of the accused Everlight products. The court also ordered a recall of all accused Everlight products sold after 13 July 2012 from the distributor's commercial customers.



The Korean Patent Court has now reversed this first-instance decision and declared the challenged claims of Everlight's patent to be invalid

"To ensure that the efforts and value of technology innovators are respected, we have visited numerous companies around the world to explain our technologies while concurrently monitoring suspected infringing products," says vice president Sam Ryu.

www.SeoulSemicon.com

NRC Electronics signs franchise distribution agreement with Seoul Semiconductor

NRC Electronics Inc of Boca Raton, FL, USA (an ISO-certified distributor of electronic products and provider of engineering support and logistics services) announced the signing of a synergistic franchise distribution agreement with South Korean LED maker Seoul Semiconductor Co Ltd.

"The newly forged alliance between NRC Electronics and Seoul Semiconductor provides the market with a focused partnership, concentrated on bettering the design and supply chain efforts for the lighting community," says Seoul Semi's marketing manager Andrew Smith. "Seoul's extensive LED portfolio complements NRC's vast lighting-oriented catalog, allowing NRC to better address general, architectural and specialty lighting segments," he adds.

"With today's ever evolving market, Seoul's engineering and technology advantages — coupled with NRC's lighting ecosystem line card and flexibility, in regards to price and supply chain variables — make this a great fit," comments Jared Davidson, Seoul Semi's general manager & senior director of channel and marketing.

"The new agreement allows NRC to provide highly flexible and responsive logistics, goods, marketing and design-oriented services that increase Seoul's current reach and technological visibility," says NRC's CEO Dennis Eisen. "Our goal is to provide, promote and support Seoul's cutting edge technology to the entire global LED lighting Industry."

www.nrcelectronics.com
www.SeoulSemicon.com

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Samsung unveils modular micro-LED display technology

During its annual First Look CES (Consumer Electronics Show) event at the Aria Resort & Casino in Las Vegas, South Korea's Samsung Electronics Co Ltd has introduced its latest innovations in modular micro-LED display technology. The new designs include a 75" display, a 219" version of The Wall as well as various other sizes, shapes and configurations for a next-generation modular micro-LED display.

"Our micro-LED technology is at the forefront of the next screen revolution with intelligent, customizable displays," says Jonghee Han, president of Visual Display Business at Samsung.

Featuring self-emissive technology and modular capabilities, Samsung's micro-LED displays deliver what is claimed to be unparalleled picture quality, versatility and design. The TV displays consist of individual modules of self-emissive micro-LEDs, featuring millions of inorganic red, green and blue micro-LED chips that emit their own light.

At last year's CES, Samsung introduced micro-LEDs by unveiling the 146" display The Wall. Following further technical advances in the ultra-fine-pitch semiconductor packaging process that narrow the gap between the micro-LED chips, Samsung has created a 4K micro-LED display in a smaller, more home-friendly 75" form factor.

Due to its modular nature, micro-LED technology offers flexibility in screen size that allows users to customize it to fit any room or space. By adding micro-LED modules, users can expand their display to any size they desire. The modular functionality can allow users in the future to create displays even at irregular 9x3, 1x7 or 5x1 screen sizes that suit their spatial, aesthetic and functional needs.

Samsung says that its micro-LED technology also optimizes the content regardless of the size and shape of the screen. Even when adding more modules, the micro-LED displays can scale to increase the resolution — all while keeping the pixel density constant. Additionally, micro-LEDs can support everything from the standard 16:9 content, to 21:9 widescreen films, to unconventional aspect ratios like 32:9 or even 1:1 — without any compromise to picture quality.

Finally, because micro-LED displays are bezel-free, there are no borders between modules — even when you add more. The result is a seamless infinity-pool effect that allows the display to blend into a living environment, says Samsung.

www.samsung.com

Nichia begins to enforce PSS-related LED patents

Japan-based LED maker Nichia Corp has filed a patent infringement lawsuit with the Tokyo District Court against Corlant Inc (a distributor of automotive aftermarket parts under the brandname of Valenti), seeking an injunction and compensation for damages.

The accused product distributed by Corlant is an automotive LED position lamp T10S-W0909-1, which is equipped with LEDs that Nichia believes infringe its patents JP5800452 and JP6320582 relating to patterned sapphire substrate (PSS) technology (a core technology for LED chips). Nichia currently owns over 100 PSS- related patents in more than 15 countries.

Nichia says that it seeks to protect its patents and other intellectual property rights and takes actions against alleged infringers in any country where appropriate and necessary.

www.nichia.com

SemiLEDs' quarterly revenue falls by half

For its fiscal first-quarter 2019 (to end-November 2018), LED chip and component maker SemiLEDs Corp of Hsinchu, Taiwan has reported revenue of $972,000, roughly halving from $1.95m last quarter and $2m a year ago.

Gross margin has worsened further, from +3% a year ago and −11% last quarter to −23%. Likewise, operating margin has worsened from −43% a year ago and −62% last quarter to −105%, despite operating expenses being cut from $1m last quarter to $0.8m.

However, although up on $0.4m a year ago, GAAP net loss has been cut from $1.13m ($0.32 per diluted share) last quarter to $983,000 ($0.27 per diluted share).

Due to the excess capacity charges experienced for the last few years, the firm disposed of certain idle equipment, reducing the net loss

Due to the excess capacity charges experienced for the last few years, considering the risk of technological obsolescence and based on the sales forecast, the firm disposed of certain idle equipment, reducing the net loss.

Cash and cash equivalents hence fell during fiscal 2018 from $3.4m to $2.6m.

For fiscal second-quarter 2019 (to end-February), SemiLEDs expects revenue to rebound to $1.5m.

www.semileds.com

Nanoco and Plessey partner to shrink full-colour micro-LED pixels by 87%

Cadmium-free quantum dots to be integrated into regions of blue LED wafers to add red and green light

Plessey Semiconductors Ltd of Plymouth, UK and Nanoco Technologies Ltd of Manchester, UK have partnered to shrink the pixel size of monolithic micro-LED displays using Nanoco's cadmium-free quantum dot (CFQD) nanoparticle technology.

Using its existing proprietary monolithic gallium nitride on silicon (GaN-on-Si) process, Plessey will integrate the CFQD quantum dots into selected regions of blue LED wafers to add red and green light. This shrinks the smallest practical pixel size by 87% from 30µm currently to just 4µm, a reduction. The process should enable the production of smaller, higher-resolution micro-LED displays in applications such as AR/VR devices, watches and mobile devices, while enhancing both colour rendition and energy efficiency.

For pixels of 30µm or greater, colour conversion is currently performed by adding phosphors to the blue die. However, since the smallest phosphor particle is around 30µm, the efficiency of colour conversion deteriorates as the pixel size shrinks. Nanoco's CFQD technology overcomes this limitation while facilitating efficient, compact device packaging.

"Quantum dots offer the best solution for today's emerging display requirements," says Mike Lee, president of corporate & business development at Plessey. "The nano-sized emitters with narrowband emission make them a suitable solution for Plessey's micro-LED display roadmap, which will see pixels being driven down to 4µm in size by 2019," he adds.

"The combination of Plessey's blue micro-LEDs with Nanoco's red and green cadmium-free quantum dots gives display customers the performance they require to rapidly commercialize products," says Dr Brian Gally, Nanoco's head of product.

Compared with other display technologies, micro-LEDs are brighter, smaller, lighter, more energy-efficient and have a longer operating life, it is claimed. Where they replace organic light-emitting diodes (OLEDs) — for example in augmented reality/virtual reality (AR/VR) goggles or head-up displays — Plessey says that its micro-LEDs offer ten times the resolution, 100 times the contrast ratio and up to 1000 times the luminance while consuming half the power, doubling battery life in portable devices. The firm also claims that they feature perfect blacks, realistic color and immunity to burn-in or decay over time.

Plessey showcased its micro-LED technology at the Consumer Electronics Show in Las Vegas (8–11 January). The firm was recently named as a 'CES 2019 Innovation Awards Honoree'.

www.nanocogroup.com
www.plesseysemiconductors.com/

Plessey demos first AR/VR glasses powered by micro-LEDs

At CES 2019 in Las Vegas, Vuzix was the first firm to present Plessey's micro-LEDs in action in AR and VR glasses.

Plessey micro-LEDs offer 10 times the resolution, 100 times the contrast ratio, and up to 1000 times the luminance of traditional OLEDs. This is achieved using just half the power consumption, doubling battery life in portable headsets. These benefits have been recognized by the Consumer Technology Association (CTA), owner and producer of CES, which has named Plessey a CES 2019 Innovation Awards Honoree in the Embedded Technologies category.

Other demonstrations on the Plessey booth included a 0.7" 1080p micro-LED comprising separate red, green and blue panels, and an addressable blue 0.7 inch micro-LED display running 1080p video.

"Compared with all other display technologies, micro-LEDs are brighter, smaller, lighter, more energy-efficient, and have a longer operating life," says Mike Lee, president of corporate & business development. "Plessey is helping its customers to be first to bring the technology to market in 2019."

Plessey micro-LEDs are developed using a uniquely scalable and economical, repeatable GaN-on-silicon monolithic process that guarantees uniformly high quality and exceptional performance. This process eliminates the problems associated with the pick-an-place micro-LED display manufacturing techniques being pursued by other companies.

Micro-LEDs are also about to have an impact on the design of pico- and micro-projectors. Micro-LED illuminators enable the form factor to be cut by 40% and optical efficiency boosted by 50%. The projects not only become smaller and lighter but they need less battery power and deliver higher quality images in every respect: brightness, resolution and contrast ratio. DMD (including DLP) and LCOS technologies are about to go the way of the cathode ray tube.

www.plesseysemiconductors.com/products/microleds

China's Hongli Zhuihui and European distributor Selectronic collaborating with Epistar

Hongli to buy $75m of Epistar LED chips to produce automotive lighting products

Packaged LED manufacturer Hongli Zhihui Group Co Ltd (HongliTronic) of Guangzhou, China and its European distribution partner Selectronic Ltd of Witney, UK (which designs and provides optoelectronic products, focused on displays) have formed a collaboration with Taiwan-based LED epitaxial wafer and chip maker Epistar Corp to boost product development and hence strengthen their position in the automotive LED sector.

"Partnering with the Taiwanese company Epistar forms a strategic alliance aimed at harnessing resources from both sides to develop automotive lighting products," says Selectronic's managing director Kevin Dry.

Hongli's automotive interior and exterior LED lighting applications already provide products including head lamps, daytime running lights (DRLs), fog lamps, turn signals, brake lamps, work lamps, dashboard backlights, and reading lamps.

The strategic collaboration agreement runs through to October 2021, during which Hongli will buy patented automotive LED chips from Epistar worth RMB500m (US$75.37m) in order to produce packages exclusive to automotive lighting. As well as developing automotive lighting products, the collaboration also aims to cut verification time.

"This coalition will also protect Hongli products from potential patent infringements and provides Epistar chips of substantial quality, enabling us to bring down prices and speed up expansion of the two companies into this sector," concludes Dry.

www.selectronic.co.uk
http://en.honglitronic.com
www.epistar.com.tw

Sanan's mini-LED and micro-LED chips on display at CES

Xiamen-based San'an Optoelectronics Co Ltd (China's largest producer of full-color ultra-high-brightness LED epiwafers and chips) says that at the 2019 Consumer Electronics Show (CES) in Las Vegas, Nevada (8–11 January) several panel makers for TVs, digital displays, smartphones, smart watches, augmented/virtual reality (AR/VR) goggles, and gaming notebooks have unveiled new products using its latest mini-LED and micro-LED chips.

Since the technology debuted at CES in 2017, the firm has entered large-scale production of RGB mini-LEDs, and has complemented its portfolio with capacity investments for micro-LED, including 27 applied patents and key partnerships.

Given the maturity of mini-LED technology, display panel makers are widely implementing across a broad range of consumer applications, including for cinema screens, and soon also for automotive. With their compact unit size of 100–200μm, mini-LEDs allow for high-density backlight designs with local dimming capabilities. They help to create ultra-thin, ultra-compact designs with features for notch and curved form factors, for example. As a display technology, mini-LEDs are said to provide superior energy efficiency with ultra-high brightness, high dynamic range (HDR), with higher color saturation, contrast and resolution compared with the traditional liquid-crystal display (LCD) approach.

Micro-LEDs are poised to be the next-generation technology, offering significant advances in image quality through individually driven self-emitting pixels and even more miniaturized form factors, says the firm.

"We see tremendous growth in the mini-LED market, and are delighted to see its increased adoption from among the product launches here at CES", says CEO Simon Lin. "The industry is certainly taking full advantage of the key benefits that mini-LEDs bring, namely enhanced power savings, and higher performance," he adds. "Given the success of our core business in LED chips combined with our manufacturing infrastructure and cost competitiveness through economies of scale, we have been able to overcome the high barrier of entry for the mini-LED market. While we are fully committed to drive innovation further for this technology and are well positioned to support the market's high volume demand, we are also ramping up R&D and scaling up capacity for micro-LED production to meet the demands of the next wave of innovative LED displays".

Sanan Optoelectronics offers a family of RGB display and backlight mini-LEDs with various element sizes, dimensions and light output power (LOP) ratings, suitable for these emerging applications and market trends, with high-volume production capacity. Customized form factors and solutions are also available. The firm has also expanded its manufacturing capabilities and facilities for micro-LED production.

www.ces.tech
www.sanan-e.com/en

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FerroTec

Osram launches Oslon Black SFH 4736 near-infrared LED for smart farming

Osram of Munich, Germany has launched the Oslon Black SFH 4736 near-infrared LED (NIRED). Installed in a smartphone or tablet, the NIRED offers a simple way for farmers to scan fruit, vegetable or grain crops, generating reliable information about the sugar, water and fat content.

A key decision for farmers and vineyard owners is picking the right time to harvest, not only ensuring that the produce has the best possible taste but also saving time and money in processing and shipment.

Determining ripeness is enabled by near-infrared spectroscopy. This process involves scanning the content of various types of fruit, vegetables and grains — and takes only a few seconds. For example, a farmer can select a random ear of wheat, scan it with a smartphone, and just a few seconds later read the results on the display.

The NIRED irradiates the sample with a defined spectrum of light. Depending on its precise composition, the sample will reflect only a certain proportion of that light. The spectrometer then processes the information and integrates it into the smartphone or tablet. The reflected light can be considered as a 'photometric fingerprint'. These measurements indicate the existence and quantity of certain nutrients, allowing farmers to take samples and easily monitor the progress of their crops in real time so they can plan the ideal time for harvest.

"By focusing on making progress for farmers, the new Oslon Black SFH 4736 near-infrared LED takes farming technology to the next frontier," says Karl Leahy, director of Emitters, Lasers and Sensors at Osram Opto Semiconductors GmbH of Regensburg, Germany. "Our unique NIRED allows farmers to optimize their crop yield, as well as enhance harvest efficiency while keeping costs down."

In late 2016, Osram Opto Semiconductors unveiled the SFH 4735 as what was claimed to be the first broadband emitter of its kind. This previous model is being used in applications including in SCiO, one of the first near-infrared micro-spectrometers for the consumer market from Consumer Physics, based in San Francisco, CA, USA and Israel. The SFH 4736, which achieves almost twice the output (due to its newly integrated lens), is also suitable for use in the professional sector and can provide valuable assistance to farmers.

www.osram.com/os/applications/mobile-competence/mobile-competence-spectroscopy.jsp

Osram launches 810nm and 940nm infrared LEDs for iris scans and facial recognition biometric identification in automotive sector

Osram Opto Semiconductors GmbH of Regensburg, Germany has launched two new infrared LEDs (IREDs) for biometric identification applications in the automotive sector.

Biometric identification offers many benefits, not least the time and frustration saved in searching for car keys. For example, if more than one person uses the same car, personalized information such as the seat position and favorite radio stations can be automatically set as soon the person steps into the car. In future, the new Synios SFH 4772S A01 or Synios SFH 4775S A01 infrared LEDs will help the vehicle to identify the driver using iris scanning or facial recognition, unlock the doors and even disable the engine immobilizer.

"With these products we are covering a number of different applications and have now succeeded in extending biometric identification to cars," says Walter Rothmund, marketing manager automotive for Emitter Laser Sensor at Osram Opto. "Once more, light-based technology is laying the foundation for innovations in the vehicles of tomorrow."

The SFH 4772S A01 is suitable for use in iris scanning systems. This application is best known at present for unlocking smartphones and tablets without the need for a password. The IRED functions as a light source, illuminating the iris with infrared light in a suitable wavelength so that a camera can capture an image of the iris pattern — whatever the color of the eye. The system then compares this information with the stored data and unlocks the device if there is a match. SFH 4772S A01 emits infrared light with a wavelength of 810nm and achieves an optical output of 1070mW at 1A.

The SFH 4775S A01 is particularly suitable for facial recognition and driver monitoring, among other things. Both these applications ideally require a wavelength of 940nm. The IRED has an optical output of 1650mW at 1.5A, but has also been designed for high pulse loads up to 5A.

Osram says that, with these two new components, it is offering greater freedom of design, and not only due to the compact dimensions of 2.0mm x 2.8mm x 0.6mm. Depending on requirements, customers can place matching optics over the component to save space. The power emitters are Lambertian emitters with flat encapsulation. Double-stack chip technology ensures high output power. Available from spring 2019, both products are qualified for automotive applications and approved for temperatures up to 125°C.

Osram LEDs and lasers increase safety and enable customizable interiors in Rinspeed microSNAP vehicle

Osram of Munich, Germany says it is the exclusive lighting partner for microSNAP, the latest concept vehicle from Switzerland-based think-tank Rinspeed, that made its debut in Harman's exhibit at the 2019 Consumer Electronics Show (CES) in Las Vegas (8–11 January).

The vehicle features a variety of Osram components for lighting and sensing applications, such as biometric identification, ambient lighting and smart headlights, showing the way to an automotive future that is more urban, efficient and dynamic. For the third year, Osram has supported the Rinspeed concept vehicle, which shows how advanced sensing technologies and illumination can transform the way the world moves.

Similar to Rinspeed's previous Snap vehicle, the microSNAP has a chassis (known as a 'skateboard') that contains the drivetrain and most of the IT, which connects to various body types (pods). The microSNAP design is considerably more compact, making it a versatile tool for last-mile transportation or express delivery of goods. As autonomous driving and urbanization proliferates, having smaller, more flexible vehicles will be critical in reducing congestion in cities and optimizing vehicle efficiencies, says Osram.

While versatility and efficiency are important for future mobility, safety will still be paramount. That is why Osram delivered both visible lighting and infrared components to microSNAP's interior and exterior, giving the vehicle unique abilities to monitor its internal and external environment.

Outside the vehicle, microSNAP uses Osram's Eviyos, the first hybrid LED for smart headlights. Eviyos contains individually controlled pixels that automatically turn on and off, allowing more of the road to be illuminated without blinding oncoming drivers. Beyond headlights, Eviyos projects images and messages on the road to alert passengers and pedestrians, ultimately improving safety.

Self-driving vehicles will lead to new safety concerns outside of vehicles. As a provider of high-power infrared pulse lasers in LiDAR systems, Osram aims to make autonomous driving as safe as possible. With driverless cars, understanding the movement and intent of both pedestrians and vehicles is crucial in urban environments. The front and rear of the vehicle is made safer through a dynamic brake indicator that communicates with those outside the vehicle. LEDs on the pillars of microSNAP's pod and the front of the skateboard are illuminated at different levels to show the entire braking process. This intuitive lighting application helps to let pedestrians know when the vehicle is at a complete stop.

"Visible and infrared lighting create numerous safety opportunities that are integral for autonomous vehicles as they become a reality," states Wolfgang Lex, VP & general manager of Automotive at Osram Opto Semiconductors GmbH of Regensburg, Germany. "From LiDAR sensing to adaptive headlights and information projection, LEDs carry the torch to a safer and more robust driving future."

Inside microSNAP, Osram continues to increase safety with infrared components by applying them to the vehicle's 3D facial recognition and iris scanning systems. Not only do these technologies increase security by ensuring only approved individuals occupy the vehicle (such as for autonomous ride-sharing), they also allow the vehicle to adapt to an individual's desired settings. Once an individual is recognized through biometric identification, everything from personalized lighting options to preferred temperature can be adjusted to meet a passenger's previously set needs. These same components also empower gesture recognition used to move and enlarge content from a center console screen to the windshield.

Further assistance for ride-sharing includes passenger monitoring, which scans the interior for forgotten objects after a rider leaves and notifies them with an audible signal or mobile message. Health monitoring is also featured in microSNAP through Osram's infrared LEDs (IREDs), which track passengers' vital signs for sudden changes.

"Autonomous vehicles create new and transformational opportunities for our infrared emitters and sensors," says Bodo Ischebeck, VP & general manager of Industry and Mobile Devices at Osram Opto. "Osram's IREDs are enabling advanced biometric applications in Rinspeed's microSNAP — enhancing safety, security and well-being for passengers," he adds. "Our focus will continue to be delivering dynamic LEDs to customers and giving them ultimate design freedom so they can create innovative spaces that improve people's lives."

Supporting microSNAP's highly customizable environment, Osram provides human-centric lighting to the vehicle's interior, which emphasizes the interplay of light, atmosphere and space to enhance the well-being of passengers. Osram's Osire E4633i LED connects lighting to the sound system for a fully integrated light show. As vehicles begin to take over driving functions, their interiors will become more of a living space, making this kind of customization a gateway to new interior uses such as for work and leisure.

www.rinspeed.eu/en/microSNAP_50_concept-car.html
www.osram.com/os/applications/automotive-applications/eviyos-digital-light.jsp

Osram and GaN Systems introduce ultrafast driver for high-power, multi-channel LiDAR laser

Osram Opto Semiconductors GmbH of Regensburg, Germany has announced an ultrafast laser driver with a high-power, multi-channel surface-mount (SMT) laser for LiDAR (light detection and ranging) systems. Osram partnered with GaN Systems Inc of Ottawa, Ontario, Canada (a fabless developer of gallium nitride-based power switching semiconductors for power conversion and control applications) to develop the laser driver technology enabling longer-range and higher-resolution LiDAR architectures.

To accommodate the needs of customers, Osram has continuously expanded its LiDAR laser portfolio, including increasing the peak power of its SPL DS90A_3 to 120W at a current of 40A. In addition, in 2019 it plans to release an SMT laser with four channels, increasing the field of view and total peak power (with each channel able to generate 120W).

One of the issues with LiDAR technology has been its inability to transmit lasers at short pulses, while maintaining high peak power, which is necessary to ensure that the LiDAR is eye safe with a long range and high resolution. To address this need, Osram worked with GaN Systems to develop a laser driver with a 1ns pulse rise time, while driving all four channels at 40A each to deliver 480W peak power, which can then be modulated at low-duty cycles to produce high-resolution 3D cloud points at long range for new LiDAR designs.

"Operating at the elevated current levels and nanosecond rise times necessary for long-distance LiDAR requires the high power, high frequency and robust thermal performance that are the hallmarks of GaN Systems' products," says GaN Systems' CEO Jim Witham. "It is great to see the industry recognize these performance attributes and leverage them for its systems."

Scanning LiDAR is a key technology for advanced driver-assistance systems (ADAS), which is designed to increase road safety and enable autonomous driving. These electronic devices react instantly to potential collisions without wasting precious seconds of reaction time. Scanning LiDAR creates high-resolution 3D images of a car's surroundings and registers obstacles early enough for ADAS or self-driving cars to initiate the appropriate driving maneuvers, such as automatic braking to prevent collisions.

"Osram enables LiDAR technology for autonomous vehicles by not only developing high-power, multi-channel SMT lasers that meet automotive quality standards, but also working with eco-system partners like GaN Systems to address the technological barriers that arise," says Osram Opto's senior marketing manager Rajeev Thakur.

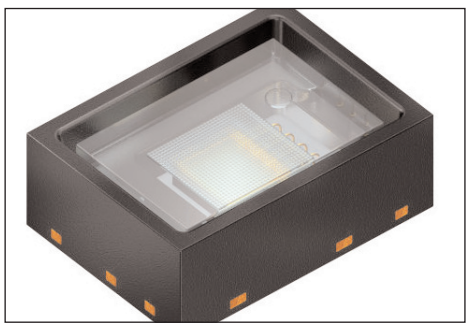
www.osram-os.com
www.gansystems.com

Osram enters 3D sensing market with PLPVCQ 850 and PLPVCQ 940 VCSELs

Osram Opto Semiconductors GmbH of Regensburg, Germany has unveiled the PLPVCQ 850 and PLPVCQ 940 (available in first-half 2019) as the latest additions to its Bidos product family of vertical-cavity surface-emitting lasers (VCSELs).

Applications for the new VCSELs include machine vision or facial recognition, as well as object or architectural scanning that involves mapping an area in 3D and positioning virtual furniture and other items. The application helps to save time and money when designing spaces, the firm adds.

VCSELs combine the high power density and simple packaging of an infrared light-emitting diode (IRED) with the spectral width and speed of a laser. Unlike edge-emitting



laser diodes, VCSELs and are much less sensitive to temperature fluctuations.

One of the most familiar applications for the technology is facial recognition for mobile devices. VCSELs illuminate the face with infrared light for cameras. The image captured by the camera is then compared to the image stored on the device. If they match, the device is unlocked. These 3D sensing applications can now use the PLPVCQ 850 and PLPVCQ 940 for time-of-flight (ToF) measurements.

The new VCSELs come with a compact black package measuring only 2.40mm x 3.30mm x 1.20mm. Depending on the application, the 2W component can be selected with the appropriate wavelength — either 850nm (PLPVCQ 850) or 940nm (PLPVCQ 940). The infrared beam is formed with the aid of a special micro-lens array to achieve what is claimed to be exceptionally homogeneous illumination of the field of view (FOV). Another benefit of the VCSEL chip from Osram subsidiary Vixar is the ease of installation, the firm adds.

www.vixarinc.com

Mitsubishi Electric to launch 3W pulsed 638nm red laser diode for projectors

Tokyo-based Mitsubishi Electric Corp has begun sample sales (prior to launch on 1 April) of the ML562G86 pulse laser diode (LD) for projector applications, emitting 638nm-wavelength red light with record output power of 3.0W under pulsed operation (20% more than the 2.5W of the existing model ML562G84) and mean time to failure (MTTF) extended to over 20,000 hours (due to improvements in chip structure and manufacturing processes).

Projector light sources are shifting from mercury lamps to solid-state light sources that offer wall-plug efficiency, a wide color gamut, and highly reliable operation. Laser diodes achieve the best wall-plug efficiency among solid-state light sources, contributing to lower power consumption, and are thus viewed as the most promising light source for projectors.

In September 2015, Mitsubishi Electric launched its ML562G84 red laser diode, achieving 2.5W output under pulse operation for RGB light-source projectors. With conventional laser diodes, extended operation at 3.0W output power causes the laser's light-emitting surface crystals to melt, making it difficult to achieve an MTTF of 20,000hr. In response, Mitsubishi Electric has developed the technology required to suppress degradation of the light-emitting surface even at 3.0W.

The high output power and high-luminosity 638nm laser light of the new ML562G86 achieves luminous efficacy of 145 lumens per laser diode.

Also, due to a large 9.0mm-diameter transistor-outline can (TO-CAN) package with excellent heat dissipation, the ML562G86 has a wide operating temperature range of 0ºC to 45ºC at 3.0W pulse operation, and what is claimed to be world-leading pulse-light output power of 2.1W at a case temperature of 55ºC. The wide operating temperature range allows a simplified cooling structure, contributing to projector miniaturization and a reduced cost of cooling units.

Together, the high output power and wide operating temperature range are targeted at contributing to not just projector miniaturization but also enhanced luminance.

Mitsubishi Electric expects in future to use laser diodes to develop not only superior projectors but also advanced laser TVs capable of more vibrant images than liquid-crystal TVs.

www.mitsubishielectric.com/semiconductors/products/opt/laserdevice

SLD Laser launches production of LaserLight sources for automotive and specialty lighting applications

At the Consumer Electronics Show (CES) in Las Vegas (8–11 January), SLD Laser of Goleta, CA, USA (a spin-off from LED lighting firm Soraa Inc said that is commercializing visible laser light sources for automotive, specialty lighting and display applications) demonstrated real-world applications for its high-brightness light source technology and its vision for intelligent illumination.

It is reckoned that LaserLight can deliver more than 10 times the brightness of LEDs, extended range illumination of up to 1km, minimal power consumption, long lifetime, and highly directional output not possible with LEDs. SLD Laser has achieved the first UL safety certification for laser lighting, and its technology can be found in a growing range of products including portable lights such as flashlights and drone lights, entertainment and architectural lighting, and automotive headlights and interior lights.

At the 2018 SCORE Baja 1000 off-road race, the first and second place finishers in the Trophy Truck category utilized Baja Designs LaserLight powered by SLD Laser components (available this year for the first time). "This new SLD LaserLight technology gives you more penetration and confidence when racing in the dark because you can count on being able to see deep down the course when you are going 110 or even 120mph," commented winner Cameron Steele. The Baja Designs LaserLight bar throws light to over 1km range (over 3.5 times further than premium LED offerings, it is reckoned).

LaserLight will hit the streets for the first time with the arrival of select premium car models deploying LaserLight Fiber for high-beam boost functionality, complemented by a conventional LED unit for low-beam. This signals SLD Laser's production launch in the automotive category, with units shipping now for cars to be delivered to customers in Europe in third-quarter 2019.

At CES, SLD Laser is unveiling the smallest LaserLight headlight concept, measuring just 1.5cm high with low-beam and high-beam functionality, together with a 1.5mm daytime running light (DRL). Using the same fiber-based technology, the compactness of these lighting sources is inspiring new ideas in headlamp designs, says the firm, which has partnered with mechatronics company HSL Italia.

In addition to headlamps, the same versatile light source can be used for interior or exterior fiber-based accent lighting. The sources couple efficiently into fiber optics, making the replacement of a light source as simple as connecting a headphone jack.

SLD Laser expects that in the future LaserLight technology will enable new lighting functions in next-generation autonomous driving applications using a 1mm mirror based on micro-electro-mechanical system (MEMS) technology to steer the light to the road. For connected cars, LaserLight sources can enable LiFi data communications — high-speed, networked, wireless communications using light — that eclipse the capabilities of conventional WiFi communications, with vastly increased data transmission rates (in excess of 5GB per second) and extended range.

Beyond automotive applications, LaserLight sources can deliver high-luminance performance for consumer products related to portable lighting, as well as professional products in entertainment, architectural, security, search & rescue and outdoor lighting. New products being launched include handheld, battery-powered flashlights that allow 1km visibility and power-efficient, light-weight modules that can be drone-mounted to provide better visibility than can be achieved with alternative lighting technology.

www.SLDLaser.com

nLIGHT launches 400W passively cooled laser

nLIGHT Inc of Vancouver, WA, USA (which was founded in Seattle in 2000 and provides high-power semiconductor and fiber lasers for industrial, microfabrication, aerospace and defense applications) has launched the element e24i, a 400W fiber-coupled packaged laser small enough to fit in the palm of your hand.

"The e24i represents a major step forward in power, brightness and packaging for a semiconductor laser," claims Michael O'Connor, general manager of nLIGHT's Semiconductor Laser Business. "This product enables our customers to scale to new power levels with favorable economics."

Delivering 400W of output power at 915nm or 375W at 976nm from a 200µm fiber, the element e24i is said to greatly simplify the system architectures of direct diode, solid-state and fiber lasers for industrial, microfabrication and defense applications.

"nLIGHT is committed to enabling our customers with differentiated products that further their growth and competitive advantage," says O'Connor.

nLIGHT is exhibiting the element e24i at the SPIE's Photonics West 2019 event in San Francisco, CA, USA (5–7 February).

www.spie.org/SPIE_PHOTONICS_WEST_Conference

www.nlight.net/products/diode-lasers

Kaiam lays off 310 of 338 staff at plant in Scotland

Buyer sought after European operation enters administration

Kaiam Corp of Newark, CA, USA (which makes optical transceivers for hyperscale data centers) said on 24 December that 310 of the 338 workers at its manufacturing site in Livingston, Scotland were being made redundant with immediate effect, on account of lack of orders and trading losses.

This followed a warning on 21 December that staff would not receive their monthly wages on time because of cash-flow problems, and were not required for work before 3 January. While the plant is mothballed, the remaining 28 staff have been retained to help Blair Nimmo and Alistair McAlinden of KPMG, who were appointed on 22 December as joint administrators of subsidiaries Kaiam Europe Ltd and Kaiam UK Ltd while a buyer is sought for the European operation.

Kaiam bought Gemfire, its strategic photonic lightwave circuit (PLC) supplier, in 2013, and operated an 8"-wafer silica-on-silicon line for fabricating integrated optical components in the former Gemfire's large-scale manufacturing facility in Livingston, where it also operated 40–100Gb/s optical packaging lines.

"We are exploring a sale of the business and are working with Scottish Enterprise, Skills Development Scotland and West Lothian Council to provide a full range of support to the company's employees as this process takes place," said Nimmo. "Partnership Action for Continuing Employment (PACE), the Scottish Government's partnership framework for responding to redundancy situations, has already mobilized," he adds. "We are also liaising with the UK Government in relation to the timing of redundancy payments via the Insolvency Service.

According to the Herald Scotland newspaper, the Scottish Government says that it first learned of 'financial difficulties' on 22 November. In 2014, Scottish Enterprise gave Kaiam a £850,000 taxpayer-funded grant to relocate some of its manufacturing from China to Scotland, on condition that jobs and project assets would be in place until 2021. Kaiam's president & CEO Bardia Pezeshki claims that those funds were consumed up by massive overheads at the plant.

Scottish Enterprise aims to recover some of that money. "Scottish Enterprise will work with the administrators to understand the potential options for the business going forward and explore all possibilities to rescue the jobs," said the Scottish National Party's Jamie Hepburn, a Member of the Scottish Parliament (MSP) and the Scottish Government's Minister for Business, Fair Work and Skills.

www.kaiam.com

CST Global launches T@CST forum for commercializing photonics technologies

III-V optoelectronic foundry Compound Semiconductor Technologies Global Ltd (CST Global) of Hamilton International Technology Park, Blantyre, near Glasgow, Scotland, UK has launched the T@CST forum, which aims to coordinate knowledge, opinion, legislation, funding and influence for government and industry in order to commercialize new photonics and III V compound semiconductor technologies.

The initial forum, held in November at the House for an Art Lover, Glasgow, was focused on commercializing quantum technologies and atomic clocks, and included the following keynote speakers.

Professor Sir Peter Knight (senior research investigator in the Physics Department at Imperial College and senior fellow in residence at the Kavli Royal Society International Centre at Chicheley Hall) covered the use of quantum technology in five recognized application areas: compact atomic clocks for timing and GPS resilience; metrology and sensors for accurate resolution and measurement; secure communications; simulation and modelling accuracy and speed; and computation and fast information processing.

From left, Nick Bowden, Thomas Slight, Stephen Taylor, Carol Monaghan, Sir Peter Knight, Trevor Cross and Euan Livingston.

Professor Trevor Cross (chief technology officer & head of quantum technologies at Teledyne e2v) gave a keynote on commercializing quantum technology. Teledyne e2v is amongst the first companies in the world already developing and selling products utilizing quantum technology.

Carol Monaghan (MP for Glasgow North West, member of the House of Commons Science and Technology Select Committee and chair of the All-Party Parliamentary Group for Photonics) covered issues facing talent and recruitment in the sector.

Stephen Taylor (CEO of Technology Scotland, a membership body for companies operating in the Enabling Technology Sector) gave a market summary, showing the exponential growth felt by many photonics companies in a world market where quantum sensing is expected to exceed $1bn by 2030.

Finally, senior device development engineer Dr Thomas Slight gave a summary of the five government-funded quantum technology research projects that CST Global is currently working on.

Together, attendees at the T@CST forum identified the key enablers — in the areas of talent, market readiness, technology maturity, economics, industrial environment and political support — necessary to take quantum technology into mainstream applications.

www.technologyatCST.org
www.CSTGlobal.uk

CST Global supports Innovate UK's Emerging Technologies Showcase on Compound Semiconductor technologies

CST Global says that it supports the Emerging Technologies Showcase on Compound Semiconductor technologies, organized by Innovate UK's Knowledge Transfer Network (KTN), which has profiled new and emerging compound semiconductor technologies from UK universities and industrial partners involved in consortium research projects funded by UK Government agency Innovate UK.

"The showcase identifies emerging compound semiconductor technologies with commercial, societal or environmental benefits," says CST Global's technical director Andrew McKee. "Industrial and end-user collaborations are facilitated, expediting the development of new products and services and identifying many grant-funding opportunities," he adds.

Andrew McKee.

"CST Global is currently an active member in ten UK and European Technology Consortium Programmes, with over 20 industrial and academic partners," McKee continues. "CST Global brings expertise in device development, fabrication and process improvement, as well as extensive experience of taking low technology readiness level (TRL) III-V compound semiconductors into commercial applications."

CST Global's current collaborative projects include MacV, producing miniaturized atomic clocks with vertical-cavity surface-emitting lasers (VSCELs); Super8, developing high-speed transceiver platforms; CoolBlue2, focused on short-wavelength quantum light sources; and MIRAGE, targeting mid-infrared photonic components for sensing. Potential applications span the telecoms, industrial, defense and healthcare markets.

www.CSTGlobal.uk

CSC, SPTS, Cardiff and Swansea conclude high-efficiency VCSEL manufacturing project

Process modules delivered for transitioning small-diameter manufacturing processes to high-uniformity 150mm epi platform

The Compound Semiconductor Centre Ltd (CSC) of Cardiff, Wales, UK and its partners (Orbotech company SPTS Technologies Ltd, Cardiff University and Swansea University) have successfully concluded the project 'High Efficiency Manufacturing of Vertical Cavity Surface Emitting Lasers (VCSELs)', which was funded by UK Government agency InnovateUK.

The project has delivered key process modules required to transition small-diameter manufacturing processes currently used for VCSELs to a high-uniformity 150mm epitaxial platform. The need for scale-up is driven by significant benefits in terms of productivity (4x more die sites in transitioning from 75mm to 150mm) and yield (a smaller ratio of edge sites to total area for larger wafer diameters) to facilitate a step change in cost reduction for VCSELs, and thus accelerate adoption in mass-market applications such as 3D imaging, proximity sensing, range-finding and light detection and ranging (LiDAR).

The work included the commissioning of a custom 150mm oxidation tool at Cardiff University's Institute for Compound Semiconductors (ICS) which is used for a particularly challenging stage of preferential oxidation of aluminium-rich layers in the VCSEL layer structure, in order to produce a high-efficiency optical waveguide in the device. High-quality mesa dry etch processes to >5μm were developed by SPTS on GaAs/AlGaAs epitaxial structures supplied by CSC, with Swansea supporting plasma-enhanced chemical vapor deposition (PECVD) and photo process steps, to complement the oxidation process module; essential for a high-uniformity, high-reliability 150mm VCSEL fabrication platform. A robust process solution was developed, including in-situ depth targeting end-point detection capability. A benchmark of <±5% mesa depth uniformity across a full 150mm VCSEL epitaxial wafer structure was demonstrated.

The capability will form the core of a future 150mm VCSEL prototyping capacity that will be leveraged by the consortium to work on custom VCSEL development, device-scale optimization and validation of VCSEL epitaxial materials development as a core research and manufacturing competence in the emerging CSconnected compound semiconductor cluster in South Wales.

www.compoundsemiconductorcentre.com

TRUMPF acquiring Philips Photonics

TRUMPF focusing on new business fields such as sensor technology and photonics for data transmission

TRUMPF GmbH of Ditzingen, near Stuttgart, Germany is acquiring Philips Photonics GmbH of Ulm, Germany, a wholly owned business of Royal Philips of Eindhoven, The Netherlands that provides vertical-cavity surface-emitting laser (VCSEL) technology for datacom, consumer and industrial applications.

Established in 2000 as ULM Photonics GmbH and acquired by Philips in 2006, Philips Photonics in November announced its third production capacity expansion in the last three years (to be completed within the next 18 months).

With about 13,400 employees, TRUMPF makes machine tools, laser technology and electronics for industrial manufacturing. The firm says that the acquisition opens up a new market segment for it in addition to its existing business with high-power diode lasers as well as expanding its product portfolio. Employing about 280 people, laser diodes from Philips Photonics are used in, for example, smartphones, digital data transmission, and sensors for autonomous driving. As well as its manufacturing facility in Ulm, Philips Photonics also has sites in Aachen, Germany, Eindhoven in The Netherlands, and sales offices in Shenzhen, Shanghai and Qingdao in China.

"We want to open up new product fields and expand our existing portfolio at a strategically important point," says TRUMPF's CEO Nicola Leibinger-Kammüller. Through the acquisition, the firm should expand its access to fast-growing markets in the photonics and digital products sectors.

"Philips Photonics employs a large number of very good developers who have opened up new areas of photonics and who will strengthen our research and development area in the long term," comments chief financial officer Lars Grünert, member of the group's management board responsible for the new TRUMPF product sector. "Together, we want to further develop the Photonics division." In its past fiscal year 2017/18, TRUMPF has invested €337m in R&D (a development ratio of 9.5%).

We want to open up new product fields and expand our existing portfolio at a strategically important point says TRUMPF's CEO

"Since our foundation in 2000, we have grown strongly. More than half a billion cell phones worldwide are equipped with laser diode technology from Philips Photonics," notes Philips Photonics business leader Joseph Pankert. Becoming part of TRUMPF "will ensure that the division can continue to grow in a highly innovative company in the future."

The acquisition is expected to be completed in second-quarter 2019. Authorities still have to approve the acquisition.

www.photonics.philips.com
www.trumpf.com

II-VI unveils direct-diode laser engine with active rectangular-beam shaping for micro materials processing

Engineered materials and optoelectronic component maker II-VI Inc of Saxonburg, PA, USA has unveiled its DirectProcess 900 direct-diode laser engine with active rectangular-beam shaping for micro materials processing.

Next-generation consumer electronics, with their increasing capabilities in small form factors, are driving innovation in laser-based manufacturing to solve new challenges in microelectronics assemblies, says the firm. The new DirectProcess 900 FlexShape, with its top-hat beam parameter profile of 6mm x mrad, can be dynamically adjusted to an arbitrary rectangular beam width and length ranging from 0.2mm to 50mm for non-contact localized soldering, bonding and annealing in microelectronic components and connectors.

"This new product delivers on the fundamental advantages of direct-diode technology for micro materials processing," says Haro Fritsche, product line manager, II-VI DirectPhotonics. "Direct-diodes lasers are intrinsically the most power efficient materials processing tools, have unique beam geometries that delineate process areas precisely, and are virtually maintenance free. Leveraging these and other benefits, direct-diode lasers are rapidly emerging as the preferred tools in micro materials processing."

The DirectProcess 900 product platform can be programmed by users to perform precisely timed processes, and can be managed and diagnosed remotely through its TCP/IP or EtherCAT interfaces, says the firm. II-VI's direct-diode laser engines are available with powers ranging from 200W to 1200W. They are small, lightweight and robust, making them suitable for direct mounting on automated stages or robots. They can be deployed along with II-VI's laser processing heads and laser light cables.

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

II-VI launches red lasers for workpiece alignment in multi-kilowatt fiber-laser systems

II-VI Inc of Saxonburg, PA, USA has launched red lasers for workpiece alignment in multi-kilowatt fiber laser systems.

Red lasers integrated into high-power fiber-laser systems allow precise alignment of multi-kilowatt infrared laser beams to the target process areas and must operate in the presence of very high back-reflections from the workpiece. The new red lasers can maintain a tightly controlled high output power of 350mW to within 2% while under the presence of up to 5W of reflected optical power. The design ensures a controlled and reliable process in applications such as welding, cutting, brazing and laser additive manufacturing.

"Leveraging our core competency in high-power semiconductor laser packaging, this red laser adds innovative optics that enable its unique performance in output power stability," says Chris Koeppen, VP of the II-VI Industrial Laser Group. "Our new red laser improves process performance and reduces down-time and maintenance cost of multi-kilowatt fiber laser systems."

www.ii-vi.com/alignment-laser-modules/?SingleProduct=695

II-VI launches 22W pump laser diodes for fiber lasers

II-VI Inc has launched a new generation of pump laser diodes that achieve a high output power of 22W from a single chip.

Fiber lasers have represented an improved cost of ownership for industrial materials processing over the last several years. Advances in the power of individual laser diodes further represent a cost advantage in laser systems. The new laser diodes achieve 22% more output power than the existing product, enabling fiber-laser designs with fewer emitters for use in cutting, welding, brazing and laser additive manufacturing.

"The pent-up demand for our new laser chips is strong and we're beginning to ramp up production," says Karlheinz Gulden, general manager, II-VI Laser Enterprise. "Customers increasingly rely on II-VI's innovation in high-power semiconductor laser technology to produce the most competitive fiber lasers in terms of performance, reliability and cost," he adds.

The 22W pump laser diodes are available at wavelengths of 915nm and 976nm. The laser chips have a 190µm-wide output facet designed to achieve optimum coupling efficiency into widely used 200µm-core fibers. The chips include II-VI's proprietary E2 front-mirror passivation that prevents catastrophic damage to the laser, even at extremely high output powers. The new chip generation has completed qualification with 4000 hours of accelerated aging.

II-VI's pump laser diodes are offered as bare dies, chips on ceramic sub-mount or in fiber-coupled multi-emitter modules.

www.ii-vi.com/multimode-pump-laser-diodes-for-fiber-lasers-2/?SingleProduct=881

II-VI introduces 405nm laser for biomedical instruments

II-VI Inc has extended its compact, low-noise QOMO laser series for analytical instruments in life sciences, including for flow cytometers, confocal microscopes and biomedical imaging applications.

Now available at 405nm in addition to the existing laser wavelengths of 488, 638 and 660nm, the extremely stable, low-noise optical output power of the QOMO laser enhances the measurement sensitivity of next-generation flow cytometers, enabling greater accuracy and faster measurements.

"Our lasers enable high measurement sensitivity in flow cytometers, which is critical to accurately identify residual traces of target cells or markers," says Chris Koeppen, VP of the II-VI Industrial Laser Group. "This laser leverages II-VI's well-established hardware and software platform with decades of field-proven reliability in optical networks."

The firm says its QOMO laser is cost effective due to vertical integration of components manufactured in-house, including semiconductor lasers, optics and thermo-electric coolers. The laser spot size and beam geometry can be configured to match a wide variety of analytical instrument designs and can achieve up to 150mW of output power.

II-VI's portfolio of products for flow cytometry includes optics and filters for fluorescence spectroscopy in the visible and ultraviolet wavelength ranges, as well as sheath cells and precision air and fluid temperature control systems based on thermo-electric coolers.

II-VI is showcasing its engineered materials, lasers and optics for materials processing, life sciences, consumer electronics and automotive applications at the following events:

- SPIE BIOS Expo 2019 in San Francisco, CA (2–3 February), on biomedical optics;
- SPIE Photonics West 2019 in San Francisco, CA (5–7 February) on photonics; and
- EALA — European Automotive Laser Applications 2019 in Bad Nauheim, Germany (12–13 February) on laser-based processes for future car body productions.

OIP4NWE project to create open-innovation photonics pilot line

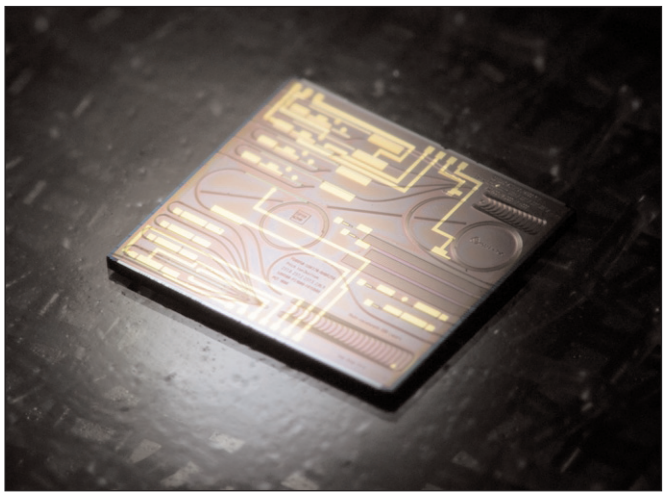
Partners in north-western Europe aim to reduce costs and time for pilot production of new products, and to incubate photonics SMEs

The €13.9m project OIP4NWE (Open-Innovation Photonics pilot for North West Europe) has kicked off, supported by the Interreg North-West Europe (NWE) European Territorial Cooperation Program (which is based on the cooperation of organizations from eight countries: Belgium, France, Germany, Ireland, Luxembourg, The Netherlands, Switzerland and the UK).

The project has €8.3m in funding from the European Commission via the European Regional Development Fund (ERDF) plus €5.6m from participating parties. These are led by Eindhoven University of Technology (in collaboration with its Photonic Integration Technology Center) joined by companies Aixtron SE (Germany), SMART Photonics, VTEC Lasers & Sensors, Technobis Fibre Technologies (all Netherlands), mBryonics Ltd (Ireland) and Oxford Instruments Nanotechnology Tools Ltd (UK) along with the research centers Photonics Bretagne (France), Cluster NanoMikroWerkstoffePhotonik (Germany) and Photon Delta Cooperatie (Netherlands).

Compared with electronics, photonics uses much less energy, is faster and opens up new opportunities. A key problem that photonics can help to tackle is the exploding energy consumption of data centers, as photonic chips consume much less energy. Another example is a high-precision monitoring system for aircraft wings, bridges or tall buildings.

After two decades of basic photonics research, the first companies producing photonic integrated circuits (PICs) are taking off, but sparsely. Innovative small- and medium-sized enterprises (SMEs) are at the forefront of photonics development, but a major hurdle is the high cost of R&D. Apart from needing expensive cleanroom equipment, existing PIC production processes still have a high defect rate and are too slow. This was workable for basic research but not for commercial R&D. The technology readiness level (TRL), which ranges from 1 to 9, needs to be raised from the current 4 to 7.



The OIP4NWE project will create an efficient open-access pilot-production line for shared use by European SMEs, reducing the defect rate in pilot production and shortening throughput time. This should lead to a cost reduction that significantly lowers the threshold for developing new photonic products. The target is to help establish many integrated photonics firms and thousands of jobs within ten years of the project.

The front-end process (producing PICs on wafers) will be realized in the existing NanoLab@TU/e cleanroom at Eindhoven University. The PICs of different companies will be combined on one multi-project wafer (MPW) to keep costs low. The back-end process will be performed at the Vrije Universiteit Brussel (optics for beam shaping and light coupling) and at the Irish Tyndall National Institute (assembly of fiber-optic connections and electronics in the package). All steps require nanoscale precision to avoid product defects.

The first stage of the project is equipment installation. The second stage focusses on automation of the equipment. A third stage will involve intensive industrial research together with equipment manufacturers to optimize and develop new processes. The line should be fully in operation in 2022. To incentivize initial uptake by SMEs, a voucher scheme for external SMEs will be established.

www.nweurope.eu
www.tue.nl/en/research/research-areas/integrated-photonics/institute-for-photonic-integration

Representatives of the parties involved at the kick-off meeting in Eindhoven.

EC-funded InPulse indium phosphide photonic integrated circuit project launches

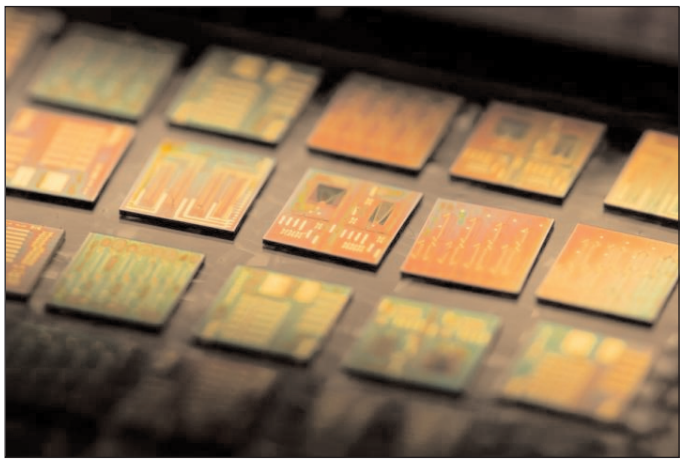
Pilot line enables start-ups to take concepts from prototype to pilot production using industry tools and processes

Supported by the European Commission (via €14m of funding) together with the Photonics21 Public Private Partnership (PPP) and the PhotonDelta integrated photonics eco-system, 16 European partners (led by Eindhoven University of Technology in The Netherlands) have started project InPulse, which will offer new-entrant companies direct access to the manufacturing of photonic integrated circuits (PICs) based on indium phosphide (InP), enabling the development of products for a wide range of new markets. The European Commission has defined photonics as one of the six key enabling technologies of Europe.

The project pilot line will enable innovators to develop products rapidly, allowing them to focus on their products rather than the technologically complex task of fabrication.

Currently there are just a few firms that can develop PIC-enabled products, by using their own in-house fabrication lines. Consequently, start-ups with promising ideas have trouble entering the market. The InPulse pilot line therefore enables new entrants to take their concepts from prototype to pilot production on industry tools and processes. InPulse connects the design process to manufacturing, testing and packaging to streamline the development cycle for businesses that do not own a fabrication plant or have production knowledge.

The InPulse consortium partners are the Eindhoven University of Technology, AMIRES, Aarhus University, Bright Photonics, European Photonics Industry Consortium (EPIC), ficonTEC Service, Fraunhofer HHI, III-V Lab, Mellanox Technologies, Photon Design, Synopsys, Smart Photonics, Technobis Fibre Technologies, Tyndall National Institute, VLC Photonics and VPIphotonics. Collectively, they will create manufacturing-grade process design kits (PDKs) that will be the automated intermediary between the design, production and testing. The separation of design and fabrication process know-how enables newcomers to avoid the prohibitive investment overheads in PIC fabrication technology.



InPulse will offer new-entrant companies direct access to manufacturing of photonic integrated circuits based on indium phosphide, enabling the development of products for a wide range of new markets. They are backed by €14m of funding from the European Commission. CREDIT: Florian Lemaitre/ Eindhoven University of Technology.

Partners will create manufacturing-grade PDKs that will be the automated intermediary between the design, production and testing. The separation of design and fabrication process know-how enables newcomers to avoid the prohibitive investment overheads in PIC fabrication

InPulse will use closely aligned methods that scale in volume and that focus on accelerating the design cycle, creating more accurate and predictable design tools, manufacturing and high-throughput testing.

The project builds on the pioneering work and technology of the Joint European Platform for Photonic Integration of Components and Circuits (JePPIX.eu), which is already offering PIC prototyping services. InPulse enables the transition to manufacturing.

The first phase of the project will focus on making the technology more robust and on putting in place the business processes for accelerated development programs. In the second stage some 30 new products will be developed to demonstrate the pilot line capability. For this phase the project consortium is looking for additional companies and designers that want to take their ideas and designs to pre-production.

Last November, a second pilot line 'OIP4NWE' (Open-Innovation Photonics pilot for North West Europe) was launched to create a new generation of production tools, with support from the European Commission and PhotonDelta. Equipment developed in OIP4NWE (which is also led by Eindhoven University of Technology) may be expected to play a role in the later stages of InPulse, which is highly complementary (focusing on accelerating time to market and eco-system development).

www.tue.nl/en/research/research-areas/integrated-photonics

Cisco to acquire silicon photonics firm Luxtera

Integration of optical transceiver portfolios to broaden Cisco's 100GbE/400GbE range

Cisco of San Jose, CA, USA intends to acquire privately held fabless silicon photonics firm Luxtera of Carlsbad, CA, USA for $660m in cash and assumed equity awards. The firm plans to incorporate Luxtera's technology across its intent-based networking portfolio, spanning enterprise, data center and service provider markets.

"With Cisco's 2018 Visual Networking Index projecting that global Internet traffic will increase threefold over the next five years, our customers are facing an exponential demand for Internet bandwidth," says David Goeckeler, executive VP & general manager, Networking and Security Business at Cisco. "Optics is a fundamental technology to enable this future. Coupled with our silicon and optics innovation, Luxtera will allow our customers to build the biggest, fastest and most efficient networks in the world," he reckons.

The acquisition is intended to:

- *Future-proof networks for emerging applications*: The emerging class of distributed cloud, mobility and Internet of Things (IoT) applications is creating an unprecedented strain on existing communications infrastructure. The combination of Cisco's and Luxtera's capabilities in 100GbE/400GbE optics, silicon and process technology should enable customers to build future-proof networks optimized for performance, reliability and cost, it is reckoned.
- *Expand Cisco's 100GbE and 400GbE portfolio*: Integration of Luxtera and Cisco's optical transceiver portfolio will broaden Cisco's offering of 100GbE and 400GbE optics. As system port capacity increases from 100GbE to 400GbE and beyond, optics plays an increasingly important role in addressing network infrastructure constraints, particularly density and power requirements, the firm adds.

The acquisition is expected to close in Cisco's fiscal third-quarter 2019, subject to customary closing conditions and required regulatory approvals. Upon completion, Luxtera employees will join Cisco's Optics business under David Goeckeler, executive VP & general manager, Networking and Security Business.

www.luxtera.com

Rockley appoints non-executive director to chair audit committee as it structures business for growth

Rockley Photonics of Pasadena, CA, USA (formed in 2013 to develop a silicon photonics platform for optical I/O in next-generation sensor systems and communications networks) has appointed Caroline Brown to its board of directors.

"Chairing our audit committee is a critical role as we structure our business for growth," states chief finance officer Mahesh Karanth. "Our technology addresses multiple markets from data centers to the sensing environment for automation, autonomy, IOT and AI," he adds. "We need the right financial platform in place to be successful in these high-growth sectors."

Brown has served as senior independent director and audit chair for several AIM businesses and currently holds several non-executive directorships. She has over 18 years of experience in driving strategic growth and leading high-performing teams in the technology and professional services sectors, including roles with Merrill Lynch (New York), UBS and HSBC. Brown is also a Fellow of the Chartered Institute of Management Accountants and holds a first-class degree and PhD in Natural Sciences from the University of Cambridge, and an MBA from the Cass Business School, University of London.

"Caroline brings an impressive range of skills and experience, which adds to and complements the board's extensive background in the public markets," says Rockley's founder, CEO & chairman Andrew Rickman. Rickman previously founded Bookham Technology (the first firm to commercialize silicon photonics), which had an IPO in 2000. He later became chairman of Kotura (sold to Mellanox in 2013).

"Recent industry M&A activity has highlighted the strategic value that manufacturers see in integrated photonics," comments Brown.

Rockley says that its photonic technology platform was developed for high-volume manufacturing of highly integrated optical/electronic devices for high-performance applications. Exploiting optimized waveguide dimensions, it is claimed to offer benefits over conventional solutions, including the production of higher-density optical circuits, the ability to create more complex integration, better manufacturing tolerances, superior power handling, lower loss and higher-efficiency photonic IC interfaces. The firm adds that its technology can be adapted to be application specific, while simplifying manufacturing, assembly, test and validation, and optimizing power, size and cost of complex optical systems.

www.rockleyphotonics.com

NeoPhotonics raises Q4/2018 profit guidance

Sale of Russian operation agreed; Lestina lawsuit settled; client transceiver module manufacturing to be discontinued

For fourth-quarter 2018, NeoPhotonics Corp of San Jose, CA, USA (a vertically integrated designer and manufacturer of hybrid photonic integrated optoelectronic modules and subsystems for high-speed communications networks) has announced preliminary results that reflect recent developments including the end-of-life of certain client transceiver modules, a legal settlement, and the signing of a definitive agreement to sell its manufacturing operations in Russia.

The firm will discontinue manufacturing and selling the end-of-life client transceiver modules after completing last-time production runs through May 2019. This will result in about $3.5m in charges for inventory and asset write-downs in fourth-quarter 2018 and accelerated depreciation of about $3m, to be amortized over the final production during the first and second quarters of 2019. These products contributed about $10m of revenue in 2018.

Regarding the lawsuit with Lestina International Ltd (pursuant to a purchase commitment for materials related to product assets sold by one of NeoPhotonics' foreign subsidiaries to APAT Optoelectronics Components Co Ltd in January 2017), NeoPhotonics has agreed to settle the lawsuit with a cash payment of $2.2m (to be recognized as an expense in fourth-quarter 2018).

Also, NeoPhotonics has agreed to sell its manufacturing operations in Russia for approximately book value (consistent with the firm's financial results disclosed in the 10-Q filing for third-quarter 2018).

Collectively, these actions should reduce cost of goods sold (COGS) by an amount roughly equivalent to one percentage point of non-GAAP gross margin, beginning in Q1/2019.

Including these factors, for Q4/2018 NeoPhotonics expects revenue of $90–92m (compared with the $87–92m guidance announced in early November), and non-GAAP gross margin of 27–29% (compared with 24–28%). Excluding total restructuring and other charges of about $5.7m (comprising restructuring costs of $1m, end-of-life inventory write-downs of $2.6m, and the $2.2m legal settlement expenses), diluted non-GAAP earnings per share should be a profit of $0.00–0.04 (compared with the prior expected range of between a net loss $0.08 to a net profit of $0.02).

"We remain committed to our core capabilities, including our industry-leading coherent components and solutions for data-center interconnect and telecommunications systems," says chairman & CEO Tim Jenks. "These actions will complete our move from module- to component-level solutions for client network applications and will further increase our focus on our more profitable, industry-leading platforms for 400 Gigabits/sec to beyond 1 Terabit/sec on a single wavelength, in which our advanced hybrid photonic integration technology provides the highest value."

www.neophotonics.com

Lumentum completes Oclaro acquisition

After receiving anti-trust clearance on 6 December from China's State Administration for Market Regulation, optical and photonic optical component and subsystem maker Lumentum Holdings Inc of Milpitas, CA, USA has completed its acquisition (announced on 12 March) of Oclaro Inc of San Jose, CA, USA (which provides components, modules and subsystems for optical communications), terminating trading in Oclaro's common stock on the NASDAQ Stock Market. Oclaro's stockholders previously approved the merger on 11 July.

"The combined scale, resources, talent and breadth of technologies will help us accelerate innovation and the development of the products our customers and network operators around the world need to handle the tremendous and unrelenting growth in network bandwidth," believes Lumentum's president & CEO Alan Lowe.

For each share held, Oclaro stockholders receive $5.60 in cash and 0.0636 of a share of Lumentum common stock. It is likely that the transaction will be fully taxable to Oclaro stockholders for US federal income tax purposes, and therefore Lumentum will report the transaction as taxable.

"Completion of the transaction creates a powerful force in the optical industry and tremendous opportunity for employees, customers and shareholders," comments Oclaro's CEO Greg Dougherty.

Lumentum expects to achieve $60m in synergies in the 12–24 months following closing of the transaction.

Lumentum financed the cash portion of the transaction with cash from the combined company balance sheets and $500m from a new term loan entered into in connection with the closing of the transaction.

Oclaro board member Ian Small has joined Lumentum's board, as per the terms of the merger agreement. Small is CEO of Evernote, a mobile and desktop personal productivity application company and was previously with Telefónica S.A., where he was its global chief data officer, and also served as chairman of the board of TokBox, a platform-as-a-service provider of embedded video communications.

www.lumentum.com

AOI sampling 400G silicon photonics optical module

Applied Optoelectronics Inc (AOI) of Sugar Land, TX, USA — a designer and manufacturer of optical components, modules and equipment for fiber access networks in the Internet data-center, cable TV broadband, fiber-to-the-home (FTTH) and telecom markets — has announced customer sample availability of 400G optical modules based on silicon photonics technology.

The modules are designed to demonstrate the feasibility of applying AOI's silicon photonics platform to the requirements of on-board optics (OBO), as outlined in specifications such as the recently released version 1.1 of the onboard optical module specification published by the Consortium for Onboard Optics (COBO), of which AOI is an active member.

In contrast to traditional pluggable optical modules, OBO modules are designed to be used in higher-speed data switches, with interface speeds ranging from 400Gbps to 1.6Tbps. By designing the optical modules to be mated directly to a circuit board within such a switch, the OBO modules enable an increase in the density of optical interfaces to the switch, which in turn enables greater data throughput through the switch fabric, while also simplifying cooling and electrical interfaces (two areas where traditional pluggable modules have increasing difficulty as interface speeds increase).

AOI's sample OBO modules are specifically designed for customers developing next-generation switches for large data centers, as these switches gradually evolve from 100Gbps interconnects to 400Gpbs, and higher. The modules currently leverage new silicon-based optical technology to support 16 optical channels with a total data throughput of 400Gbps. Future versions of the device are expected to leverage the same silicon photonics technology, but increase the bandwidth up to 100Gbps per optical channel, ultimately enabling 1.6Tbps of data throughput over a single OBO module. In turn, this would enable next-generation 12.8Tbps switches to utilize only 8 optical modules, significantly improving density and reducing power consumption compared with a similar solution, which would require 32 400Gbps pluggable modules.

"We gathered very positive feedback while demonstrating early 16-channel OBO prototypes at the European Conference on Optical Communications (ECOC) in Rome last year," notes David Chen, assistant VP of Transceiver Technology. "This OBO module incorporates several new technologies, including an advanced silicon photonics-based optical sub-assembly, which are the culmination of years of R&D effort by AOI and our technology partners. We believe that this platform will enable solutions well beyond 400Gbps, and eventually, 1.6Tbps," he adds.

"AOI has made significant progress on the development of OBO modules since the publication of revision 1.0 of COBO's specification," comments Brad Booth, president of the Consortium for On-Board Optics. "AOI's ability to sample OBO modules after their ECOC demonstration of an OBO prototype shows their commitment to bringing alternative solutions for the next generation of networking equipment," he adds. "Having a single module footprint that supports bandwidth scaling from 400Gbps to 1.6Tbps provides flexibility to equipment vendors," Booth concludes.

www.ao-inc.com

Emcore quarterly revenue rebounds by 42.5%, driven by larger-than-expected cable TV orders

For full-year fiscal 2018 (to end September), Emcore Corp of Alhambra, CA, USA — which makes indium phosphide (InP)-based optical chips, components, subsystems and systems for the broadband and specialty fiber-optics markets — has reported revenue down by 30.3%, from $122.9m for fiscal 2017 to $85.6m for fiscal 2018. "2018 was a challenging year for us as we worked through an inventory overhang in the cable TV supply chain," notes president & CEO Jeffrey Rittichier.

But despite being down 13.7% on $29.2m a year ago, fiscal Q4/2018 revenue of $25.2m has rebounded by 42.5% from $17.7m last quarter (above the initial guidance of $21–23m, and at the top of the revised guidance of $24.2–25.2m). Recovery was driven by larger-than-expected cable TV orders (received late in Q4) related to increasing adoption of the linear externally modulated laser (L-EML) product line, coupled with the expected return to normalized inventory levels of legacy distributed feedback (DFB) products at a CATV customer (working through an inventory overhang throughout much of fiscal 2018) plus completion of the long-term Navigation supply agreement.

"Our L-EML product line continues to perform beyond expectations, with record volumes of L-EML transmitter shipped in the quarter, including production shipments of all seven of the L-EML design wins that we previously announced," says president & CEO Jeff Rittichier. "It further validates the competitive advantage that the L-EML provides. By enabling substantially higher transmission efficiency versus legacy DFB solutions, our L-EML transmitters give MSOs a cost-effective powerful tool to break bottlenecks in their networks without ripping up and replacing their existing linear based infrastructure," he adds.

All end-markets grew sequentially, with CATV driving the largest upside within the broadband market and Chips and Navigation products growing in line with expectations. Of total revenue, CATV comprised 71% (up from 66% last quarter, with L-EML products comprising over half of CATV revenue). Of the 29% in non-CATV revenue, Chips comprised 10%, Satcom video & wireless 9%, and Navigation 10%.

In the chip market, Emcore continued to see sequential growth, driven by increased demand in 2.5 GPON products within China. "We see this growth trend accelerating substantially in Q4, with strengthening demand in both PON and non-PON-related products driving the increase," says Rittichier.

On a non-GAAP basis, full-year gross margin fell from 35.1% in fiscal 2017 to 22.2% in fiscal 2018. But, despite still being well down on 36.9% a year ago, quarterly margin has more than doubled from 7.3% last quarter to 18.1% in fiscal Q4. This was driven by unique events in Q3 that did not repeat in Q4, offset by additional excess & obsolete (E&O) charges due to accelerating adoption of L-EML products, incremental long-term inventory impairments and expediting charges related to sourcing raw materials for the L-EML order. The latter expenses totaled $1.5m (6% of sales). Pro forma for these expenses, gross margin would have been 23.5%, within expectations as the firm continues to increase chip capacity and transition to L-EML-based transmitters (which in the near-term carry a lower gross margin than the corporate average).

Operating expenses (OpEx) have risen further, from $8.9m a year ago and $9.1m last quarter to $10m (with full-year OpEx rising from $34.8m for 2017 to $36.8m for 2018). "In Q4, we continued to increase our R&D investments in Navigation products, while selling, general & administrative (SG&A) was primarily impacted by an increase in consulting and litigation-related expenses (rising from $0.13m to $1.17m)," notes chief financial officer Jikun Kim.

Compared with income of $14.3m ($0.52 per diluted share) for fiscal 2017, full-year fiscal 2018 yielded a pre-tax loss of $11.3m (–$0.41 per diluted share). But quarterly loss has been halved from $6.7m (–$0.26 per diluted share) last quarter to $3.3m (–$0.12 per diluted share) in fiscal Q4, although this compares with income of $3.4m ($0.12 per diluted share) a year ago.

Capital expenditure (CapEx) rose from $1m last quarter to $2.8m (out of $6.6m for the full year). Depreciation remained at $1.5m. Cash and cash equivalents fell by $2.2m over the quarter and $5.2m over the year to $63.1m.

"In the fourth quarter, we received a sizable L-EML order which was well above our customer's original forecast. While we do not expect this level of activity to repeat in the first quarter, we are encouraged by the overall pace at which the industry is moving to this technology," says Rittichier. "We expect that our CATV business will be on a solid footing in fiscal-year 2019," he adds. "We've also entered the year with robust backlog in our Navigation and Chip product lines and look forward to realizing growth in these areas."

For fiscal Q1/2019 (to end-December 2018) Emcore expects revenue of $23–25m, with growth in all three non-CATV product lines helping to offset a more normalized demand environment within the CATV market. "With the inventory overhang [in legacy DFB products] now exhausted, we expect demand for these products to serve as a baseline to cable TV product revenue as our customers transition to L-EML solutions," says Rittichier. L-EML products could rise to 60–80% of CATV revenue in full-year fiscal 2019, it is reckoned.

www.emcore.com

First Solar expects full-year revenue to grow to $3.25–3.45bn in 2019

Margins and profit to rise as OpEx is cut, despite Series 6 module ramp-up and plant start-up expenses

First Solar Inc of Tempe, AZ, USA — which makes thin-film photovoltaic modules based on cadmium telluride (CdTe) and provides engineering, procurement & construction (EPC) services — has forecasted full-year 2019 net sales of $3.25–3.45bn (up from the $2.3–2.4bn for 2018 forecasted in late October), of which solar power systems should comprise 55–60% and third-party modules the remainder (with shipments representing 5.4–5.6GW of energy-generating capacity).

Gross margin should rise to 20–21%, inclusive of production ramp costs of $20–30m.

Despite including plant start-up expenses of $90–100m from the deployment of Series 6 module capacity in 2019, operating expenses are expected to be cut to $390–410m.

Operating income should rise to $260–310m (up from 2018's forecasted $90–110m), yielding earnings per share (EPS) of $2.25–2.75 (up from 2018's forecasted $1.40–1.60).

Capital expenditure (CapEx) is expected to fall to $650–750m (from $800–900m). Due mainly to the continuing investment in new Series 6 capacity, the net cash balance (cash, marketable securities and restricted cash minus expected debt) is projected to drop further, from about $2–2.2bn at end-2018 to $1.6–1.8bn during 2019.

www.firstsolar.com

Series 6 PV module completes CSA/ANSI C450 Test Protocol

First Solar says that its Series 6 cadmium telluride (CdTe) thin-film photovoltaic (PV) module technology has met completion criteria in the newly published CSA/ANSI C450, PV Module Testing Protocol for Quality Assurance, which is administered by CFV Solar Test Laboratory in Albuquerque, NM, the ISO17025-accredited PV test center that is jointly owned by the standards and research organizations CSA Group, Fraunhofer ISE and Fraunhofer CSE. The test results provide confidence in the harsh-climate durability and long-term performance of Series 6 modules, says First Solar.

"CSA/ANSI C450 is the first publicly available standard to address extended stress testing of PV modules beyond that required for safety certification and qualification," says Dana Parmenter, CSA Group's VP of industrial. "The public nature of the standard, with a Technical Committee consisting of key stakeholders in the PV industry, ushers in a new era of transparency and standardization for project developers, independent engineers and investors looking to evaluate module quality and reduce potential risks."

CSA/ANSI C450 consists of a portfolio of extended environmental tests including temperature cycling, damp heat exposure, mechanical load testing, UV exposure and PID (potential induced degradation) testing. The test protocols were established because of their effectiveness in replicating actual field failure experiences.

"This is a significant milestone demonstrating the robustness of our technology," says Lou Trippel, First Solar's VP of product management. "Our relentless pursuit of rapid innovation and evolutionary design has paid off with a unique market offering that enables maximizing value and reducing risk," he adds.

The Series 6 module attained IEC and UL certification earlier this year, so CSA/ANSI C450 is the third of three major independent laboratory tests completed in 2018 that support Series 6 reliability and durability in extreme conditions. In October, VDE completed successful Thresher Test evaluation of the Series 6 module, followed by Long Term Sequential testing in November.

www.firstsolar.com/en/Modules/Series-6

www.csagroup.org

Alta sets seventh consecutive single-junction solar cell efficiency record, at 29.1%

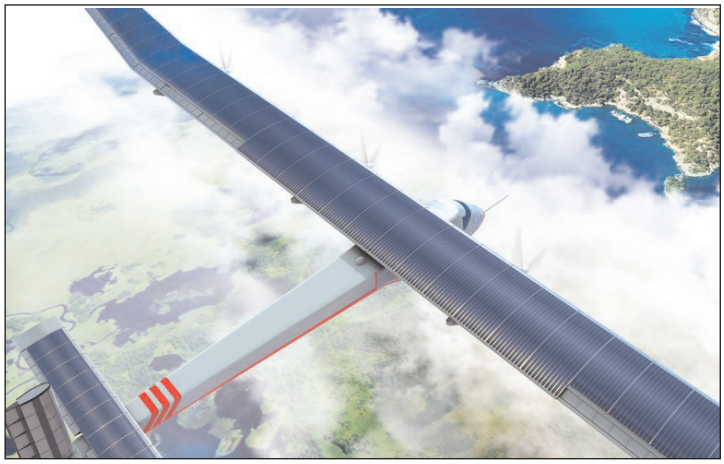
NASA selects Alta for Materials International Space Station Experiment

Alta Devices of Sunnyvale, CA, USA (a subsidiary of Hanergy Thin Film Power Group Ltd of Beijing, China since 2014) in November set a new solar energy conversion efficiency record for gallium arsenide (GaAs) single-junction solar cells (for the seventh consecutive time since 2010), certified by German solar energy testing laboratory CalLab at Fraunhofer ISE (Institute for Solar Energy Systems) at 29.1% (an increase from its 28.9% record announced in July). This is also the 13th cell or module solar efficiency record achieved by Alta (joining its single-junction solar module efficiency record of 25.1%).

Alta focuses on GaAs because of its unique advantages such as intrinsic high efficiency, excellent UV and radiation resistance, flexibility and low weight as well as its ability to generate electricity at high temperatures and in low light. The firm's solar technology is hence suited to powering products that need autonomous power such as small satellites, unmanned aerial vehicles (UAVs), electric vehicles (EVs) and autonomous vehicles (AVs).

In addition to Alta's technical advances (which push the limits of energy density), the firm's manufacturing economics enable formats and form factors that were previously not possible, it is claimed. GaAs is typically expensive to produce, but Alta invented a manufacturing technique that develops extremely thin layers (about 1μm thick - a fraction of the thickness of other GaAs solar cells). By utilizing a very thin layer of material with the highest energy density possible, the amount of material needed is low. System costs can hence be dramatically reduced.

Alta recently launched its Gen4 AnyLight solar technology, boosting power-to-weight ratio by 160% over its third-generation technology. Continuous advances in power-to-weight ratio are critical for future small satellites, autonomous UAVs, electric vehicles and autonomous sensors, notes the firm.



Unmanned aerial vehicles (UAVs) using Alta Devices solar cells. Source: Hanergy Thin Film Power Group.

Also, NASA is testing Alta's solar technology at the International Space Station (ISS) in order to evaluate it for future low-Earth orbit missions, including powering CubeSats.

"NASA's interest in Alta's record-setting performance demonstrates that our technology withstands some of the most challenging environments endured by autonomous systems in space, high altitude, and on land," says CEO Jian Ding.

Following years of collaboration, the US National Aeronautics and Space Administration (NASA) Marshall Space Flight Center (MSFC) selected Alta to participate in the MISSE-X (Materials International Space Station Experiment) flight investigation launched in November on board the NG CRS-10 mission. The goal of this test is to evaluate new solar cell and package technologies in support of future NASA missions requiring solar cells with high efficiency, high packing density and very low mass.

Alta engineers worked with MSFC scientists and vendors to develop an array of nine solar cells with innovative packaging materials. The cells were fabricated and delivered to NASA for testing during first-half 2018. Integration into the MISSE sample carrier was carried out at the Alphaspace facility in Houston, Texas in August, and the experiment was transported to the International Space Station by the NG-10 Antares rocket on 17 November. The solar cells will be installed into a zenith-facing position on the station in the coming weeks.

After one year of exposure, the solar cells will be returned for evaluation. NASA and Alta have developed scientific models to simulate how the solar cells may be affected by their on-orbit exposure, and the final sample evaluation will allow the teams to refine their models, enhancing the accuracy of predictions related to solar cell and package performance in future, longer missions.

"The High Efficiency, Low-Mass Solar Cell Systems experiment exposes candidate solar cells to the space environment," says NASA. "In addition, thin polymeric films, developed as cover slide materials for these solar cells, are exposed as separate samples, to measure atomic oxygen erosion yield and transmission changes due to ultraviolet radiation. The test results will be especially important for the design of small but highly capable spacecraft needed to explore our solar system."

www.altadevices.com
www.nasa.gov/mission_pages/station/research/experiments/2984.html

MehrSi project achieves record 22.3% efficiency for tandem solar cell with III–Vs grown directly on silicon

Fraunhofer ISE to speed development in new R&D center from 2020

In cooperation with partners, Fraunhofer Institute for Solar Energy Systems ISE of Freiburg, Germany has achieved a new energy conversion efficiency record of 22.3% for a multi-junction solar cell made of silicon and III–V semiconductor materials. The III–V layers were directly grown on the silicon.

Silicon solar cells dominate the photovoltaic market today but the technology approaches the theoretical maximum efficiency that can be achieved with silicon as the only absorber material. In contrast, tandem solar cells combine several absorber materials, enabling better energetic use of the solar irradiance spectrum and hence higher efficiency.

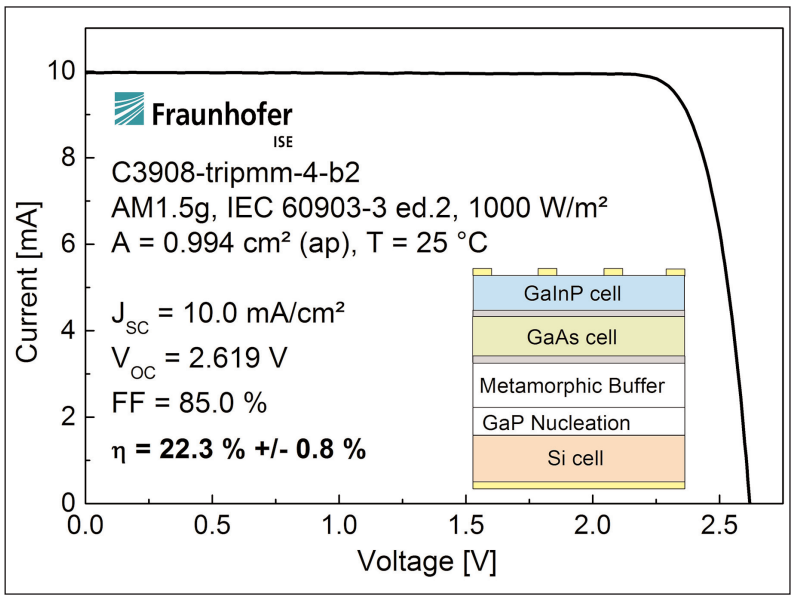
Combining best materials

By combining different semiconductor materials, researchers are attempting to surpass the theoretical efficiency limit of 29.4% for a single-junction silicon solar cell.

A promising approach is the combination of silicon material with III–V semiconductor compounds like gallium arsenide (GaAs), for example by first depositing the III–V solar cell structures on GaAs substrates then transferring to a silicon solar cell using semiconductor bonding technology and lastly etching away the GaAs substrate.

However, a less costly approach is to directly grow the III–V layers on the silicon solar cell. The atomic structure must be controlled extremely well during growth so that the gallium and phosphorous atoms arrange on the correct lattice sites at the interface to the silicon material. Also, the distance between the atoms in the crystal lattice must be increased in order to produce the GaAs material.

Researchers have been working on these challenges for over ten years. Now they have been able to greatly reduce the defect density in the III–V layers on the silicon and have successfully produced a III–V/Si tandem solar cell with a new efficiency record of 22.3% using this direct-growth approach. The efficiency value was published on 25 December in the internationally recognized table of the best research-cell efficiencies worldwide.



Current–voltage characteristic of new III-V/Si tandem solar cell with 22.3% efficiency. III-V layers were directly deposited on the silicon bottom cell in an epitaxial process. To match the atomic bonding between atoms in the crystal structures, a nucleation layer of GaP and a metamorphic buffer was introduced between the Si and GaAs. Optimizing these transition layers was a main challenge in the project.

Direct growth of III–Vs on silicon is "an important research approach for tandem solar cells," says Fraunhofer ISE director Dr Andreas Bett. "We are presently building a new research center for high-efficiency solar cells. Our work on tandem cells will be carried out in the new facilities upon its completion in 2020," he adds. "With the improved technical infrastructure, we expect the developments in multi-junction solar cells based on silicon to accelerate rapidly."

Within the MehrSi project over the past few years, the junction between the silicon crystal and the first III–V semiconductor layer of gallium phosphide (GaP) was investigated and continuously optimized in close cooperation with the research groups of professor Thomas Hannappel at TU Ilmenau and professor Kerstin Volz at the Philipps University Marburg. The defects in the crystalline structure were first made visible and then reduced step by step. "The record efficiency of our III–V/Si tandem solar cell demonstrates that we have achieved a very good understanding of the materials," says MehrSi project coordinator Dr Frank Dimroth. "With the successful direct growth of III–V layers on silicon, we can avoid using expensive III–V substrates for epitaxy," he adds. "This approach is, therefore, a key technology for the cost-effective manufacture of high-efficiency tandem solar cells in the future."

The MehrSi project, in which the record multi-junction solar cell on silicon was created, was financed by the German Federal Ministry for Education and Research (BMBF). Project partners were TU Ilmenau, the Philipps University of Marburg and metal-organic chemical vapor deposition (MOCVD) system maker Aixtron SE.

www.ise.fraunhofer.de/en/research-projects/mehrsi.html
www.nrel.gov/pv/assets/pdfs/pv-efficiency-chart.20190103.pdf

Solar Frontier raises thin-film solar cell efficiency record from 22.9% to 23.35%

Improved CIS absorber & enhanced surface treatment boost 1cm² cell

In joint research with the Japan National Research and Development Agency's New Energy and Industrial Technology Development Organization (NEDO), Tokyo-based Solar Frontier — the largest manufacturer of CIS (copper indium selenium) thin-film photovoltaic (PV) solar modules — has set a new record for thin-film solar cell energy conversion efficiency, achieving 23.35% on a 1cm^2 cell using cadmium (Cd)-free CIS technology. This is a 0.4 percentage point increase over the prior record of 22.9% that Solar Frontier set for Cd-containing CIS thin-film solar cells in November 2017. The new mark sets a record for all CIS thin-film solar cell types.

The technical development team that achieved the record efficiency.

The latest result was independently verified by Japan's National Institute of Advanced Industrial Science and Technology (AIST) in November.

The record was achieved through R&D on technologies such as CIS absorber engineering and enhanced surface treatment of the absorber — used together with Solar Frontier's proprietary Cd-free CIS thin-film technology. Making performance improvements to each of the technologies then combining them under optimal conditions led to the new record.

www.solar-frontier.com

Solar Frontier Americas acquires Canadian Solar's 210MWp Mustang Two solar project

Canadian Solar Inc says that its US-based utility-scale solar and energy storage project development subsidiary Recurrent Energy LLC has completed the sale of its 150MW$_{ac}$/210MWp Mustang Two solar project to Solar Frontier Americas (SFA).

"The Mustang Two transaction is the latest example of the strong demand we see globally for Canadian Solar's high-quality solar assets, given our ability to partner at various points in a project's development." says chairman & CEO Shawn Qu.

Located on 1400 acres in Kings County, California, the Mustang Two project is expected to create about 400 jobs during peak construction. Recurrent Energy will continue to manage development of the project, readying it for construction; Solar Frontier Americas will finance and manage construction. Due to achieve commercial operation in 2020, the project will then be operated by Solar Frontier Americas' growing independent power producer (IPP) business.

Solar Frontier Americas' completed Mustang Two solar project in Southern California.

"With this important acquisition, SFA further expands its US business to become an independent power producer, an owner of operating electric power facilities," says Charles Pimentel, CEO of Solar Frontier Americas' IPP business unit.

"We already have a substantial greenfield pipeline and are actively acquiring utility-scale projects and development assets to further scale our business."

Once the project is operational, the energy generated by the solar power facility will be split between two long-term power purchase agreements: Peninsula Clean Energy (the community choice energy agency that serves San Mateo County) is contracted to receive 100MW$_{ac}$, and the Modesto Irrigation District will acquire 50MW$_{ac}$. The combined energy generation from the two PPAs will power 37,500 homes.

www.recurrentenergy.com
www.canadiansolar.com
www.showa-shell.co.jp

Midsummer's record orders in 2018 driven by California and southwest US markets

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 reported record order intake of SEK265m ($29.3m; €25,8m] for 2018, driven mainly by increasing demand for its end products in the US market (specifically California and southwestern USA), where solar panel manufacturing partner Sunflare of La Verne, CA, USA has released several new products.

"California is a huge market and the state is far ahead of other regions in both regulatory and technical terms," says CEO & founder Sven Lindström. "All new homes built in California must have solar power installed from 1 January 2020 and the state has nearly half of US total installed solar power capacity," he adds. "Our partner Sunflare is investing heavily in this region and has launched several new innovative products in this market that has received great interest."

Solar energy accounts for nearly 17% of California's total energy production. The installed capacity is expected to double in the USA in five years, and more than half of all new electricity in the USA today comes from solar energy. The payback time for a solar energy system in California is shorter than four years, while the systems have a technical lifetime of at least 25 years.

California is a huge market and the state is far ahead of other regions in both regulatory and technical terms. All new homes built in California must have solar power installed from 1 January 2020 and the state has nearly half of US total installed solar power capacity

"We are witnessing a true revolution in renewable energy, with the United States as the driver, and the potential is simply enormous, not just in the southwestern United States but throughout the world," Lindström says. "Solar energy is very competitive, even without subsidies and also in cold countries," he adds. "The future lies in BIPV, building-integrated solar panels, which can easily be integrated with or attached to roofs, walls, vehicles, tents, over landfills, etc in urban environments and close to the end consumers," Lindström believes. "The only limit is production capacity. It would necessitate 435 of our DUO machines to manufacture solar panels to cover just 5% of California's membrane roofs."

Midsummer's revenue was SEK115m in 2017 ($12,7m; €11,2m) and SEK165m ($18m; €16m) in the first nine months of 2018, with operating profits of SEK25m ($2.8m; €2.4m), and SEK30.7m ($3.4m; €3m), respectively. Midsummer's annual report for 2018 will be presented on 22 March.

www.midsummer.se

Midsummer receives $7m order from Sunflare for new solar panel

Midsummer has received an order from solar panel maker Sunflare of La Verne, CA, USA worth over US$7m for thin-film solar cell production equipment, to be delivered in 2019 to a new solar panel factory in China.

"The type of flexible thin-film solar cells that Midsummer develops production equipment for is coming into increasing demand worldwide, not least because of its low weight and flexibility, which fits well in urban environments," says Midsummer's CEO Sven Lindström. "They are also produced in an environmentally friendly manner with simplicity of installation. As an example of how strong the global trends are: the recent decision in California that all new homes built in the state must have solar power installed from 1 January 2020, that's already in a year. There are over 70,000 houses built in that state alone each year. Other states are expected to follow, as well as other countries."

"The demand for our products in the US has exceeded our expectations, and we rapidly need to expand our production capacity with the help of our established partner Midsummer," says Sunflare's CEO Philip Gao. "Our new products, including our modern design-driven solar roof shingle, have attracted a lot of attention in the industry," he claims. "We are keen on delivering innovative solar in applications that have been largely unserved. The market is facing strong growth."

Sunflare provides mass-produced flexible CIGS thin-film solar cells that are especially suitable for weak roofs and new roofs for private homes as well as for factories and offices. Manufacturing takes place in China and the company focuses primarily on the Californian market and in the long term also on the rest of the USA and Asia.

"The future is very bright for solar energy, even without subsidies," says Lindström. "We have hired 40 new employees this year and expanded our factory in Järfälla with 1200m^2 to meet the demand for our products."

www.sunflaresolar.com

Mid-IR AlGaN quantum cascade detector on silicon

Device promising for integrated-optoelectronics technology, showing potential for ultra-fast operation at very wide spectral range

Technion-Israel Institute of Technology claims the first demonstration of an aluminium gallium nitride (AlGaN) quantum cascade detector (QCD) grown on 4-inch-diameter silicon substrates [Ben Dror et al, IEEE Electron Device Letters, published online 7 December 2018]. The detection wavelength was in the mid-infrared range (3–8μm). The long wavelength was enabled by inter-sub-band transitions (ISBTs) in the quantum cascade structure.

The team comments: "The successful implementation of [a] GaN ISBT optoelectronic device on silicon is promising [for] integrated-optoelectronics technology, showing great potential for ultra-fast operation at a very wide spectral range."

The QCD (Figure 1) was based on a 30-period cascade structure with an inter-sub-band transition energy of 267meV, corresponding to 4.49μm wavelength. The electron flow between stages was facilitated by longitudinal optical (LO) phonon-assisted tunneling. Infrared excitation of the structure produced a photovoltage.

The AlN/Si (111) 4"-diameter templates for the QCD structure were prepared by metal-organic chemical vapor deposition (MOCVD). The device layers were added by plasma-assisted molecular beam epitaxy (PAMBE) at 720°C.

Devices were fabricated on 7mmx7mm pieces diced from the epitaxial wafer. Mesas measuring 700μmx700μm were etched by inductively coupled plasma. The metal contacts consisted of titanium/aluminium (Ti/Al). The center of the top of the mesa was kept clear of contact metal as a window for front illumination into the absorbing layer.

The determination of the peak detection wavelength was hampered by the nearby presence of carbon dioxide absorption at 4.3μm (Figure 2). The researchers

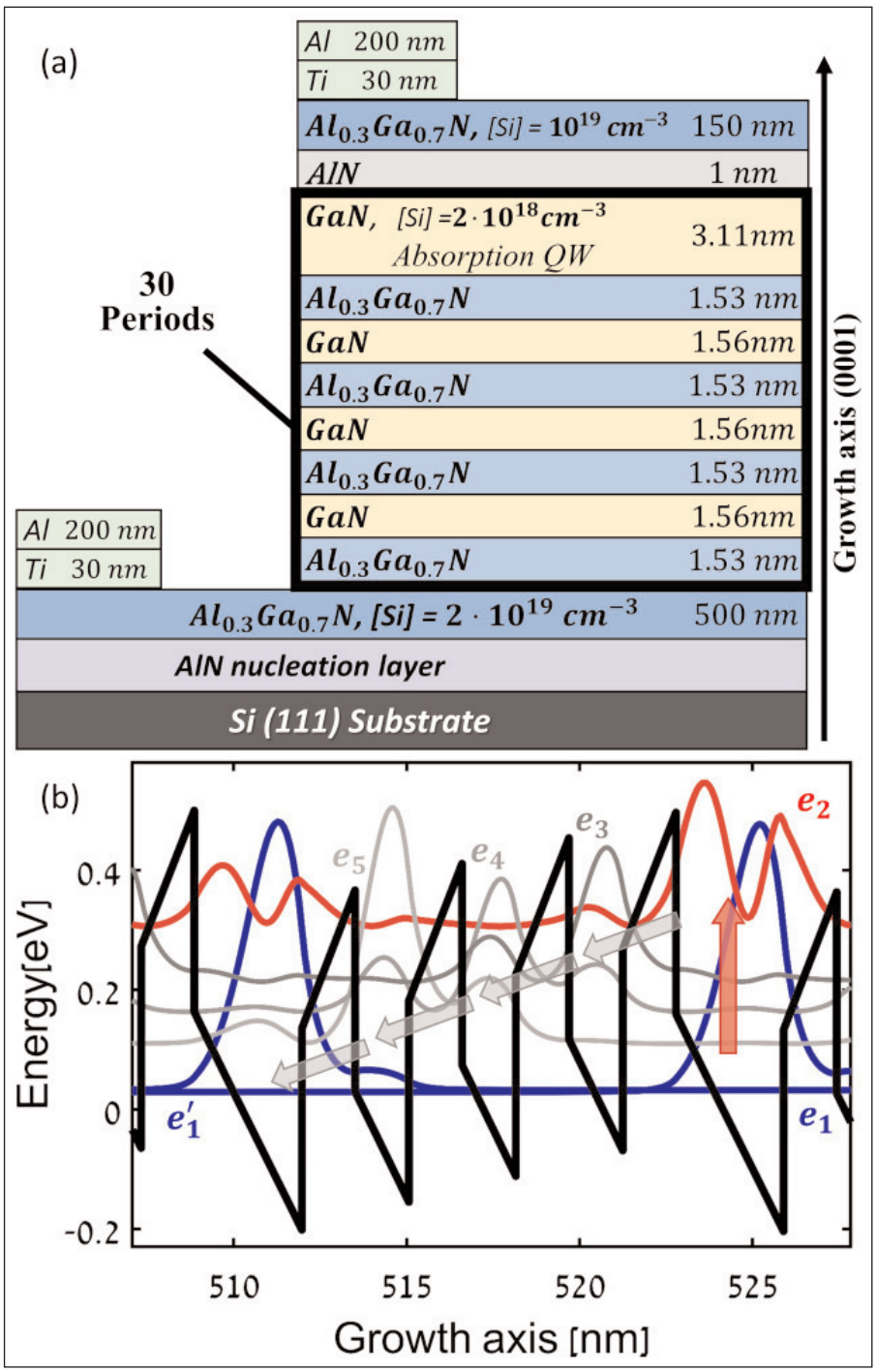


Figure 1. (a) Schematic of QCD structure. (b) Calculated conduction-band profile of 1.5 period of QCD's active area and shifted squared envelope functions of electronic bound states. Red vertical arrow indicates optical transition; gray arrows indicate transport direction of electrons in extractor region.

extracted a peak value of 4.14μm at 18K, red-shifting to 4.5μm at 150K. The 18K detection linewidth was 1.26μm full-width at half maximum (FWHM). The peak response also declines with increasing temperature, apparently disappearing into noise above 150K.

Absolute responsivity was measured using a 1000K silicon carbide globular blackbody source. At 18K, a measured photocurrent of 162pA corresponded to a 44μA/W response. The detectivity, which incorporates the responsivity, the area of the blackbody aperture, and the current noise spectral density (15.4fA/Hz$^{1/2}$), was 2x10^{8}Jones at 19K.

The researchers suggest a number of potential improvements: optimizing the trade-off between absorption, extraction efficiency and resistance; reducing unwanted diagonal transitions from the ground state to the extractor quantum wells, increasing resistance and decreasing dark current; enhancing electron transport by tailoring the energy levels in the extraction stage to the LO-phonon ladder; and, increasing the doping to boost electron density in the quantum well for greater absorption. ■

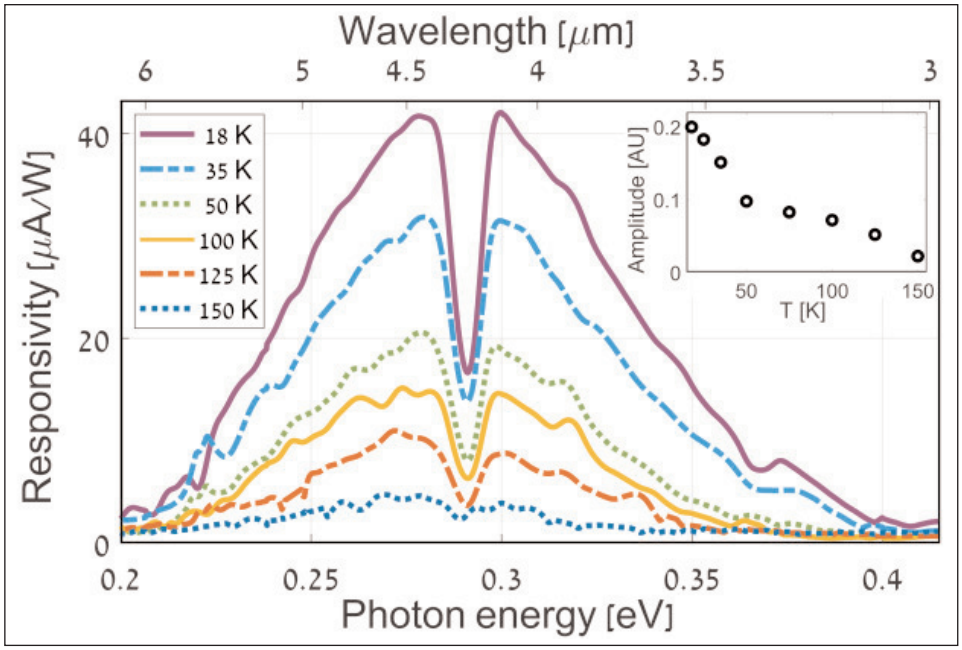


Figure 2. Spectral response of device. Dip is due to CO_2 absorption. Inset: temperature dependence of signal is shown – peak signal at 18K.

https://doi.org/10.1109/LED.2018.2885611

Author: Mike Cooke

Quantum dot laser diodes on CMOS-compatible on-axis silicon substrates

Devices deliver total light output power of more than 110mW near the mid-/long-haul optical fiber C-band infrared range.

Hong Kong University of Science and Technology (HKUST) has developed its on-axis indium phosphide (InP) on silicon (Si) as a template for indium arsenide (InAs) quantum dot (QD) laser diodes emitting at ~1.5μm [Si Zhu et al, Appl. Phys. Lett., vol113, p221103, 2018].

The researchers hope that such C-band (1530–1565nm) lasers could become part of the growing opportunities for low-cost silicon photonic (SiPh) optoelectronic circuitry. The team used on-axis (001)-oriented Si, which is the preferred substrate material for mainstream complementary metal-oxide-semiconductor (CMOS) electronics. Often off-cut Si substrates are used to avoid anti-phase boundaries and other defects in InP buffer growth.

The C-band emissions cover the low-loss range of mid-/long-haul optical fibers and commercial erbium-doped fiber amplifiers (EDFAs) for dense-wavelength division multiplexing (DWDM) data transmission. QD structures have advantages over quantum wells in terms of optical performance and defect tolerance. The latter property is important in heterostructure growth where different lattice structure constants and thermal behaviors create strains that more easily generate dislocations.

Substrates were prepared with V-grooves that relax misfit strain in the initial gallium arsenide (GaAs) buffer by creating twinned stacking faults (SFs) aligned to the {111} nucleation planes (Figure 1). The faults are then mostly trapped by silicon ridges at the head of the V-grooves.

When the GaAs growth from the grooves had coalesced, a 15-period superlattice of 5nm/5nm aluminium gallium arsenide ($Al_{0.3}Ga_{0.7}As$)/GaAs pairs gave a smooth growth front without pinholes or anti-phase boundaries.

After some more GaAs growth, an InP buffer was added, including three 10-period strained superlattices of 10nm/30nm $In_{0.6}Ga_{0.4}As$/InP as further dislocation filters. The superlattices were separated by 250nm InP spacers, grown at high temperature.

Plan-view transmission electron microscope (TEM) inspection gave a low defect density of $1.5x10^8/cm^2$, compared with typical threading dislocation levels of 10^9–$10^{10}/cm^2$ for InP/GaAs without filtering. The team comments that the defect density is among the lowest reported defect density values for InP films grown on silicon substrates by metal-organic chemical vapor

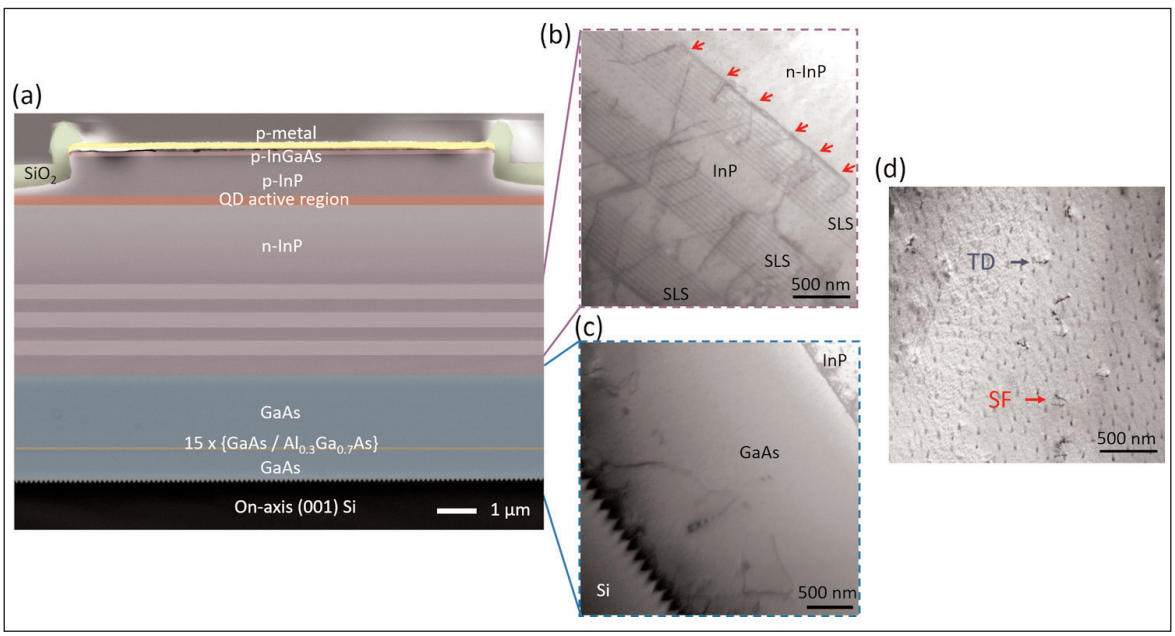


Figure 1. (a) Color-enhanced cross-sectional scanning electron microscope (SEM) image of whole epitaxial structure. Cross-sectional transmission electron microscope (TEM) images of (b) three stacks of 10-period InGaAs/InP strain layer superlattices (SLSs) with dislocation filtering effects identified by red arrows, (c) 2.2μm-thick GaAs intermediate buffer on nano-patterned V-grooved on-axis (001) Si substrate, and (d) plan-view TEM characterization of defect density of InP buffer on Si.

deposition (MOCVD).

The researchers optimized the five stacks of InAs quantum dot layers to reduce the inhomogeneous broadening of the photoluminescence by using a two-stage cap layer process. The first layer was 1.7nm $In_{0.52}Al_{0.29}Ga_{0.19}As$ grown at 510°C, the same temperature as the QDs. The second layer was 30nm 630°C $In_{0.52}Al_{0.29}G_{a0.19}As$.

The strongest peak was at 1512nm wavelength with 61.6eV linewidth. Although this was slightly wider than for QDs grown on InP substrate, the researchers say that their new material had over 4 times stronger peak intensity and 1.6 times narrower full-width at half maximum (FWHM) linewidth than previous batches of QDs on silicon.

There was also a number of other peaks that the team attributes to non-uniformity of QD sizes, as opposed to the effects of the stacking process. The areal density of QDs was ~$4.5x10^{10}/cm^2$.

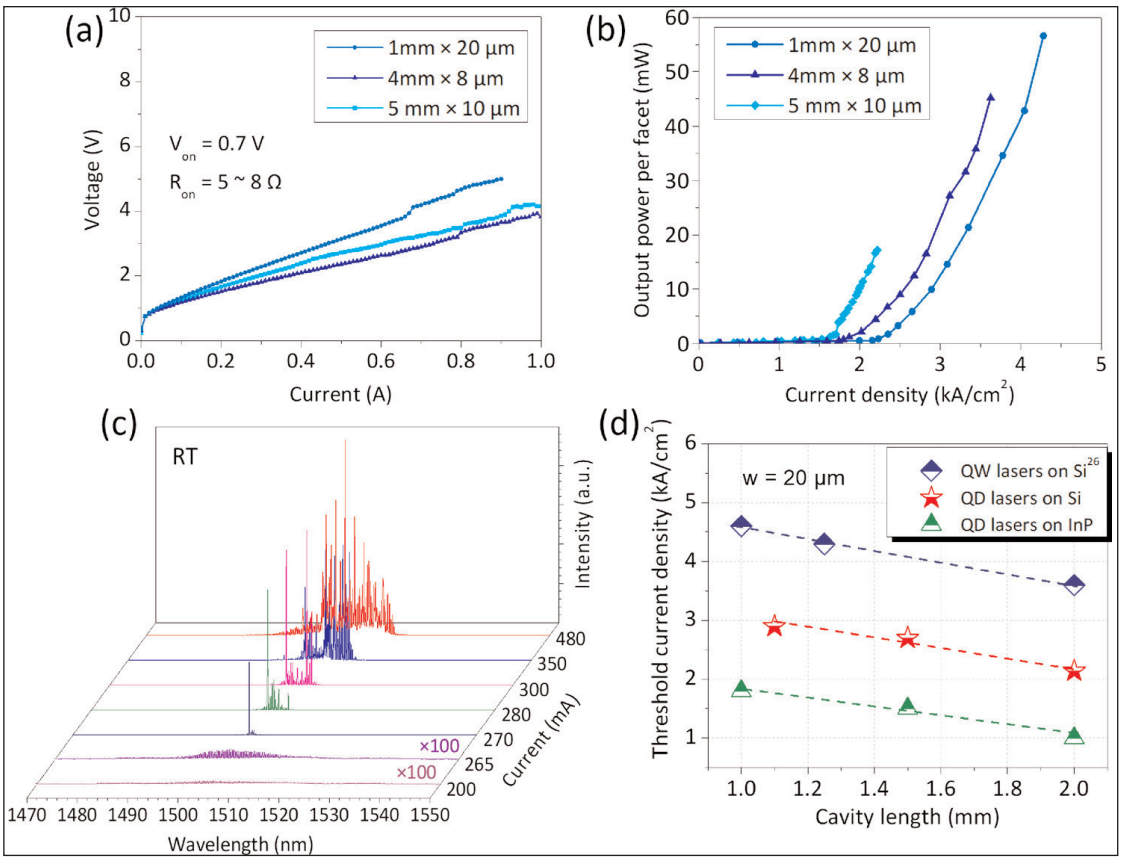


Figure 2. (a) and (b) Light output power-current-voltage (LIV) characteristics for three InAs/InAlGaAs/InP QD lasers grown on (001) Si substrate under pulsed operation at room temperature. (c) Emission spectra for 10μmx1000μm device at various injection currents. (d) Threshold current density distribution of optimized QD lasers on InP and Si, compared with QW lasers directly grown on (001) Si at varied cavity lengths (width 20μm).

The material was fabricated into standard ridge-waveguide edge-emitting lasers. The light-emitting/reflecting facets were cleaved and uncoated. The metal contacts were made on the epi-side since the III–V/Si interface had many defects, making it highly resistive to current flow.

The turn-on voltage of the device was 0.7V, while the laser threshold current density was 1.6kA/cm² from a 5mmx10μm cavity (Figure 2). The light output power reached 57mW/facet without saturation.

The devices were characterized using pulsed injection — devices grown on InP substrates have been reported that can operate in continuous-wave mode. Also, the Si-based threshold currents are about twice that of QD laser diodes grown on InP substrates.

The team hopes that further improvement of InP-on-Si templates will close this performance gap. On the other hand, the QD devices show a factor of 1.6 reduction of threshold compared with the group's previous quantum-well diodes on silicon. The team also reports that it has demonstrated wavelength tuning between 1478nm and 1523nm.

Varying the temperature of the devices between 20°C and 85°C, the researchers found the diode performance saturated around 10mW/facet at 80°C. The T_0 characteristic temperature for the threshold current was extracted as 58.7K. This is described as "a reasonable value for InAs/InAlGaAs/InP QD lasers". The researchers believe the T0 performance could be enhanced with p-type modulation doping. The wavelength stability of 0.3nm/K was found to be better than for QD lasers on InP.

The team comments on future prospects: "On-going work will be first focused towards continuous-wave (CW) operation by adopting the tunnel injection structures, in which QDs are separated from an InGaAs QW by an ultra-thin InAlGaAs barrier for more efficient carrier injection. Also, increasing the indium composition in the InGaAs interlayers to introduce a larger strain field would be beneficial for enhanced dislocation filtering. Additional structures like slotted grating couplers can be adopted forcing the light down from the epitaxial laser to the silicon waveguide to integrate with the existing SiPh circuits." ■

https://doi.org/10.1063/1.5055803

Author: Mike Cooke

GaN vertical-channel junction field-effect transistors

RWTH Aachen University claims the first experimental realization of quasi-vertical devices using selective-area regrowth.

RWTH Aachen University in Germany claims the first experimental realization of vertical-channel junction field-effect transistors (vc-JFETs) in a gallium nitride (GaN) epitaxial structure [Simon Kotzea et al, IEEE Transactions On Electron Devices, vol 65, issue 12 (December 2018), p5329]. One of the researchers involved is also associated with Aixtron SE, a producer of metal-organic chemical vapor deposition (MOCVD) equipment.

Vertical devices are attractive for high-power-density applications since the structure pushes peak electric fields away from surfaces into the bulk material, avoiding the need for surface passivation or field plates.

The researchers used lower-cost 2-inch sapphire substrates to produce quasi-vertical vc-JFETs by MOCVD. The back-side 'virtual' contact was achieved using a heavily n-type doped GaN layer (Figure 1). A true vertical device would have the drain contact conducting through the back-side of the wafer — this is not possible using insulating sapphire.

Most research on vertical devices uses the much more expensive option of free-standing or bulk GaN, allowing true vertical structures. In production, where cost would be a critical consideration, there would be several possible routes to true vertical devices — removal of the substrate or the use of conducting growth substrates such as free-standing or bulk GaN or silicon. The penalty for using silicon is lower material quality that increases leakage currents.

The RWTH device structure was grown by first applying a 2µm lightly doped n-GaN drift layer and a 20nm heavily doped n-GaN contact layer, followed by selective-area regrowth of heavily doped p-GaN using silicon dioxide as the hard mask protecting the channel during etching and MOCVD. The gate-to-gate (GTG) distance was 4µm. The channel width was 54µm.

The etching for the selective-area regrowth used a combination of dry and wet steps. The sidewalls of the channel were aligned with the m-plane of the GaN crystal structure to reduce dry etch roughness. Wet

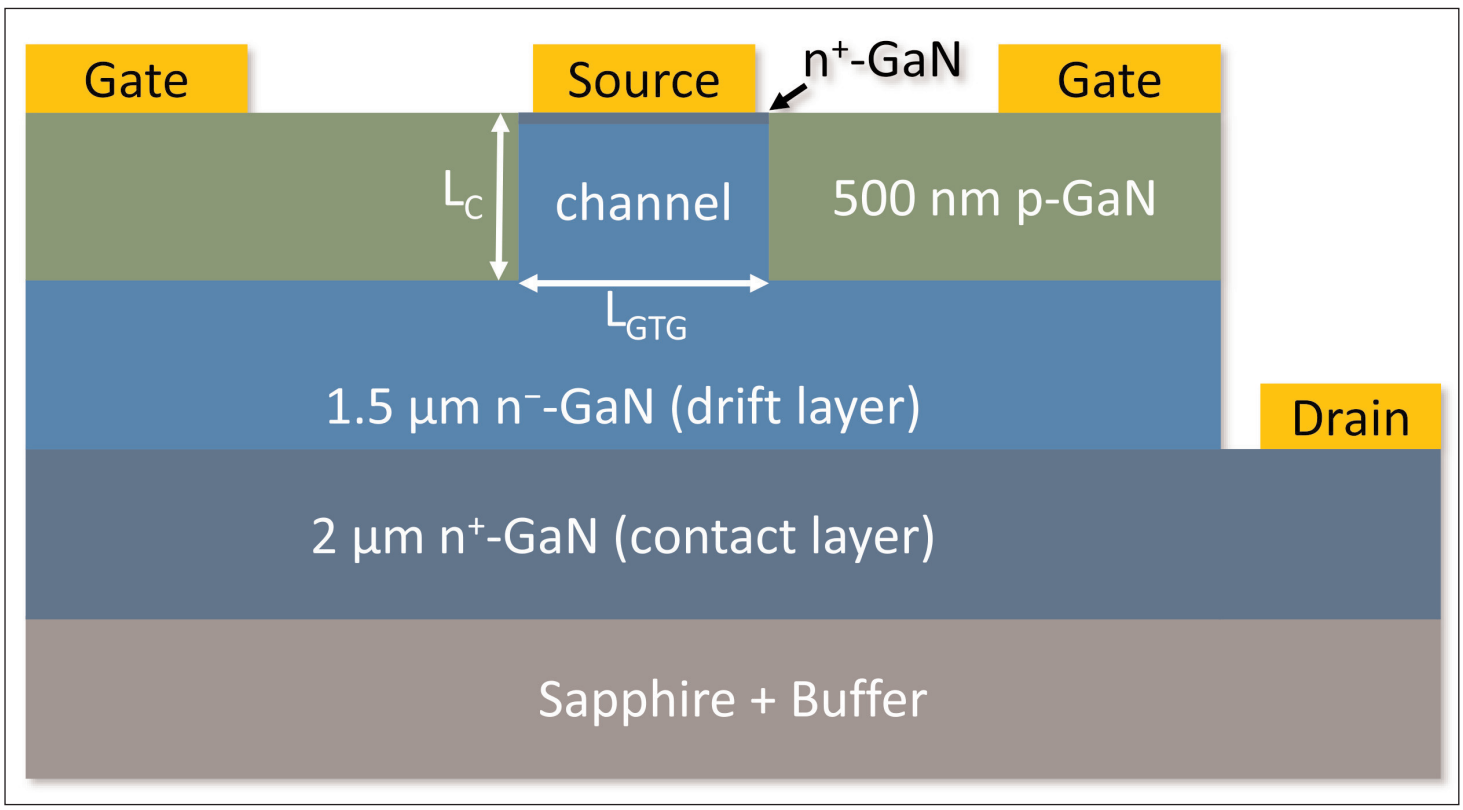


Figure 1. Schematic of quasi-vertical vc-JFET with selectively regrown p-GaN gate areas.

tetramethylammonium hydroxide (TMAH) treatment further flattened the sidewalls and removed etch damage from the c-plane surface at the bottom of the etch. After the p-GaN regrowth, the material was activated by annealing at 900°C for 900 seconds in nitrogen. The aim of the annealing was to remove hydrogen from the magnesium doping. Hydrogen–magnesium complexes interfere with the desired generation of holes in p-GaN material.

Metallization of the device consisted of titanium/aluminium/nickel/gold for the drain and source, and nickel/gold for the p-GaN gate. The drain electrode was deposited first, followed by the gate, and finally the source. The drain and gate electrodes were annealed at 830°C and 535°C, respectively. The source electrode was not annealed due to the temperature restriction of the p-GaN contact.

The drain contact was ohmic with 0.8Ω-mm contact resistance. However, the gate contact was non-linear with 900Ω-mm contact resistance at zero bias, while the source demonstrated Schottky-like behavior. These problems were related to the non-annealed nature of the source contact and the absence of a heavily doped p-GaN layer under the gate electrode.

The gate electrode allows modulation of the thickness of the depletion layer at the pn junction, choking off current in the channel region between the source and drain. The drift layer was of 'moderate' thickness, reducing the expected breakdown performance. The aim of the moderate drift layer was to allow easier access to the virtual back contact through dry etching.

Given the Schottky-like 'source' contact, the researchers decided to reverse the drain bias so the devices were operated as if the source was the drain and vice versa. The behavior of the devices including the Schottky turn-on voltage of around 0.5V delayed the current increase with drain bias. The specific on-resistance was 2.36mΩ-cm^2, normalized to the channel cross-section area. The gate leakage was two orders of magnitude lower than the drain current with gate potentials of magnitude up to 10V.

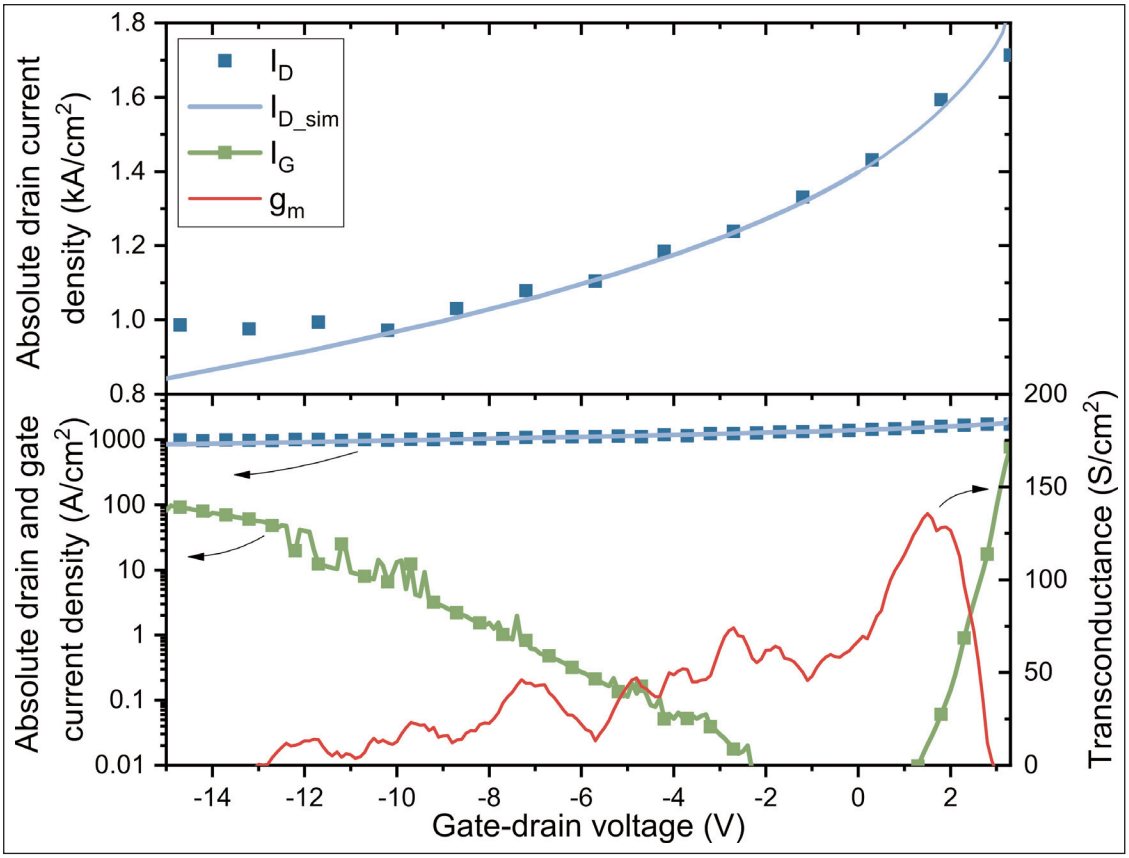


Figure 2. Drain and gate currents, and transconductance, transfer characteristics of quasi-vertical vc-JFET at 1V source–drain bias. Normalization to channel cross-section.

Vertical devices are attractive for high-power-density applications since the structure pushes peak electric fields away from surfaces into the bulk material, avoiding the need for surface passivation or field plates

Although the transistor did not pinch-off, the gate potential did modulate the drain current (up to a factor of 1.8 with the gate at –10V, Figure 2). Pinch-off would occur at around –112V, according to simulations. Bringing this in the single-digit range would require scaling the dimensions down, along with reducing the channel doping to increase the range of the space-charge region. The simulations suggested that the space-charge region only extended 1μm in from both sides of the 4μm gate-to-gate gap at –12V.

The simulations also suggested that normally-off enhancement-mode operation would result from a 1μm gate-to-gate distance, along with 5μm channel length and 5x10^{15}/cm^3 doping, giving a +2.3V threshold. The drift/channel doping of the experimental device was 1x10^{16}/cm^3, according to mercury capacitance–voltage profiling measurements. ■

https://doi.org/10.1109/TED.2018.2875534

Author: Mike Cooke

Increasing current performance in III–nitride p-channel transistors

Researchers fabricate a recessed-gate device with a channel consisting of a two-dimensional hole gas at the gallium nitride/aluminium nitride interface.

Cornell University and Intel Corp in the USA claim simultaneous records for on-current and on/off current ratio for enhancement-mode p-channel field-effect transistors (pFETs) based on a two-dimensional hole gas at a gallium nitride/aluminium nitride (GaN/AlN) interface [Samuel James Bader et al, IEEE Electron Device Letters, vol 39, issue 12 (December 2018), p1848].

Producing effective p-channel transistors in GaN-based devices would open up the potential of energy-efficient complementary p-/n-channel circuits. Unfortunately, such a development is hampered by the poor characteristics of hole transport in III–nitride materials relative to much higher-mobility electrons.

While the wide bandgaps of GaN and AlN are attractive from the perspective of power and radio-frequency electronics, this same property is at the root of the sluggish nature of hole transport. Wide gaps are associated with a large effective hole mass and low mobility. The wide gap also implies a deep valence band and generating holes is difficult since the best acceptor doping is provided by magnesium, which has an activation energy of the order 200meV, an order of magnitude higher than the typical thermal excitation energy at room temperature (~26meV). This makes the hole density exponentially smaller than the doping concentration.

A further challenge is providing enhancement-mode 'normally-off' operation in transistors, which is beneficial both in terms of power consumption and for fail-safety in high-power applications.

The structure (Figure 1) was grown on AlN-on-sapphire templates. Van der Pauw/Hall measurements gave 5.8×10^{13}/cm^2 hole density, 7.1cm^{2}V-s mobility, and 15kΩ/square sheet resistance. The relatively low

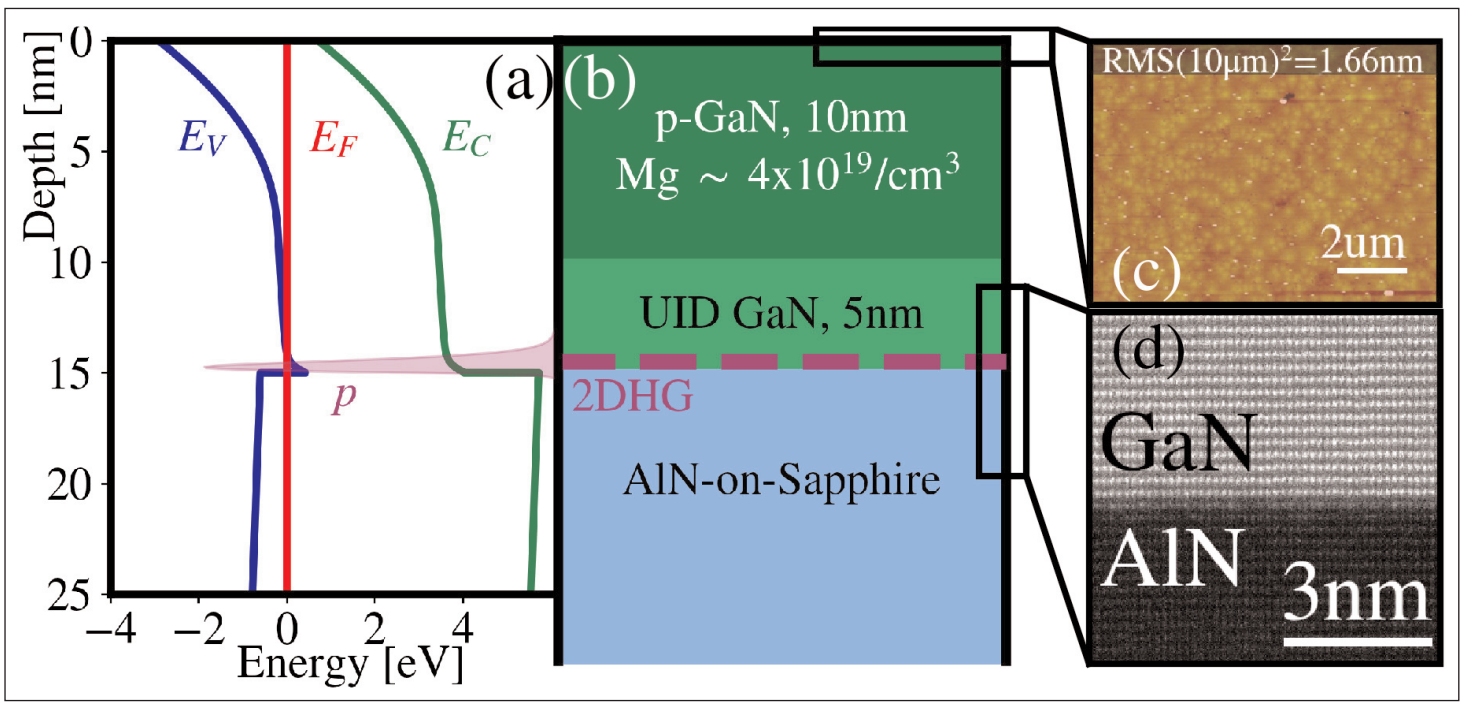


Figure 1. (a) Energy-band diagram and (b) layer structure of grown heterostructure. Holes (purple shade) are tightly confined to GaN/AlN interface, forming 2D carrier gas. (c) Atomic force microscope (AFM) scan, showing relatively rough (1.66nm root mean square) epi-surface due to high (for molecular beam epitaxy) doping levels, (d) cross-sectional transmission electron micrograph showing atomically abrupt GaN/AlN interface.

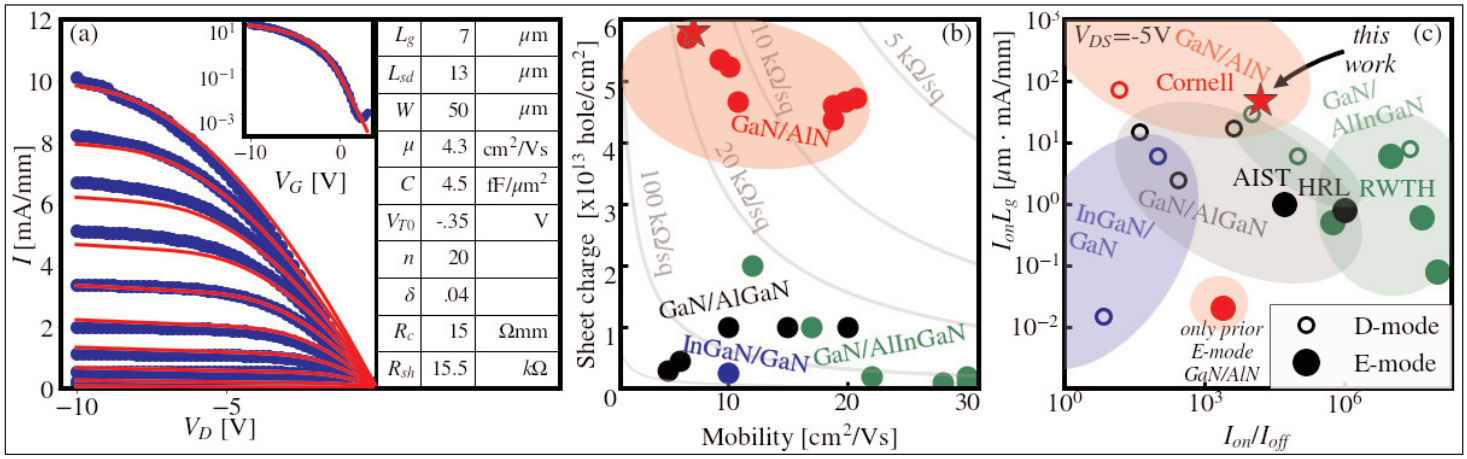


Figure 2. (a) Compact model (thin red) fitted to measured data (blue circles). (b) Sheet charge versus mobility for various reported III–nitride 2DHGs. (c) Benchmark of III–nitride pFET performance in terms of on-current and on/off current ratio.

sheet resistance promises to reduce access and contact parasitics. The mobility of electrons in two-dimensional electron gas AlGaN/GaN structures is typically more than 1000cm^2/V-s.

Simulations of the GaN/AlN structure gave an expected 5.3x10^{13}/cm^2 hole density. The simulations also predicted a low hole density in the overlying p-GaN of ~10^{11}/cm^2 due to the deep nature of the magnesium (Mg) acceptors with activation energy ~200meV. The bulk of the holes occur in the first couple of nanometers of the channel at the GaN/AlN interface, according to the model. This allows treatment of the charge carriers as belonging to a two-dimensional hole gas (2DHG). The high hole density is enabled by the large charge polarization difference between GaN and AlN.

The transistor structure was fabricated with mesa etching, source/drain ohmic contact deposition, and gate stack formation. The ohmic contacts consisted of 450°C annealed nickel/gold. The gate was recessed 10nm through the p-GaN layer. Recessing enables the gate region to be depleted, shutting off current flow at 0V gate potential, but not the access areas of the device.

The gate was insulated with 7nm silicon dioxide from atomic layer deposition (ALD) processing. The gate electrode was titanium/gold. Capacitance–voltage structures based on the gate stack revealed a negative threshold, suggesting a 2DHG with 4.5fF/μm^2 on-state capacitance.

The pFETs achieved current saturation and reasonable gate control. With 7μm gate length, a drain current of 10mA/mm was achieved with –10V drain bias. This compares with the previous best report for enhancement-mode GaN/AlN pFETs of 4mA/mm with –40V drain bias in a 2μm gate device. At –10V bias, the previous pFET only managed 0.04mA/mm. The on/off current ratio of 10^4 for the new pFET is also an order of magnitude better than previously.

Enhancement-mode GaN/AlInGaN pFETs with short 1μm gates have achieved 10mA/mm, but the researchers hope that scaling down the gate from 7μm could provide even higher drive currents.

The team attributes the high current–gate-length product ($I_{on}L_g$) to the low access and contact parasitics enabled by the low sheet resistance of the GaN/AlN structure (Figure 2). The researchers add: "The large bandgaps and band offset enable a thorough pinch-off, with the insulating AlN buffer preventing parasitic n- or p- leakage."

Benchmarking against other reports shows the GaN/AlN approach to have significantly higher sheet charge, due to the charge polarization discontinuity. At the same time, hole mobility is comparable with most other approaches. ■

https://doi.org/10.1109/LED.2018.2874190

Author:
Mike Cooke

Laser annealing enables gate-first fabrication of III-nitride transistors

A localized technique also results in 27% higher drain current than gate-last global rapid thermal processing.

South China University of Technology has used focused laser light to perform selective, micron-scale localized annealing of source and drain electrodes to enable gate-first fabrication of aluminium gallium nitride (AlGaN) high-electron-mobility transistors (HEMTs) [Zhikun Liu et al, IEEE Electron Device Letters, vol 39, issue 12 (December 2018) p1896].

Gate-first fabrication is standard in self-aligned silicon CMOS transistor fabrication. Adding gate-first GaN HEMT fabrication to the process palette could lead to novel integration options with Si CMOS such as creating new classes of digitally assisted RF mixed-signal and power conditioning circuits.

Typically, it would be preferred that the CMOS elements be processed before the AlGaN HEMTs. Unfortunately, thermal budgets of CMOS processing generally have an upper limit of 450°C to ensure that electrical performance is maintained. HEMT fabrication normally uses gate-last process flows because achieving ohmic contacts for source and drain electrodes needs very high temperatures of more than 800°C that would damage gate structures. These temperatures also clearly bust the thermal budget for silicon CMOS.

The HEMT structure consisted of a 20nm $Al_{0.25}Ga_{0.75}N$ barrier layer on a 150nm GaN channel/buffer. The two-dimensional electron gas (2DEG) channel was formed near the GaN/AlGaN interface with $1.0x10^{13}/cm^2$ carrier density, $1.5x10^3cm^2/V$-s mobility, and 450Ω/square sheet resistance.

The gate-first fabrication process flow began with plasma-enhanced chemical vapor deposition (PECVD) of 20nm of silicon dioxide. Electron-beam evaporation of nickel/gold gate metals was followed by patterning via lift-off lithography into 5μm-long, 600μm-wide gate

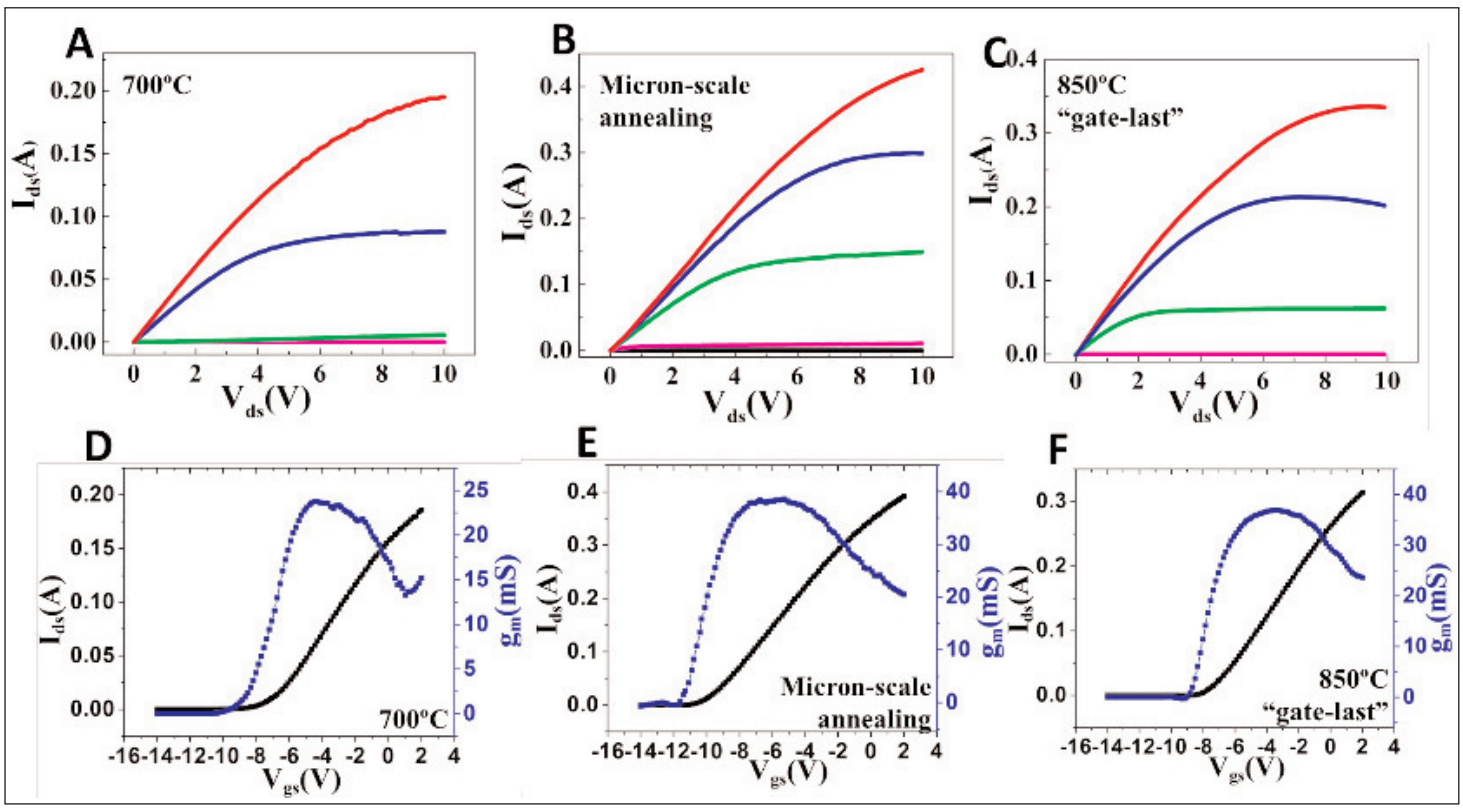


Figure 1. Output (A, B and C) and transfer characteristics (D, E and F) of devices processed by 700°C RTA , micron-scale annealing and gate-last approach, respectively.

structures. Patterned buffered oxide etching was used to remove the silicon dioxide insulation from the source/drain contact regions. Further electron-beam evaporation resulted in titanium/aluminium/nickel/gold source/drain electrodes. The source–gate and drain–gate spacings were 5μm and 10μm, respectively.

The annealing of the source/drain electrodes was achieved using 532nm continuous-wave laser light focused to a 3μm spot by a microscope objective lens. The aim was to thermally activate the out-diffusion of nitrogen from the AlGaN. The process was carried out in a home-made vacuum chamber at $5x10^{-3}$Pa pressure. Vacuum was critical for avoiding oxidation during annealing.

The laser spot scanned twice over the electrodes at 10μm/s speed. The laser power was between 0.84W and 0.96W for low-resistance contacts — the optimum was around 0.9W. Simulations suggested that the temperature at the center of the laser spot would be 850°C after 0.5s, while 6.5μm away the temperature would fall to 335°C.

Contact resistance as low as 0.3Ω-mm was achieved ($2.2x10^{-6}$Ω-cm^2 specific contact resistance). The researchers attribute the low contact resistance to the formation of a thicker ~35nm titanium nitride layer compared with the ~10nm of more conventional rapid thermal annealing (RTA). The thicker titanium nitride layer of the laser anneal is correlated with the formation of nitrogen vacancies in the underlying AlGaN, leading to the formation of an ohmic contact. Also, the fast temperature rise of ~2s allows nitrogen to escape through the titanium before titanium nitride crystallization at the interface.

Comparison gate-last devices were created with source/drain electrodes annealed rapidly at 850°C for 1 minute before reactive ion etching of the mesa and silicon dioxide deposition and gate formation. The contact resistance for this method was 0.8Ω-mm (7.2Ω-mm for 700°C annealing). Another effect of 850°C RTA was to increase the sheet resistance of the 2DEG to 600Ω/square, according to transmission-line method measurements. Further comparison devices were fabricated gate-first with lower-temperature RTA at

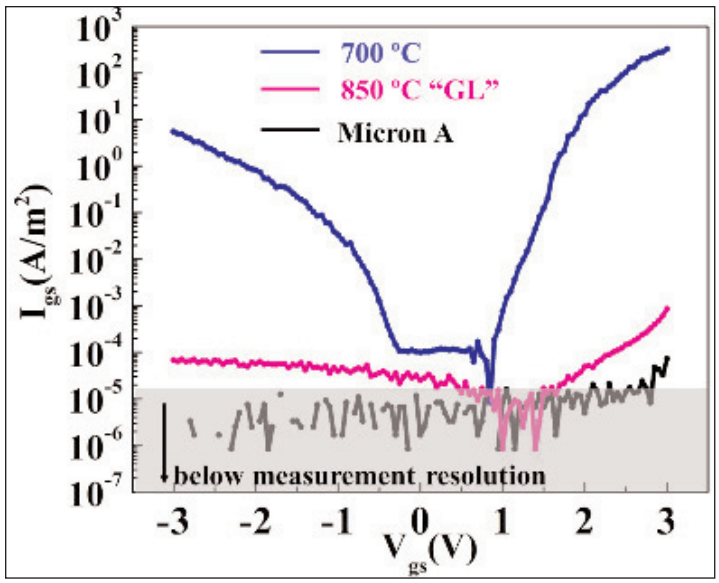


Figure 2. Gate current density-voltage (I_{gs}–V_{gs}) characteristics of GaN MOSFETs processed by RTA at 700°C, micron-scale annealing and gate-last approaches.

700°C and 800°C. The 800°C anneal destroyed the gate, while at 700°C the gate became defective, according to optical inspection.

The electrical performance of the gate-first micron-scale laser-annealed HEMTs showed higher drain current and transconductance compared with 700°C RTA gate-first and 850°C gate-last devices (Figure 1). With the gate at 2V, the maximum drain current for gate-first micron-scale annealing was 0.42A — 110% higher than for the 700° gate-first HEMT and 27% than the 850°C gate-last device.

The researchers point out that the profile of the transconductance laser-annealed device was flatter, suggesting better linearity and larger dynamic range in applications.

Micron-scale annealing also limited gate leakage to less than $7x10^{-5}$A/m^2 — comparable to the gate-last device and a factor of 10^6 lower than the gate-first 700°C HEMT (Figure 2). ■

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Author: Mike Cooke

Improving ohmic contacts in III-nitride high-electron-mobility transistors

Researchers insert gold layer between titanium and aluminium to improve both the static and radio-frequency performance.

The Indian Institute of Technology Bombay reports improved performance of III–nitride high-electron-mobility transistors (HEMTs) by a change in the composition of the source and drain ohmic metal contacts [Yogendra K. Yadav et al, IEEE Electron Device Letters, vol40, issue 1, p67]. The researchers compared a standard metal contact structure of titanium/aluminium/nickel/gold ('Ti/Al') with their new recipe of titanium/gold/aluminium/nickel/gold ('Ti/Au').

The Ti/Au contacts demonstrated low contact resistance and sharper edges that allowed the source–drain separation to be significantly reduced. The researchers explain: "Low contact resistance, sharp edge acuity and small source–drain separation is key for high-power and high-frequency applications."

The researchers worked on III–nitride material grown by metal-organic chemical vapor deposition (MOCVD) on silicon carbide (Figure 1). The barrier layer was aluminium gallium nitride (AlGaN). Transmission-line method (TLM) and HEMT metal contact structures were fabricated on the material. Mesa isolation was achieved by inductively couple plasma etch.

The ohmic source–drain metal contacts were subject to annealing at 830°C for 30 seconds in nitrogen. The HEMT structures included a nickel/gold Schottky gate: 100nm long with two 50μm wings, giving a total width of 100μm.

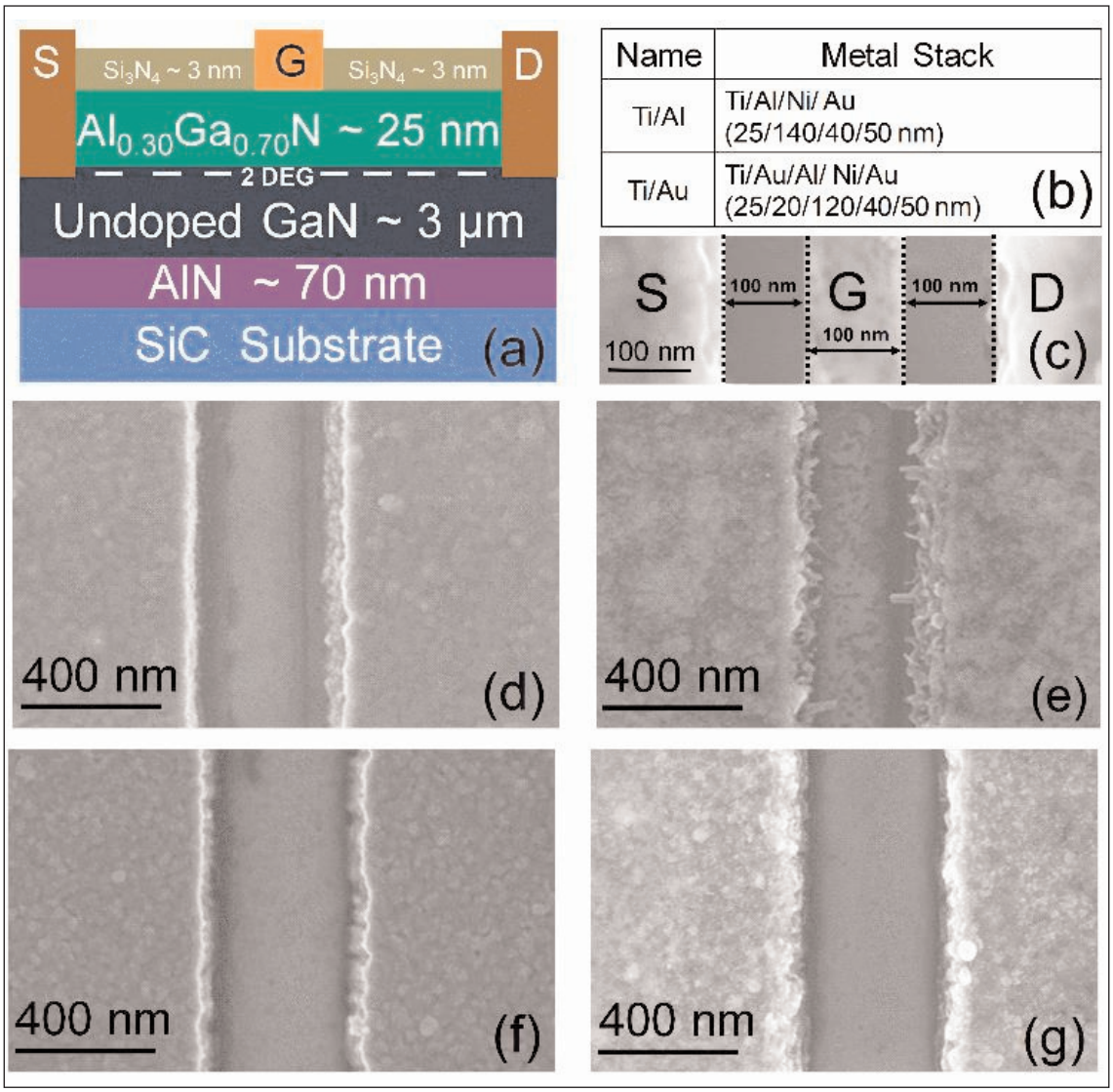

Figure 1. (a) Device schematic, (b) metal stacks, (c) SEM image of low source–drain separation HEMT; (d) & (e) SEM image of Ti/Al before and after annealing; (f) & (g) SEM image of Ti/Au before and after annealing.

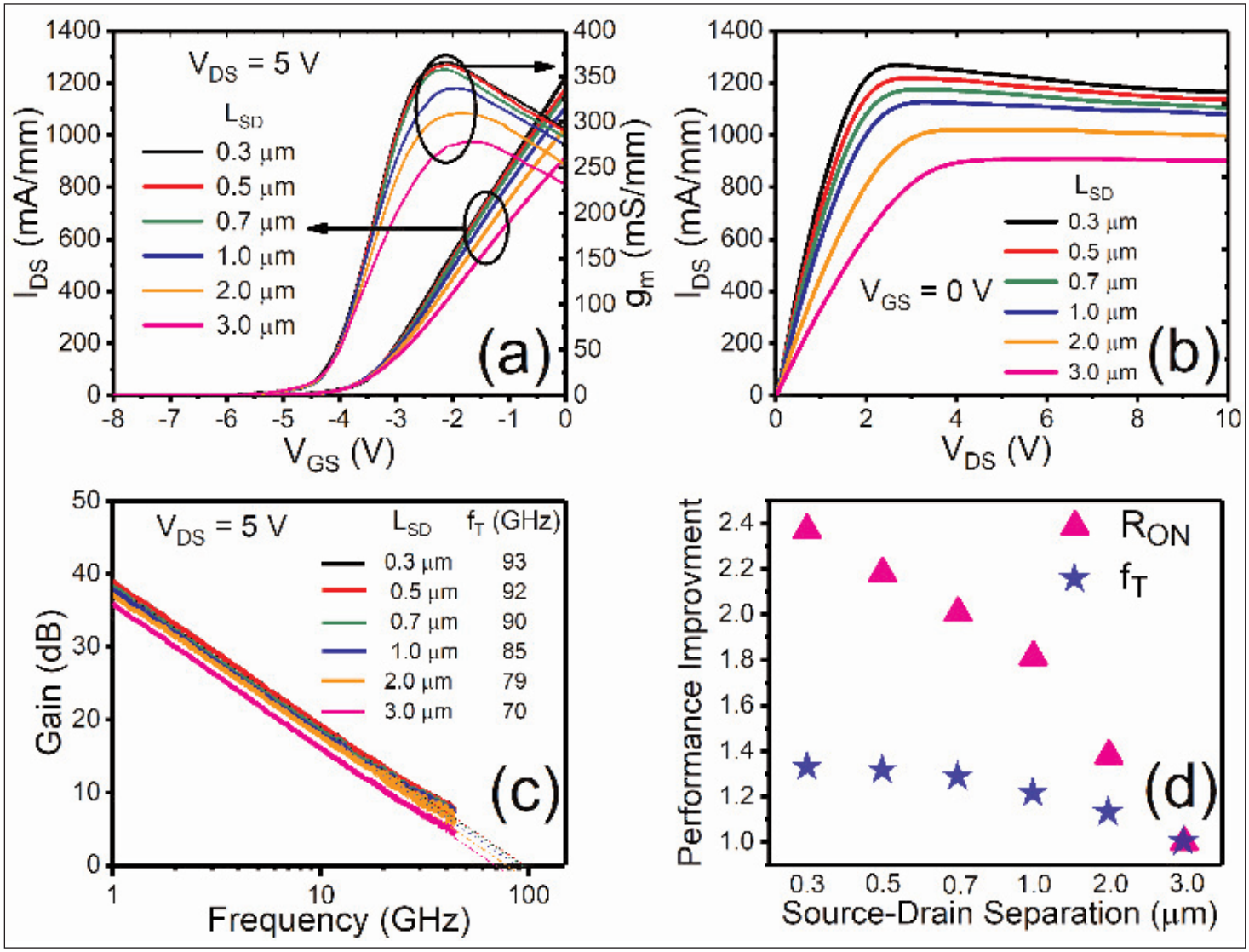

Figure 2. (a) Transfer characteristics of 0.100µmx100µm AlGaN/GaN HEMT at 5V drain bias. (b) Drain current–voltage (I_{DS}–V_{DS}) characteristics at 0V gate potential (V_{GS}). (c) Current gain (|h21|) (d) Performance improvement with source–drain separation scaling.

Scanning electron microscope (SEM) inspection showed that the Ti/Al structure suffered from significant lateral diffusion during annealing. The Ti/Au, by contrast, showed much sharper edge acuity.

Using the TLM structures, the researchers determined contact and sheet resistances: for Ti/Al, 0.67Ω-mm and 417Ω/square, respectively; for Ti/Au, 0.50Ω-mm and 420Ω/square.

On the basis of x-ray photoelectron spectroscopy (XPS), the researchers believe that the gold in the Ti/Au extracts gallium from the underlying III–nitride material, enabling the formation of more uniform TiN in the interface region during annealing.

As was to be expected, reducing the source–drain distance in the HEMT devices decreased the on-resistance (R_{ON}). At the same time, the breakdown voltage was also reduced due to the increased electric field. Knock-on effects of reduced on-resistance were increased saturation drain current at 0V gate potential ($I_{DS,sat}$) and peak transconductance (g_m). In frequency-dependent measurements, the lower resistance also enabled a higher unity current gain frequency (f_T).

The sharper edge acuity of the Ti/Au contacts enabled source–drain distances to be reduced to 300nm (Figure 2). This resulted in a number of performance improvements compared with 3µm separation (Table 1). ■

Table 1. Comparison of HEMTs with 3µm and 300nm source–drain separation.

Source–drain separation	3µm	0.3µm
R_{ON}	3Ω-mm	1.25Ω-mm
g_m at 5V V_{GS}	276mS/mm	365mS/mm
$I_{DS,sat}$	906mA/mm	1230mA/mm
f_T	70GHz	93GHz

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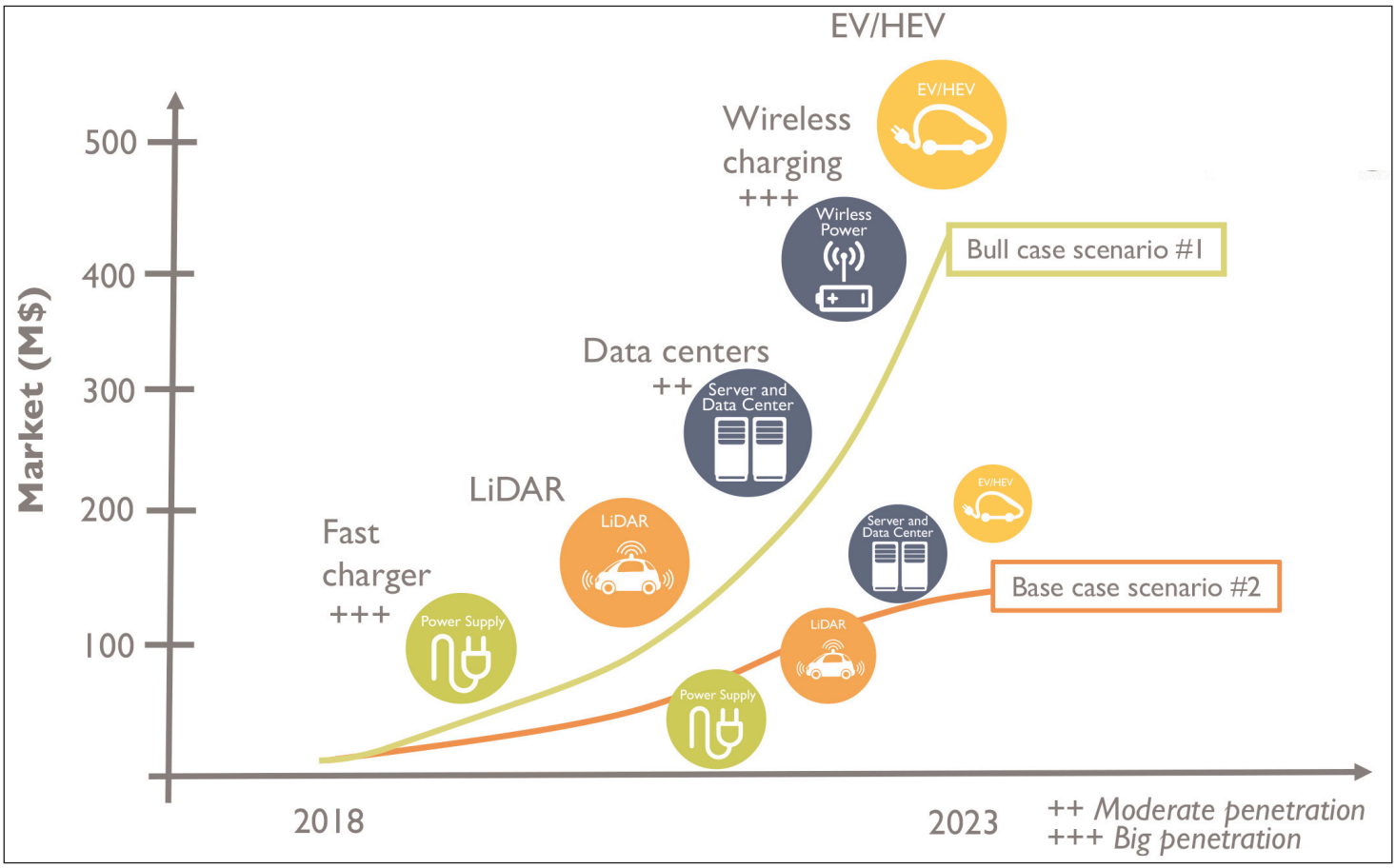
Author: Mike Cooke

GaN power market growing at CAGR of 55% to 2023, driven by power supply segment, or 93% if adopted for wireless charging in consumer electronics

Smartphone maker Apple could consider GaN technology, says Yole.

Over a long period, industrial companies followed the development of gallium nitride (GaN)-based solutions (mainly by R&D institutes and laboratories) at a distance. But since then, the context has changed. In its updated annual report 'Power GaN: Epitaxy, Devices, Applications and Technology Trends', market research firm Yole Développement has identified many power electronics and compound semiconductor companies (including leading players such as Infineon Technologies and STMicroelectronics) that are engaged in significant development projects. Some have already introduced GaN products to their portfolio, but this is not the case for the majority. So what is the status of GaN technology?

From the theoretical point of view, GaN offers fantastic technical advantages over traditional silicon MOSFETs: the technology is very appealing, and more players are entering. Moreover, the lowering of prices could make GaN devices good competitors for incumbent silicon-based power switching transistors.



GaN for power electronics applications: evolution of the market with two scenarios.

"Nevertheless, the technical panorama is not clear yet; every manufacturer presents its solution on die design and packaging integration," says Elena Barbarini PhD, head of the Semiconductors Devices department at Yole company System Plus Consulting. "This brings strong competition, which will accelerate technical innovations in terms of integration and better performances."

Even though the existing GaN power market remains tiny compared with the $32.8bn silicon power market, GaN devices are penetrating different applications.

The biggest segment in the power GaN market is still power supply applications, i.e. fast charging for cell phones. This year, Navitas Semiconductor Inc and Exagan introduced 45W fast-charging power adaptors with an integrated GaN solution. In addition, light detection and ranging (LiDAR) applications are high-end solutions that take full benefit of high-frequency switching in GaN power devices.

Also, what is the status of GaN solutions in the EV/HEV (electric vehicle/hybrid electric vehicle) market, which is step by step being dominated by silicon carbide (SiC) technology replacing silicon IGBTs in the main inverters? The SiC market will rise to US$450m in 2023, according to Yole's 'Power SiC' report.

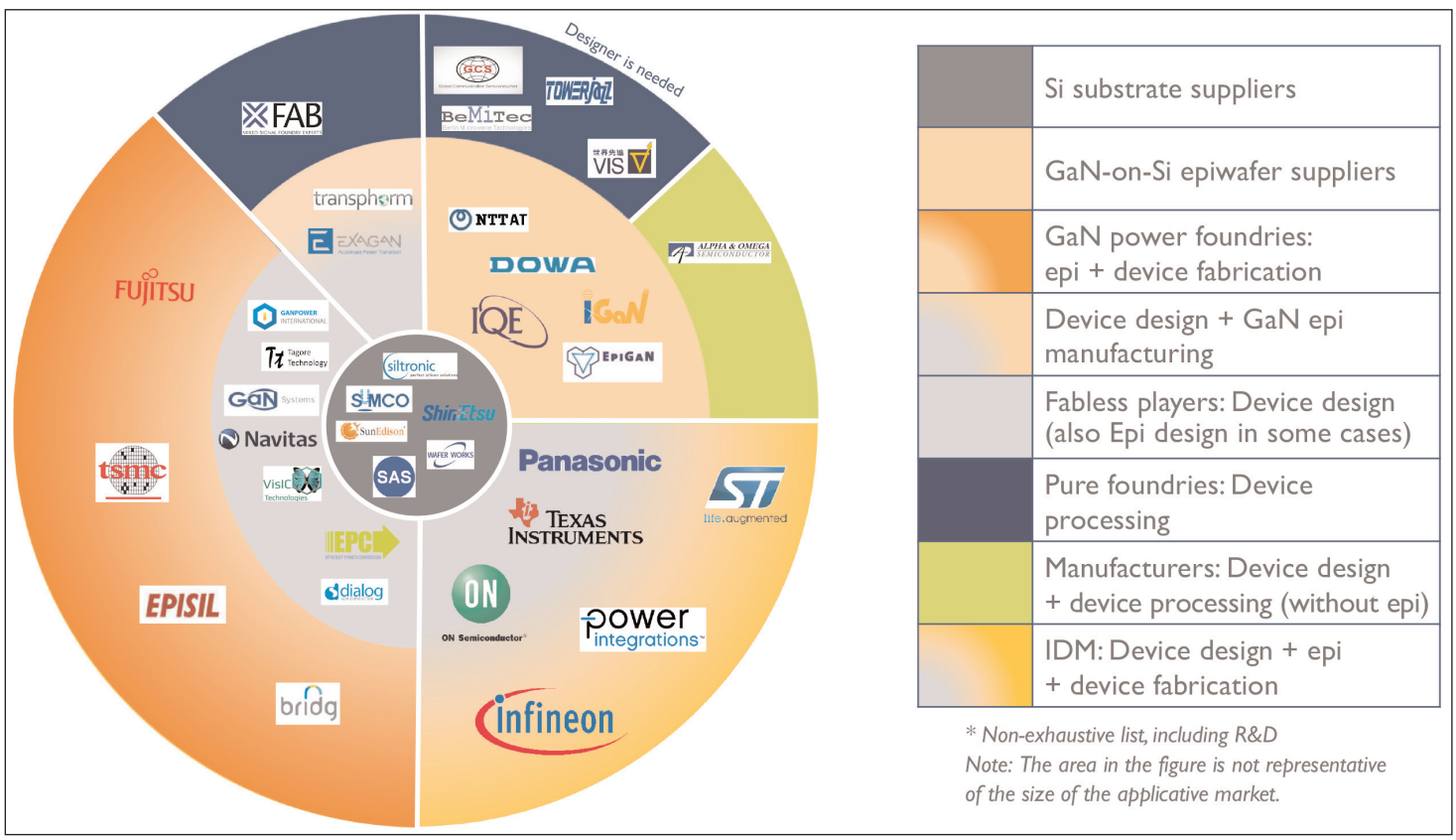
"The accumulation of the market growth in various applicative markets — especially the power supply market segment, which is the most important in that case — confirms our first scenario," comments technology & market analyst Ana Villamor PhD.

Under this 'Base Case' scenario, the GaN market is expected to rise at a compound annual growth rate (CAGR) of 55% between 2017 and 2023.

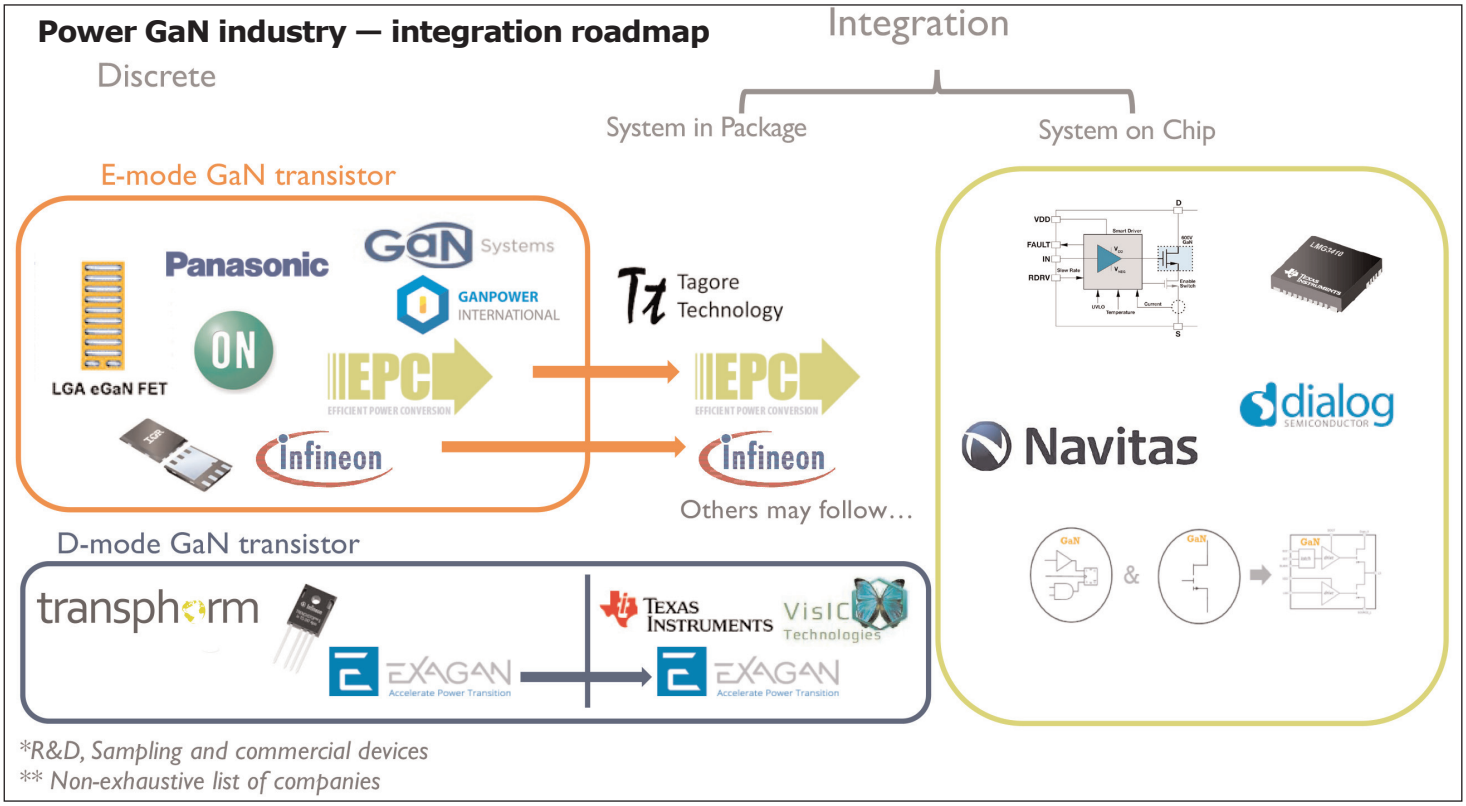
However, Yole's Power & Wireless team went further in their investigations, reckoning that there could be a killer application that causes the GaN power device market to explode. In fact, several industrial players confirm that smartphone maker Apple might consider GaN technology for its wireless charging solution. "Potential adoption of GaN by Apple or another smartphone giant would completely change the market's dynamics and finally provide a breath of life to the GaN power device industry," says technology & market analyst Ezgi Dogmus PhD, part of the Yole's Power & Wireless team. "We imagine that, after a company like Apple adopts GaN, numerous other companies would follow on the commercial electronics market."

What could be the added-value of GaN technology? Various players, such as Efficient Power Conversion Corp (EPC) and Transphorm Inc, have already obtained automotive qualification in preparation for the potential ramp-up of GaN. In addition, BMW i Ventures's investment in GaN Systems Inc clearly demonstrates the automotive industry's interest in GaN solutions for EV/HEV technology, Yole reckons.

Yole's second 'Bull Case' scenario is much more aggressive, conditioned by the adoption of GaN by leading consumer manufacturers for wireless charging. In this context, the GaN power market is rising at a CAGR of 93% from 2017 to $423m in 2023.



Power GaN industry overview 2018.



GaN supply chain

With eight years having passed since release of the first commercial power GaN devices, the power industry is becoming increasingly familiar with the names of start-ups that are actively promoting GaN technology. Not surprisingly, the list of pure GaN start-up players is getting longer: Efficient Power Supply (EPC), GaN System, Transphorm, Navitas and more are coming, according to Yole. Most of these start-ups have chosen the foundry model, mostly using TSMC, Episil or X-Fab as their preferred partner. Meanwhile, other foundries may offer this service if the market takes off. The foundry model affords fabless or fab-lite start-ups the possibility of ramping up quickly if the market suddenly takes off.

Along with these start-ups, firms with very different profiles (including industrial giants like Infineon, ON Semiconductor, STMicroelectronics, Panasonic and Texas Instruments) compete in the same field. In particular, several developments in 2018 caught the attention:

- Infineon announced it would start volume production of CoolGaN 400V and 600V E-mode HEMT products by the end of 2018;
- STMicroelectronics and CEA Leti announced their cooperation in developing GaN-on-Si technologies (for both diodes and transistors) on Leti's 200mm R&D line, and expect to have validated engineering samples in 2019. In parallel, STMicroelectronics will create a fully qualified manufacturing line (including GaN-on-Si hetero-epitaxy) for initial production running in its front-end wafer fab in Tours, France, by 2020.

These integrated device manufacturers (IDMs) will leverage their vertically integrated structure and bring to market cost-competitive products, says Yole.

A cost-effective solution?

If properly designed, the integration of GaN solutions into a final electronics product can increase system efficiency, and passive components will be smaller because the system can work at higher frequencies.

However, cost is a key consideration when introducing a new technology to the market, and it is currently not one of GaN's strong points. GaN's principal competitor is the silicon MOSFET, which has been on the market for many years and offers very competitive cost with high average efficiencies, excellent quality, and superb reliability. Currently, only one company, EPC, claims to be at the same price level as silicon with its low-voltage wafer-level package products. However, when standard packaging is added and the voltage is increased, a GaN product would cost more than the silicon alternative — and higher cost is often cited as a main barrier to adoption.

Many players have started building integrated systems in order to be cost-competitive at the system level. This is happening not only with depletion-mode (D-mode) solutions but also with enhancement-mode (E-mode) integrated solutions, which seem appealing for the end user as an easy-to-use product. Yole also finds system-in-package solutions that include silicon (i.e. Texas Instruments' and Exagan's products) as well as integrated solutions where the driver, ESD protection and other functions are monolithically integrated (i.e. Navitas' power IC products). ■

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High-speed and high-power semiconductor material advances

Mike Cooke reports on the wide spectrum of compound semiconductor advances reported at December's International Electron Devices Meeting in San Francisco.

At the International Electron Devices Meeting (IEDM 2018) in San Francisco (1–5 December), there were two main threads in the compound semiconductor contributions — high-speed and high-power devices. The first, speed aspect in general looks to narrow-bandgap materials, since these tend to have smaller effective masses of charge carriers and hence a higher-mobility response to the force supplied by electric fields. The second, power strand needs the ability to withstand high electric fields and voltage blocking, enabled by wide bandgaps, while maintaining low resistance in the on-state.

IEDM has contained presentations on compound semiconductor electronics with these aims for a number of years. While initially it was thought that high-speed, narrow-bandgap materials might replace the more traditional silicon and silicon germanium (SiGe) even for logic applications, the focus now seems more on working out ways for compound semiconductor radio-frequency devices to be combined with more conventional group IV materials (silicon, germanium, tin) providing the digital processing.

On the power side, there is a wider range of choices, and the question is finding the right materials and structures for particular applications to enhance the capabilities already on offer by silicon and such. An aspect that seemed missing this year from the wide-bandgap considerations was combined high-speed and high-power for radio transmission amplifiers for base-station and radar use.

Here we look at how these strands have been pushed forward in the research presented at IEDM.

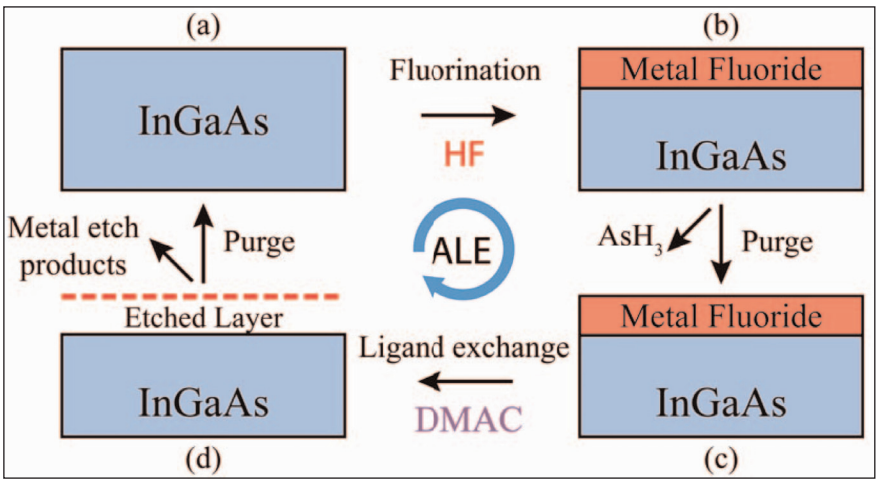

Figure 1. Schematic of InGaAs thermal ALE process: (a)–(b) fluorination of InGaAs surface with hydrogen fluoride, (c)–(d) ligand-exchange process by dimethylaluminum chloride to remove metal fluoride layer. Volatile etch products finally purged away.

High-speed performance

Fin structures

Massachusetts Institute of Technology and University of Colorado claimed the first demonstration of thermal atomic layer etching (ALE) of indium gallium arsenide (InGaAs)-based III–V heterostructures to create fin-gate transistors [Session 39.1]. "Also, we report the first transistors fabricated by the thermal ALE technique in any semiconductor system," the team adds.

The ALE technique was carried out in-situ in an atomic layer deposition (ALD) system at 300ºC. The researchers used the method to fabricate sub-5nm self-aligned fin field-effect transistors (FinFETs), claimed as the "most aggressively scaled" so far. Fins with widths down to 2.5nm were fabricated.

A number of record results in terms of peak transconductance (g_m) and subthreshold swing were achieved with 60nm gate-length (L_g) devices. The average transconductance boost was 60% — the researchers achieved 0.85mS/μm with 2.5nm-wide fins (W_f) and 1.9mS/μm for 18nm at 0.5V drain bias. The average subthreshold swing was 70mV/decade in the linear (S_{lin}) region, and 74mV/decade in saturation (S_{sat}).

The researchers attribute the improvements to high-quality metal-oxide-semiconductor (MOS) interfaces arising from the use of in-situ ALE–ALD, with ALE used for fin etching and ALD for applying the aluminium oxide or hafnium dioxide gate insulation.

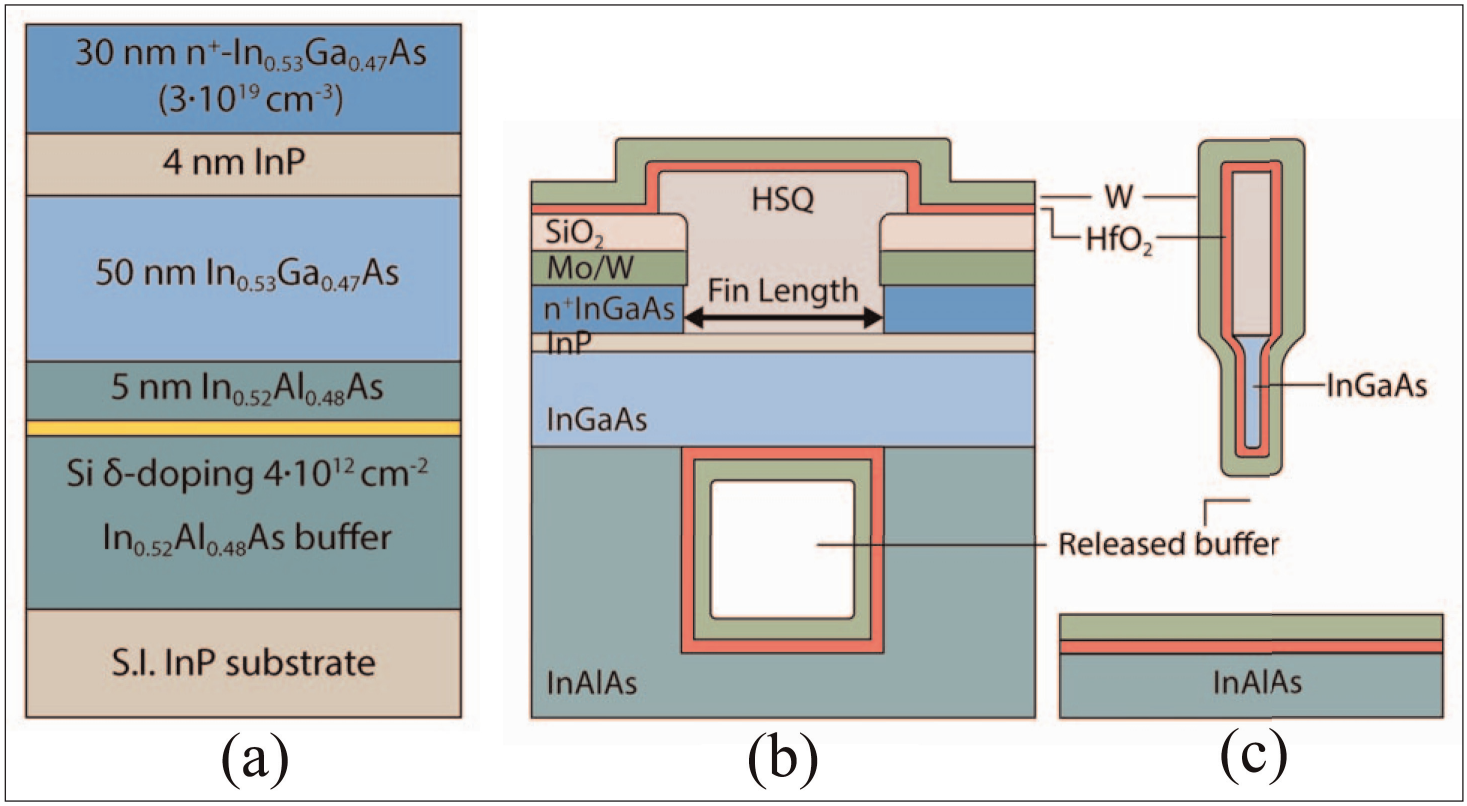

Figure 2. (a) Starting heterostructure for InGaAs n-channel FinFET fabrication. Cross-section schematics: (b) along fin length direction and (c) across fin.

The tungsten metal gate electrode was deposited in a separate ALD chamber.

Like ALD, thermal ALE is based on chemical ligand-exchange, enabling isotropic etch (Figure 1). For the thinnest finned FETs the structures were fully suspended from the buffer layer, resulting in gate-all-around structures (Figure 2).

The researchers comment: "With the usual caveats when making comparisons of this kind, our InGaAs FinFETs match the performance of Intel's 14nm node (W_f = 7nm), in spite of the lower V_{DD} and longer L_g. At W_f = 2.5nm, this work shows a record g_m/W_f > 30mS/μm. Given that this is the first demonstration of III–V MOSFETs by ALE and the first demonstration of working III–V FinFETs at W_f < 5nm, this work displays the great promise for both ALE technology and III–V devices."

Another series of record claims came from IBM Research Zurich and ETH Zurich in Switzerland [Session 39.2] for InGaAs-on-insulator on silicon FinFETs (Figure 3).

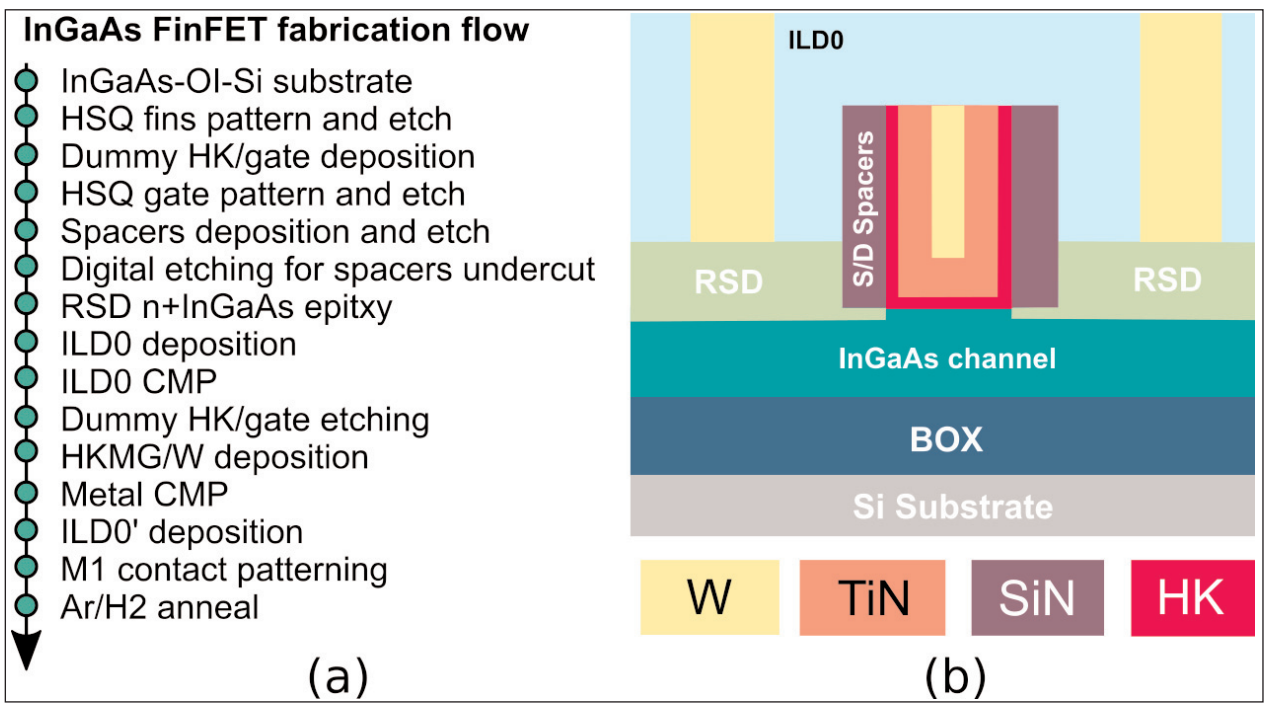

Figure 3. (a) Process flow describing self-aligned replacement-metal gate fabrication process for InGaAs FinFETs. (b) Schematic cross-section across gate.

The researchers used source/drain spacers and doped extensions to tamp down off-currents, which is difficult to suppress in narrow-bandgap high-mobility materials like InGaAs.

Devices with 20nm L_g, 10nm spacers and 15nm W_f achieved record high on-currents of 350μA/μm and off-current of 100nA/μm with 0.5V operation voltage (V_{sat}). The S_{sat} was 78mV/decade. The g_m was 1.5mS/μm. The InGaAs on buried oxide (BOX) insulator on silicon substrate was created by direct wafer bonding. The InGaAs channel layer was 20nm thick. The doped raised source/drain (R_{SD}) InGaAs contacts were 25nm thick.

MOS and CMOS

IBM Research GmbH Zürich Laboratory in Switzerland also claimed the highest reported combined cut-off and maximum oscillation frequencies (f_T/f_{max} of 370/310GHz) for III–V MOSFETs on silicon with 20nm gates [Session 39.4]. The InGaAs quantum well on silicon devices had gate lengths as short as 14nm. The replacement-metal gate fabrication process is said to be compatible with silicon CMOS processing, raising hopes for combining RF and digital signal processing on a single chip.

Again, spacers and self-aligned raised source/drain contacts are seen as significant enablers of enhanced performance. Also, channel mobility was increased three-fold using a 2nm/10nm/20nm InP/$In_{0.75}Ga_{0.25}As$/InP quantum well structure, relative to devices without the 2nm top barrier. The increased mobility was also reflected in 60% increased g_m. The InP/InGaAs/InP structures were transferred to silicon by direct wafer bonding.

IBM Research GmbH Zürich Laboratory further contributed to research at IBM T. J. Watson Research Center in the USA on a sub-50nm III–V FET on silicon with the highest on-current, according to the presentation [Session 39.5]. The device was a gate-all-around nanosheet InGaAs NFET grown using template-assisted selective epitaxy. The fabrication used a gate-last process and annealing in high-pressure deuterium. The latest work has managed to reduce the channel thickness to ~10nm. The best device had a 39nm L_g, giving 1.37mS/μm g_m, 72mV/decade S_{sat}, and 355μA/μm on-current at 0.5V gate potential and 0.5V drain bias.

The template-assisted selective epitaxy used metal-organic chemical vapor deposition (MOCVD) to grow III–V nanosheets from a silicon seed in a silicon dioxide tunnel mold on silicon-on-insulator (SOI) substrate (Figure 4). The gallium content of the InGaAs varied between 60% at the seed down to 40% at the end of the tunnel. The mold is formed by etching a 20nm-thick, 45nm-wide silicon nanosheet from the SOI material and enclosing it in oxide. The silicon nanosheet is then etched down to the seed from the other end of the tunnel structure.

Lund University in Sweden reported III–V MOSFET co-integration of n-type and p-type devices based on indium arsenide (InAs) and gallium antimonide (GaSb) channels, respectively [Session 39.3]. The self-aligned gate-last vertical nanowire devices achieved a balanced

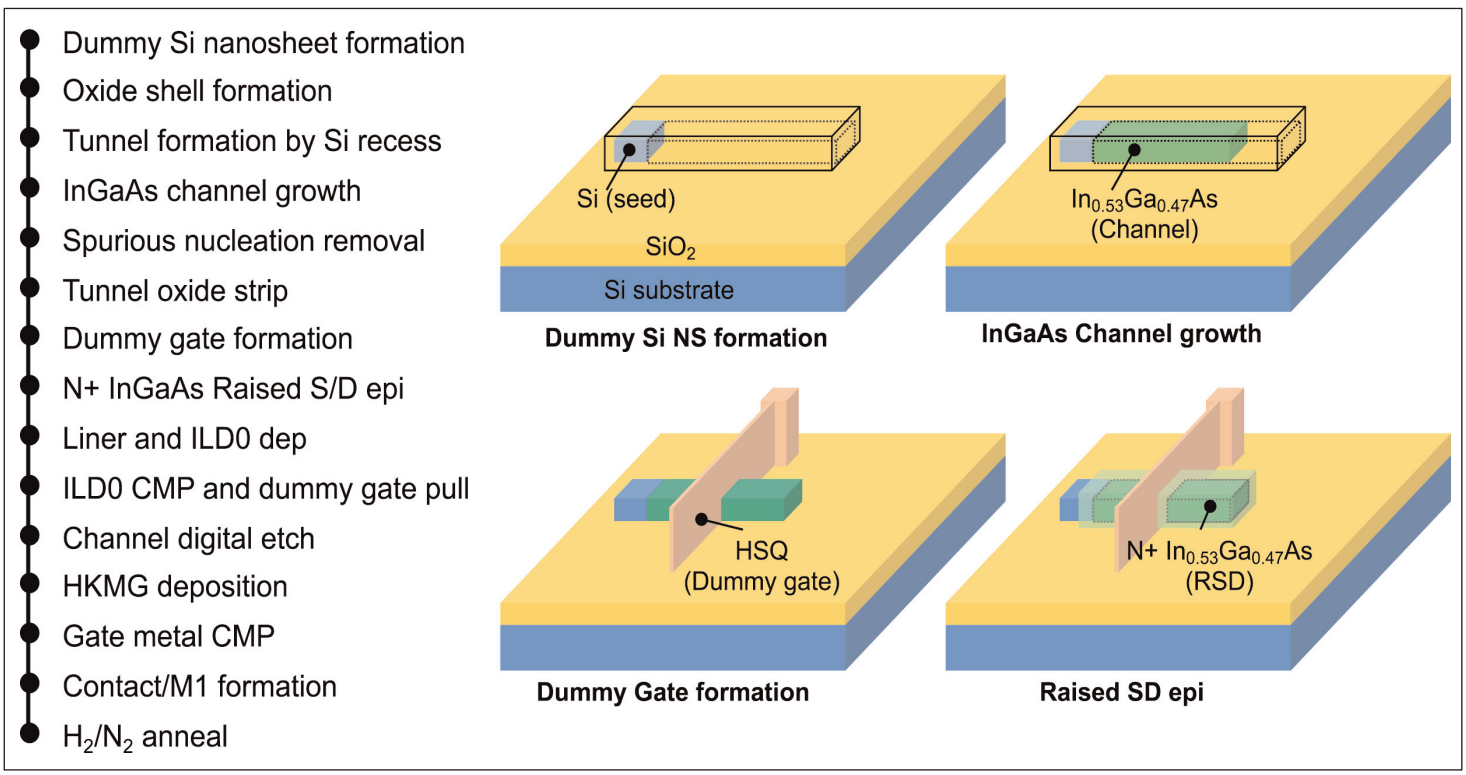

Figure 4. (left) Outline process flow of InGaAs nanosheet N-FET. (right) Schematics of process flow for nanosheet channel and raised S/D formation.

drive current at the 100μA/μm level. The off-current was 100nA/μm with the drain biased at 0.5V.

Tunneling and negative capacitance

Switzerland's EPFL, Belgium's imec and Japan's Tokyo Institute of Technology claimed the first experiments demonstrating the benefits of negative capacitance (NC) on the performance of tunneling FETs (TFETs) [Session 13.4]. Quantum mechanical band-to-band tunneling, as opposed to the thermionic injection of conventional MOSFETs, enables sub-thermionic sub-threshold-swing values (i.e. less than 60mV/decade).

The devices connected ferroelectric negative capacitors to the gate of InGaAs TFETs. The negative capacitance was chosen so that, combined with the gate capacitance, a positive value was maintained for stability over the operation range (Figure 5).

The ferroelectric used was single-crystal lead zirconate titanate ($Pb(Zr,Ti)O_3$, or PZT). The material for the negative capacitor was grown by pulsed laser deposition — the substrate was dysprosium scandium oxide ($DyScO_3$) substrate with 20nm strontium rubidium oxide ($SrRuO_3$, or SRO) bottom electrode and 46nm PZT. The top electrode was 50nm sputtered platinum.

The TFETs were homojunction devices using $In_{0.53}Ga_{0.47}As$ MOCVD material on InP substrate. The gate stack consisted of 1nm Al_2O_3 and 2nm HfO_2 insulation, and 100nm titanium nitride (TiN) as metal electrode. The TiN, diffusion doped with zinc, was also used for the source electrode.

The subthreshold swing (SS) of the TFET was as low as 55mV/decade, just below the thermionic level of 60mV/decade. The combination with 15μmx15μm negative capacitors enabled reduction of the SS to 30mV/decade, but with some hysteresis (~30mV in the threshold voltage between different sweeps). Reducing the area of the PZT negative capacitor to 10μmx10μm enabled sub-10mV hysteresis, along with a subthreshold swing as low as 40mV/decade.

The researchers see negative capacitance structures as being a "universal performance booster of FETs, significantly improving the SS and overdrive". In fact, the overdrive improvement enabled 50%-reduced supply voltages of 0.3–0.4V and lower power consumption.

Power performance

Gallium oxide

Gallium oxide (Ga_2O_3) has a wide bandgap of ~4.5eV, giving a high expected critical breakdown field of 8MV/cm. Electron mobility is a reasonable 200cm^2/V-s. Melt growth methods have resulted in Ga_2O_3 substrates that are commercially available in circular (up to 2-inch diameter and more?) and rectangular formats (e.g. 10mmx15mm). On the negative side, there are concerns arising from the low thermal conductivity that self-heating effects could be a problem.

Cornell University in the USA, Kyoto University and Novel Crystal Technology Inc in Japan claimed the highest breakdown voltage and DC/pulsed Baliga figures of merit achieved so far for β-Ga_2O_3-based power devices [Session 8.5]. The reported vertical trench Schottky barrier diodes (SBDs) also managed to keep the reverse leakage current density below 1μA/cm^2 up to breakdown.

The researchers used halide vapor phase epitaxy (HVPE) to create a 10μm lightly doped n^--Ga_2O_3 drift layer on an n-type Ga_2O_3 substrate (Figure 6).

Device fabrication involved plasma etching trenches to a depth of the 1.55μm, giving a series of fins. A wet acid treatment was used to remove etch damage. The dry/wet etching resulted in rounded corners at the trench bottoms, which is favorable for reducing field

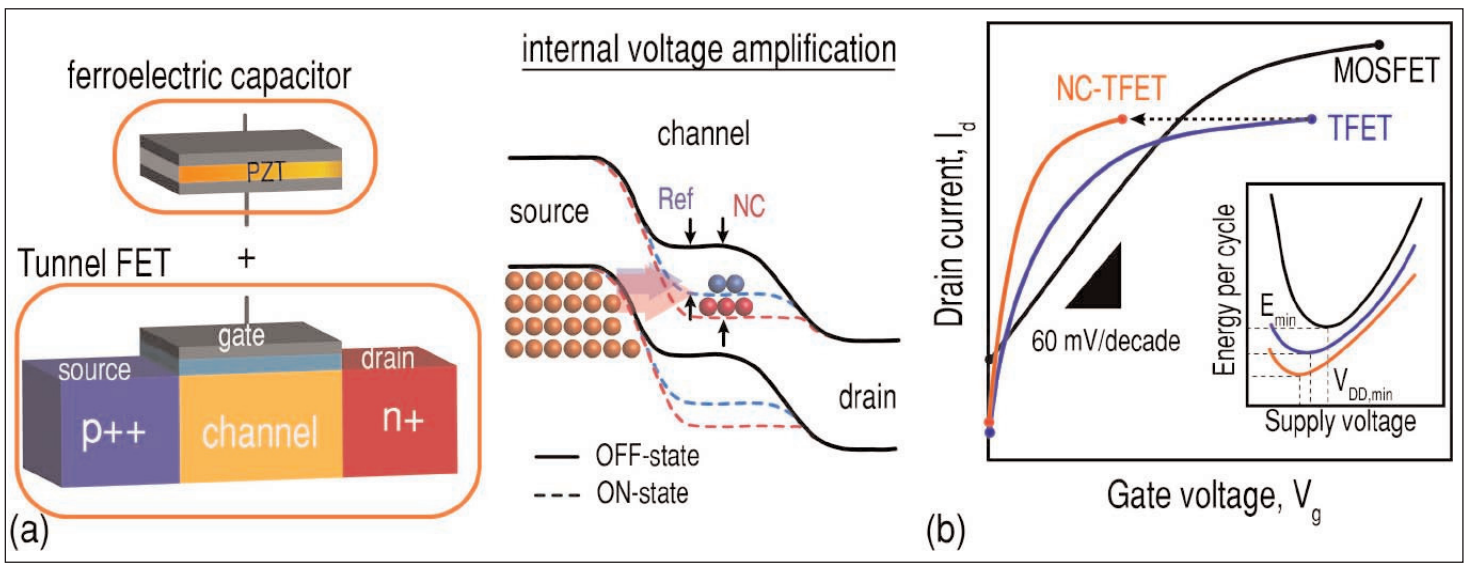

Figure 5. (a) Schematic of NC-TFET (left) combining ferroelectric capacitor with TFET gate. Series-connected NC booster amplifies gate voltage, increasing tunneling probability (right). (b) Drain current versus gate voltage plot and energy efficiency (inset) comparisons of MOSFET, TFET, and NC-TFET.

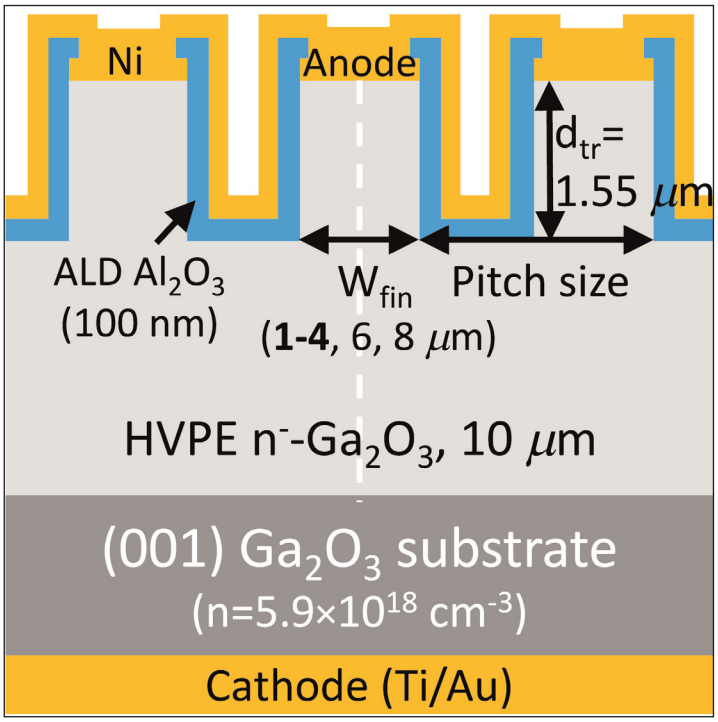

Figure 6. Schematic cross section of Ga_2O_3 trench SBDs.

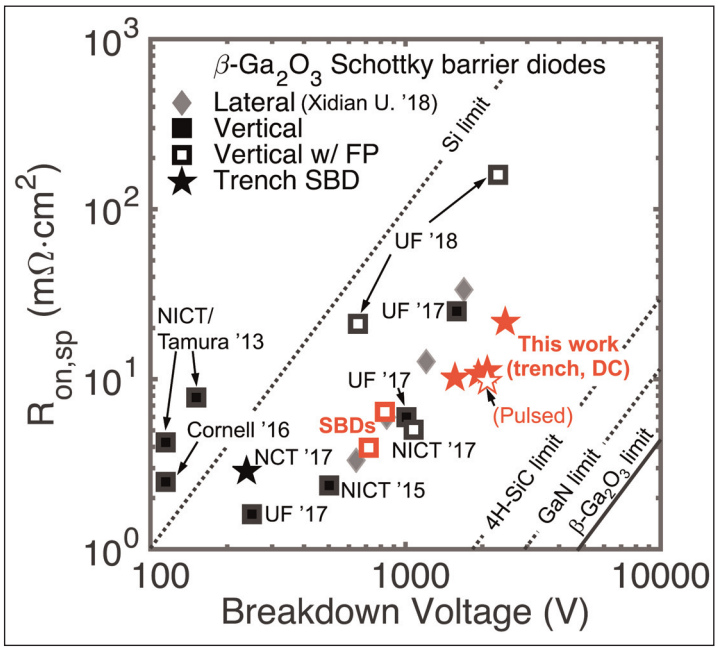

Figure 7. Benchmark plot of β-Ga_2O_3 SBDs: 1μm-trench SBD achieves highest BV, while the 2μm-trench SBD achieves the highest FOM, even without dedicated field-management techniques.

crowding. The back ohmic contact was titanium/gold (Ti/Au). Atomic layer deposition (ALD) aluminium oxide (Al_2O_3) insulated the trench sidewalls and bottoms. The Schottky contacts at the top of the fins consisted of nickel (Ni).

Devices with 1μm fin width achieved a record breakdown voltage of 2.44kV, according to the team. Simulations of devices with 2kV reverse bias gave a peak field with sharp 90° trench corners of ~5.9MV/cm. The rounding of the corners in the fabricated devices should mean the peak field was less than this.

A device with 2μm fin width and 2μm trench width gave the best Baliga figure of merit (FOM): 0.39GW/cm^2 under DC operation and 0.45GW/cm^2 using pulsed measurements. The Baliga FOM combines the breakdown voltage (BV) and specific on-resistance ($R_{on,sp}$) as BV^2/R_{on} (Figure 7).

Another effort aimed at Ga_2O_3 was the reported development of "the first self-consistent device (TCAD), circuit (HSPICE), and package (COMSOL) model considering [self-heating effects] which predicts FET performance on variety of substrates accurately" by Purdue University, USA [Session 24.6].

The Purdue team suggests on the basis of simulations that a template with a high thermal conductivity (400W/m-K) hexagonal boron nitride layer on sapphire for deposition of Ga_2O_3 could be one way to reduce self-heating in such devices.

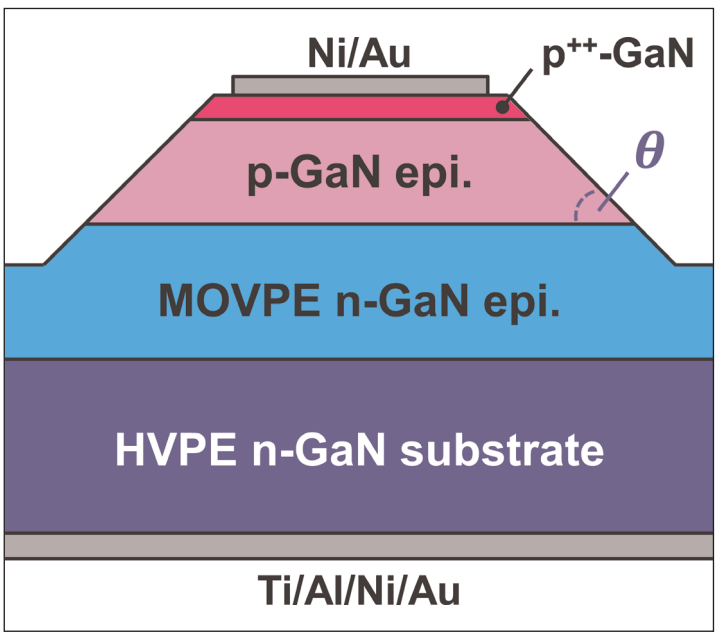

Figure 8. Schematic cross section of GaN PND with double-side-depleted shallow bevel termination. Angles were θ ~12°.

Gallium nitride

Kyoto University, Toyota Central R&D Labs Inc and Nagoya University in Japan reported novel bevel-mesa GaN pn diodes (Figure 8) with 2.8–3.5MV/cm parallel-plane breakdown electric fields "among the best of the reported non-punch-through GaN vertical devices" [Session 30.1].

The beveling was modified by the use of lightly doped p-GaN for which a growth technique has recently been developed with magnesium concentrations of order 10^{17}/cm^3. This allowed the depletion regions on the two sides of the junction to be balanced. The substrate was bulk GaN grown by hydride vapor phase epitaxy. The device layers were processed by metal-organic

vapor phase epitaxy. The researchers used growth conditions that avoided residual carbon incorporation, which can reduce doping effectiveness. The mesa angle (θ) was 12°. The mesa was created by inductively coupled plasma to a depth of 3.6μm.

The breakdown voltages of the devices depended on the thicknesses of the devices layers: 480V for 3.3μm p- and n-type layers, 180V for 1.5μm. The corresponding peak electric fields were calculated at 2.8MV/cm and 3.5MV/cm. The breakdown was not catastrophic, but occurred through avalanche, and the same characteristics could be reproduced repeatedly.

Hong Kong University of Science and Technology (HKUST) reported on the use of crystalline gallium oxynitride (GaON) channels to suppress hole-induced performance degradation in enhancement-mode metal-insulator-semiconductor FETs (MIS-FETs) [Session 30.3].

Hole-induced gate dielectric breakdown can shift threshold voltages of such devices, leading to instabilities and breakdown in performance. A GaON channel creates a hole-blocking ring in the gate region due to a valence band offset with respect to the neighboring GaN (Figure 9). The ring prevents holes attacking the gate dielectric.

The GaON was formed by oxygen exposure in an inductively coupled plasma (ICP) chamber after etching the gate recess. The material was annealed in ammonia in the low-pressure chemical vapor deposition (LPCVD) chamber used to create the silicon nitride passivation. The resulting GaON layer was 5.6nm and the bandgap was estimated at 4.1eV.

Negative-gate-bias stress tests resulted in significant threshold shifts in GaN-channel devices with the drain at 200V. This shifting was much reduced in the GaON MIS-FET. A further stress test with the gate at –20V relative to the source, and the drain at +320V relative to the gate, showed five-fold increased time to breakdown for the GaON-channel transistor, compared with a GaN channel.

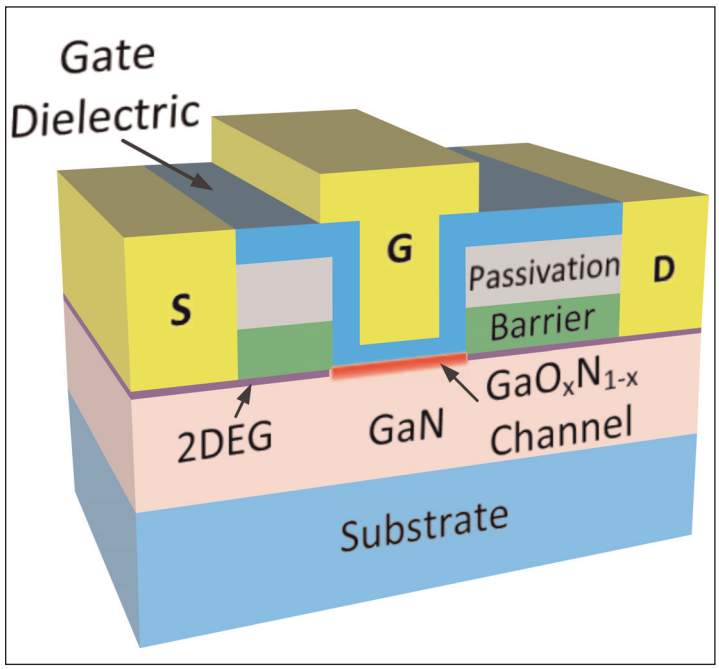

Figure 9. Schematic cross-sectional view of the MIS-FETs with recessed gate structure and GaON channel.

Silicon carbide

Japan's National Institute of Advanced Industrial Science and Technology (NAIST) claimed the lowest ever specific on-resistance ($R_{on,sp}$) for SiC-MOSFETs with a blocking voltage (B_v) of more than 600V [Session 8.1]. The researchers fabricated super-junction V-groove trench MOSFETs (SJ-VMOSFETs), with 0.63mΩ-cm^2 $R_{on,sp}$ and 1170V B_v.

The researchers report: "We have improved drastically the trade-off relationship between on-resistance and the breakdown voltage by narrowing SJ cell pitches and higher doping concentration in SJ regions. In addition, we have reduced the parasitic resistance by a thin V-groove {0$\bar{3}3\bar{8}$} channel."

Super-junction devices use vertical pillars of alternately doped regions, allowing better control of current flow between the source and drain electrodes with reduced on-resistance (Figure 10). The pillars were

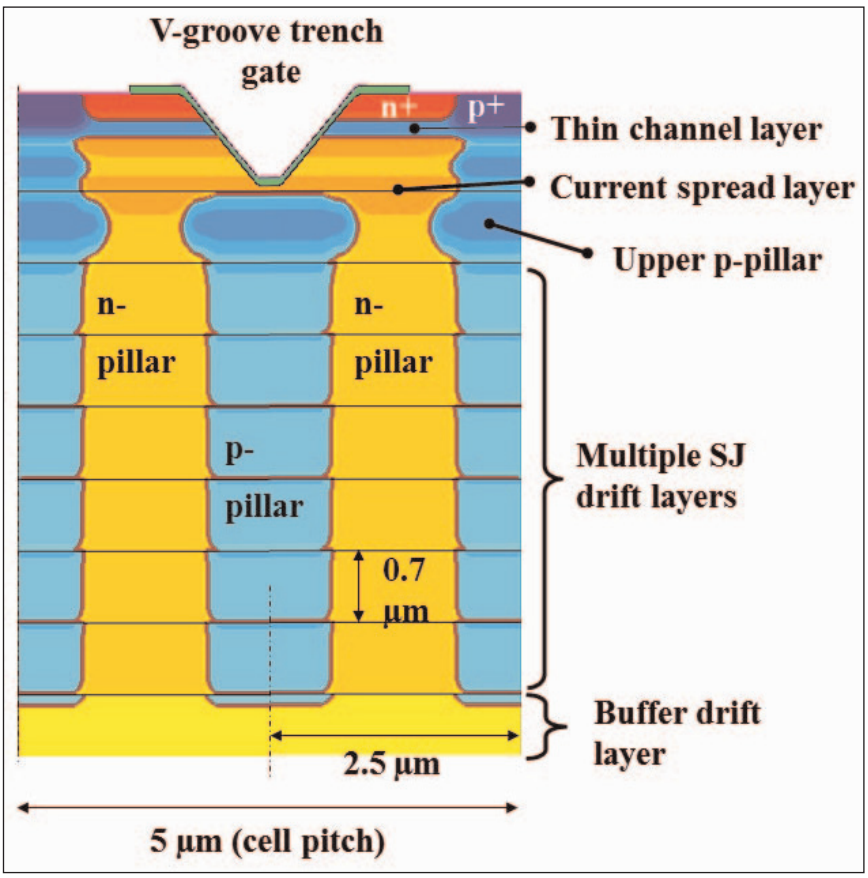

Figure 10. Schematic cross section of SJ-VMOSFET.

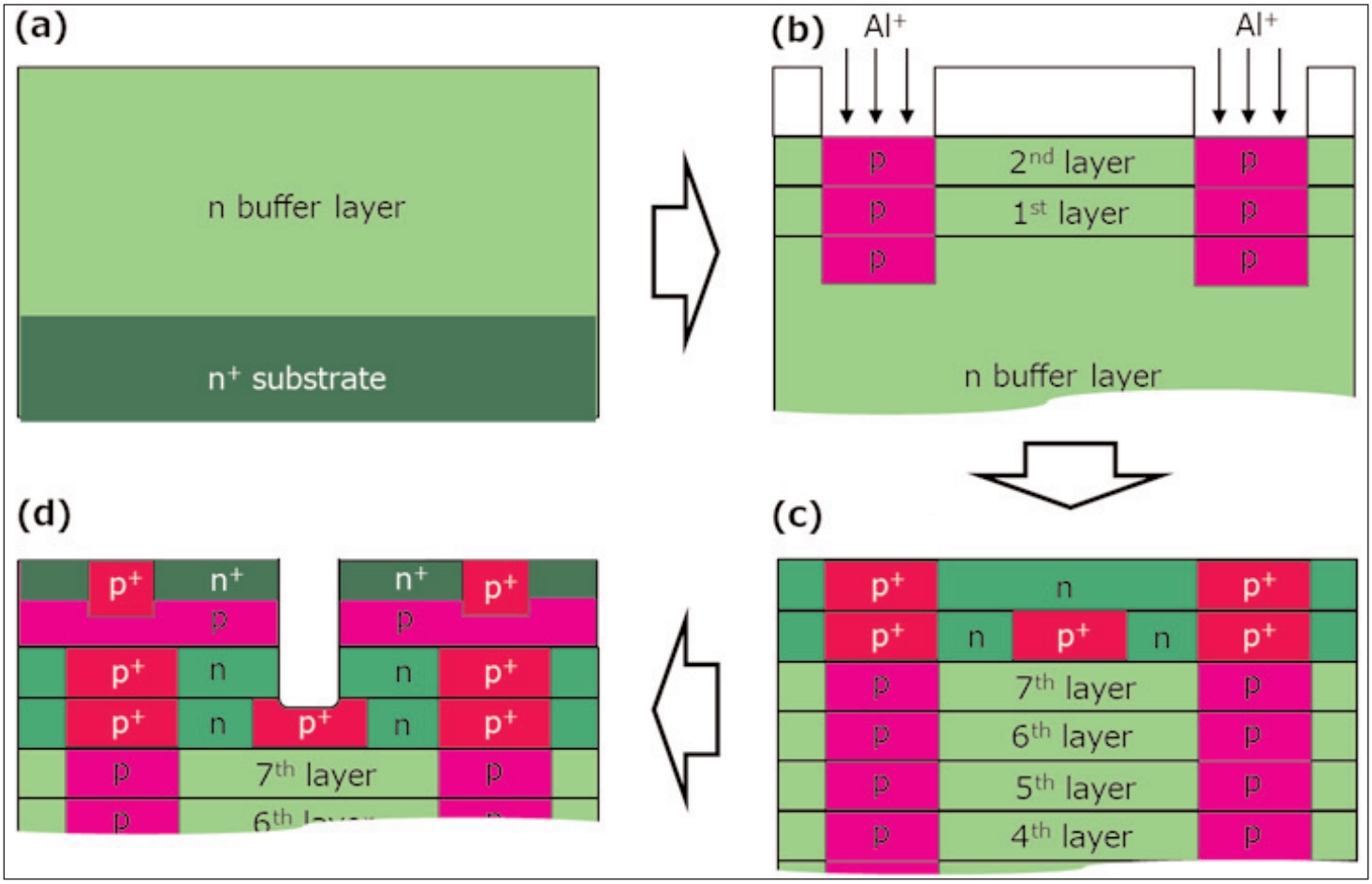

Figure 11. Fabrication flow of SiC SJ-UMOSFET through multi-epitaxial growth method.

formed by a sequence of six epitaxial growth and aluminium ion implantation steps for the n- and p-type regions, respectively.

Another group at NAIST presented 1.2kV-class U-shape trench gate MOSFETs using a similar super-junction structure produced in seven epitaxial and Al ion implantation steps [Session 8.2]. The alignment accuracy of the multi-step process (Figure 11) is reported as being within 0.1μm.

Researchers at Mitsubishi Electric Corp and University of Tokyo in Japan have found that using sulfur (S) as a deep-level donor in 4H-SiC MOSFETs (Figure 12) enables a 31% reduction of specific on-resistance with high 4.0V threshold voltage [Session 8.3]. The resistance reduction was measured in a vertical MOSFET relative to a device without sulfur doping.

These findings run counter to the general belief that deep-level donors are not suitable for high-performance electronics. The researchers' simulations suggest that the improved threshold is due to the increased ionization energy of the sulfur. At the same time, the sulfur doping improves inversion layer mobility in the channel.

The experiments were claimed as the first time that sulfur was used for donor doping in the channel region of 4H-SiC MOSFETs. Both lateral and vertical devices were fabricated. The S atoms were introduced by ion implantation. The gate insulator was formed by thermal oxidation and was subsequently subjected to nitridation in diluted nitric oxide (NO). ■

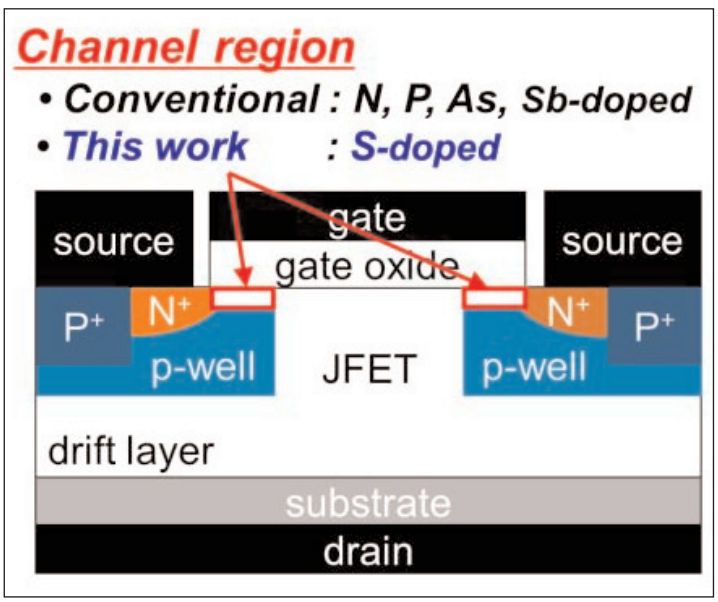

Figure 12. Schematic cross section of vertical 4H-SiC MOSFETs with S-doped channel region.

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Imec reports first direct growth of 2D materials on 300mm wafers

Together with SUSS MicroTec and Brewer Science, Imec has co-developed a tungsten disulfide channel transfer process.

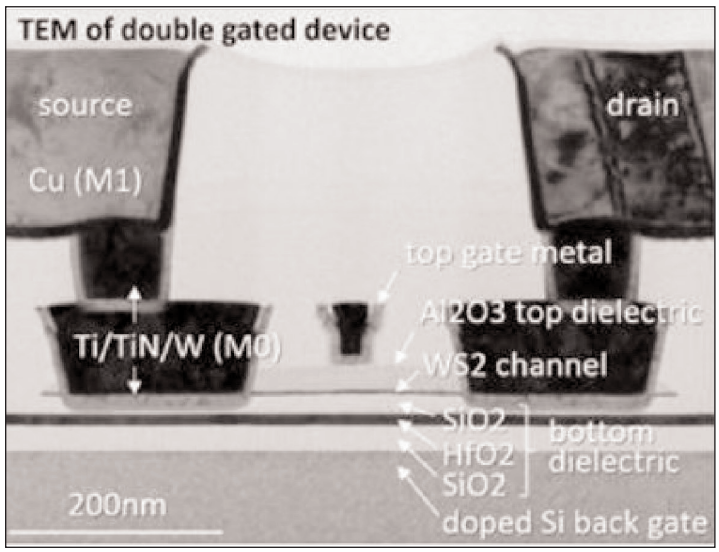
At the IEEE's 64th International Electron Devices Meeting (IEDM 2018) in San Francisco, CA, USA (1–5 December), nanoelectronics research centre imec of Leuven, Belgium presented a 300mm-wafer platform for metal-oxide-silicon field-effect-transistor (MOSFET) devices with 2D materials.

Two-dimensional materials could provide the path towards extreme scaling of device dimensions as they are atomically precise and suffer little from short-channel effects. Other possible applications of 2D materials could come from using them as switches in the back-end-of-line (BEOL), which puts an upper limit on the allowed temperature budget in the integration flow.

The imec platform integrates a transistor channel composed of tungsten disulfide (WS_2), a 2D material that holds promise for higher ON-current compared with most other 2D materials as well as good chemical stability. Imec's work reported at IEDM represents the first metal-organic chemical vapor deposition (MOCVD) growth of WS_2 on 300mm wafers. The MOCVD synthesis approach results in thickness control with monolayer precision over the full 300mm wafer, as well as potentially the highest-mobility material. However, the benefits of MOCVD growth come at the price of a high temperature while growing the material.

To build a device integration flow that could be compatible with BEOL requirements, the transfer of the channel material from a growth substrate to a device wafer is crucial. Imec claims to be first to demonstrate a full 300mm monolayer 2D material transfer, which is said to be very challenging on its own due to the low adhesion of 2D materials to the device wafer and to the exteme thinness of the material transferred (just 0.7nm).

The transfer process was developed together with SUSS MicroTec of Garching near Munich, Germany (which makes photomask aligners, laser processing systems and wafer bonders) and Brewer Science of Rolla, MO, USA (which provides thin-wafer-handling materials, processes and equipment) using temporary bonding and debonding technologies. WS_2 wafers are temporarily bonded to glass carrier wafers using a specially formulated material (from Brewer Science). Next, the WS_2 monolayer is mechanically debonded from the growth wafer and bonded again in vacuum to the device wafer. The carrier wafer is removed using laser debonding. This debonding technique is a key enabler for the controlled transfer of 2D materials.



"Building the 300mm platform for MOSFET device study with 2D materials and developing the process step ecosystem speeds-up the technological adoption of these materials," says Iuliana Radu, the Beyond CMOS program director at imec. "Several challenges are still to be resolved and are the subject of ongoing research and development." Major challenges include scaling the equivalent oxide thickness (EOT) of gate dielectric for 2D materials, and reducing channel defectivity to boost mobility.

Imec's research into advanced logic scaling is performed in cooperation with imec's key CMOS program partners GlobalFoundries, Huawei, Intel, Micron, Qualcomm, Samsung, SK Hynix, Sony Semiconductor Solutions, TOSHIBA Memory, TSMC and Western Digital. ■

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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

2–6 February 2019
IEEE International Solid- State Circuits Conference (ISSCC 2019)
San Francisco, CA, USA
E-mail: Isscinfo@yesevents.com
www.isscc.org

2–7 February 2019
SPIE Photonics West 2019, including OPTO 2019 – Optoelectronic Materials, Devices, and Applications
Moscone Centre, San Francisco, CA, USA
E-mail: customerservice@spie.org
www.spie.org/SPIE_PHOTONICS_WEST_Conference
www.spie.org/SPIE_OPTO_conference

12–14 February 2019
PowerAmerica's Annual Meeting
North Carolina State University, Raleigh, NC, USA
E-mail: poweramerica@ncsu.edu
www.poweramericainstitute.org

25–28 February 2019
GSMA Mobile World Congress 2019 (MWC19)
Fira Gran Via, Barcelona, Spain
E-mail: registration@mwcbarcelona.com
www.mwcbarcelona.com

27 February – 1 March 2019
Strategies in Light 2019
Mandalay Bay Convention Center, Las Vegas, NV, USA
E-mail: registration@pennwell.com
www.strategiesinlight.com/index.html

3–7 March 2019
Optical Networking Communication Conference & Exhibition (OFC 2019)
San Diego Convention Center, CA, USA
E-mail: OFC@compusystems.com
www.ofcconference.org

6–8 March 2019
BIT's 5th Annual World Congress of Smart Materials-2019
Rome, Italy
E-mail: snowy@wcsm-con.com
www.bitcongress.com/wcsm2019

17–21 March 2019
APEC 2019:
IEEE Applied Power Electronics Conference and Exposition
Anaheim Convention Center, CA, USA
E-mail: apec@apec-conf.org
www.apec-conf.org

17–20 March 2019
Optics Frontier – The 14th National Conference on Laser Technology and Optoelectronics (LTO 2019)
Novotel Atlantis Shanghai, China
E-mail: LTO@siom.ac.cn
http://lto2019.htcis.net

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20–22 March 2019
LASER World of PHOTONICS CHINA 2019
Shanghai New International Expo Centre, China
E-mail: info@world-of-photonics-china.com
www.world-of-photonics-china.com

20–22 March 2019
SEMICON China 2019
Shanghai New International Expo Centre, China
E-mail: semichina@semi.org
www.semiconchina.org

25–27 March 2019
CPV-15:
15th International Conference on Concentrator Photovoltaics)
Université Sidi Mohammed Ben Abdellah, Fes, Morocco
E-mail: info@cpv-15.org
www.cpv-15.org

10–11 April 2019
Sensors Europe 2019
Estrel Convention Center, Berlin, Germany
E-mail: events@IDTechEx.com
www.idtechex.com/sensors-europe

16–18 April 2019
23rd Annual Components for Military & Space Electronics Conference & Exhibition (CMSE)
Four Points by Sheraton (LAX), Los Angeles, CA, USA
E-mail: info@tjgreenllc.com
www.tjgreenllc.com/cmse

29 April – 2 May 2019
2019 International Conference on Compound Semiconductor Manufacturing (CS MANTECH)
Hyatt, Regency, Minneapolis, MN, USA
E-mail: chairman@csmantech.org
www.csmantech.org

7–9 May 2019
PCIM Europe (Power conversion and Intelligent Motion) 2019
Nuremberg Messe, Germany
E-mail: daniela.kaeser@mesago.com
www.mesago.de/en/PCIM/main.htm

15–17 May 2019
Intersolar Europe 2019
Munich, Germany
E-mail: info@intersolar.de
www.intersolar.de

27–31 May 2019
ICPE 2019 – ECCE Asia:
10th International Conference on Power Electronics
BEXCO, Busan, South Korea
E-mail: icpe2019@icpe2019.org
www.icpe2019.org

24–27 June 2019
LASER World of PHOTONICS 2019
Messe München, Germany
E-mail: info@world-of-photonics.com
www.world-of-photonics.com

24–28 June 2019
PVSC 2019:
IEEE 46th Photovoltaic Specialists Conference
Chicago, IL, USA
E-mail: info@ieee-pvsc.org
www.ieee-pvsc.org

8–10 July 2019
2019 Summer Topicals Meeting Series
Fort Lauderdale, FL, USA
E-mail: i.donnelly@ieee.org
www.sum-ieee.org

9–11 July 2019
SEMICON West 2019
Moscone Center, San Francisco, California, USA
E-mail: semiconwest@xpressreg.net
www.semiconwest.org

10–11 July 2019
UK Semiconductors 2019 (UKS'19)
University of Sheffield, UK
E-mail: edmund.clarke@sheffield.ac.uk
www.uksemiconductors.com

21–24 July 2019
AVS 19th International Conference on Atomic Layer Deposition (ALD 2019), featuring the 6th International Atomic Layer Etching Workshop (ALE 2019)
Bellevue, Washington, USA
E-mail: della@avs.org
www.ald2019.avs.org

11–15 August 2019
SPIE Optics + Photonics 2019
San Diego Convention Center, San Diego, California, USA
E-mail: customerservice@spie.org
http://spie.org/Optics_Photonics

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