ISSN 1752-2935 (online)

semiconductorTODAY

COMPOUNDS & ADVANCED SILICON

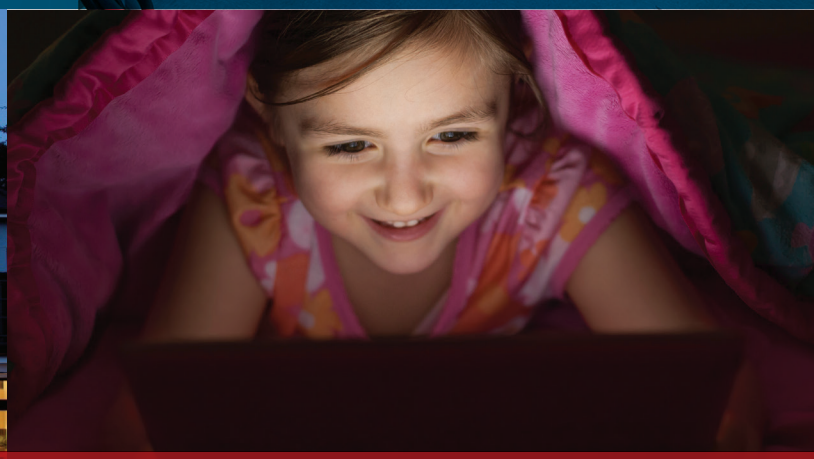
Vol. 12 • Issue 10 • December 2017/January 2018 www.semiconductor-today.com

IEDM conference report

Plessey licensing GaN-on-Si to micro-LED makers

EVG opens capacity expansion • Peregrine renamed pSemi
Optically pumped all-Si laser • Thin-film PV cell efficiency hits 22.9%

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.

The EPIK700 MOCVD system combines Veeco's award-winning TurboDisc reactor design with improved wafer uniformity, increased productivity and reduced operations expenses to enable a cost per wafer savings of up to 20 percent compared to previous systems.

It also features a reactor with more than twice the capacity of previous generation reactors. This increased volume coupled with productivity advancements within the EPIK700 reactor, results in an unmatched 2.5x throughput advantage over previous reactors.

Learn how Veeco's TurboDisc EPIK700 GaN MOCVD system can improve your LED manufacturing process today.

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

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

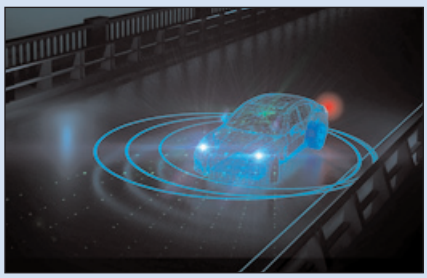
Veeco's New TurboDisc EPIK700 GaN MOCVD System

contents

semiconductorTODAY
COMPOUNDS & ADVANCED SILICON

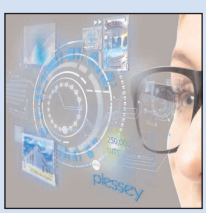
Vol. 12 • Issue 10 • Dec 2017/Jan 2018

p49 EVG has completed construction and opened a new building at its corporate HQ to expand capacity for producing process equipment.



p66 At AutoMobili-D in Detroit, Osram showcased its 905nm IR pulse lasers for LiDAR in autonomous vehicles & ADAS.

p86 CNBM has begun production at China's largest CIGS solar module factory, using technology from German subsidiary Avancis.



Cover: Plessey has demonstrated how its monolithic micro-LED technology can be used to deliver next-generation head-up displays, enabling augmented reality and virtual reality applications. The firm is now licensing its GaN-on-Si expertise to micro-LED makers. **p56**

editorial

Consumer electronics adopting III–Vs

Since our coverage of mini-LEDs and micro-LEDs last issue, South Korea's Samsung has exhibited its 146" micro-LED TV at the Consumer Electronics Show (CES) in Las Vegas. It may take a year for it to commercialize micro-LED displays, and rivals such as LG are still focusing on OLED displays, but investment by firms such as Samsung promises to spur development throughout the micro-LED supply chain.

For example, South Korea's Lumens (which supplies LED backlight modules for displays in Samsung TVs) has begun to produce both small- and large-sized micro-LED display prototypes (as showcased at CES), targeting the automotive head-up display (HUD) and digital signage display markets respectively (see page 57). The firm is partnering with the Korea Institute of Machinery and Materials, which invented the roll-to-plate transfer technology for micro-LED mass production. Meanwhile, Taiwan's Epileds is investing in R&D on micro-LEDs and mini-LEDs (page 60).

Also at CES, UK-based LED maker Plessey demonstrated its gallium nitride on silicon (GaN-on-Si) micro-LED technology for head-up displays. Its monolithic process removes the need to develop manufacturing equipment for pick-and-place of each chip individually. Produced in collaboration with Artemis Optical, an HUD demonstrator was presented to firms developing augmented reality (AR) and virtual reality (VR) headsets and eyewear (see page 56). In line with its new business strategy, Plessey now aims to license its GaN-on-Si technology to micro-LED makers.

Also, Solar-Tectic and Blue Wave Semiconductors have been granted a US patent for growing crystalline films at low temperature with a high degree of crystal orientation, which could be used for GaN-on-Si monolithic micro-LEDs.

Meantime, while technical challenges are overcome for mass manufacturing micro-LEDs (about 100μm wide), the market for less challenging mini-LEDs is forecasted to burgeon, rising to $1bn in 2023, driven initially by application to digital displays then mobile displays and large displays (see page 7).

Also at CES, Osram spotlighted automotive applications of its infrared LEDs and lasers for functions such as facial recognition, HUDs, and light detection and ranging (LiDAR) for both driver assistance and autonomous vehicles (see page 66). Such technology is also being exhibited by Germany's FBH at Photonics West in San Francisco (page 67).

The infrared laser projector market for mobile-phone 3D sensing is forecasted by LEDinside to grow from $246m in 2017 to $1953m in 2020, spurred by Apple featuring a 3D sensor in its new iPhone X (followed by Samsung and most other smartphone makers) — see page 10. Such rapid adoption has driven Apple to allocate $390m of investment to boost vertical-cavity surface-emitting laser (VCSEL) production capacity at supplier Finisar's new plant in Sherman, Texas (see page 81).

Another example at CES of compound semiconductors now penetrating consumer electronics is the demonstration of GaN-based power electronic devices by EPC for applications such as wireless power charging (of household appliances) as well as even LiDAR systems for autonomous vehicles (see page 26) and by Navitas (GaN power ICs for ultrathin TVs, fast mobile chargers, drones, AR/VR devices, gaming systems, etc — see page 30).

R&D on vertical GaN power devices is covered in our IEDM conference report on pages 98–104. A second IEDM report next issue will focus on two-dimensional electronic materials and devices.

Mark Telford, Editor

mark@semiconductor-today.com

semiconductorTODAY
COMPOUNDS & ADVANCED SILICON

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

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

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

Original design Paul Johnson
www.higgs-boson.com

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

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

***Semiconductor Today* (ISSN 1752-2935) is published free of subscription charge** in a digital format 10 times per year by Juno Publishing and Media Solutions Ltd, Suite no. 133, 20 Winchcombe Street, Cheltenham GL52 2LY, UK. See: www.semiconductor-today.com/subscribe.htm

AIXTRON
Our technology. Your future.

YOU THINK,

GaN POWER DEVICE MANUFACTURING REQUIRES HVM SOLUTIONS.

WE THINK THAT TOO.

THE NEW AIX G5+ C

DISCOVER THE NEW AIX G5+ C.

Introducing the G5+ C: built on Award Winning Planetary technology for best Single Wafer performance with Batch Reactor benefits – now coming with Cassette to Cassette wafer loading, In-Situ Reactor Cleaning and pre-qualified device processes.
Enabling full automation of your processes and a seamless integration into your Silicon line.

AIXTRON SE · info@aixtron.com · www.aixtron.com

HVM: High Volume Manufacturing

LED chip market to hit supply–demand balance in 2018 due to Chinese suppliers' production capacity expansions

Chip prices being lowered after year and a half of elevated prices

Major Chinese LED chip suppliers including San'an Optoelectronics and HC SemiTek have lowered their product prices recently, indicating the end of LED chip undersupply and the hike in LED chip price that had lasted a year and a half, according to LEDinside. The next year will see a balance in LED chip supply and demand, it adds.

"However, as the major LED chip makers continue to carry out capacity expansion plans, we do not exclude the possibility of temporary over-supply in the next two years," says senior analyst Figo Wang.

Wang also points out that prices of LED chips in China fell sharply during 2015, resulting in a surge of orders going to Chinese LED chip suppliers in 2016. To meet the demand, Chinese chip suppliers decided to raise their capital expenditure (CapEx). In comparison, other chip makers worldwide have lowered their investment in production, and some have even withdrew from the LED market. In 2017, Chinese LED chip makers continued their active investment in the industry, and this year's new metal-organic chemical vapor deposition (MOCVD) expansion plans come mainly from San'an, HC SemiTek and Aucksun.

Regarding 2"-equivalent epitaxial wafers, San'an, HC SemiTek and Aucksun have increased their monthly production capacity by 1.3 million, 1 million and 0.83 million epiwafers respectively, making them the top three LED chip suppliers in China. Due to the chip makers' capacity expansions at the end of 2017, the market is expected to enter a balance in supply and demand. Suppliers like San'an and HC SemiTek have therefore strategically adjusted their chip prices for lighting applications and digital displays, which are always a focus of competition in the industry. Prices, which have been pushed up for a year and a half, now have a chance to enter a period of stability or slight fluctuation, reckons LEDinside.

After this round of large-scale expansion, the production capacity of the three industry leaders will exceed 1 million epiwafers per month, increasing the concentration of industrial production. LEDinside adds that this can also improve the supply structure and prevent excessive price competition. In addition, new MOCVD systems have higher production efficiency than the previous generation, lowering costs by 30%. Major players like San'an and HC SemiTek will hence enhance their cost competitiveness while other suppliers that cannot afford the production expansion will be marginalized in the market, LEDinside concludes.

www.ledinside.com

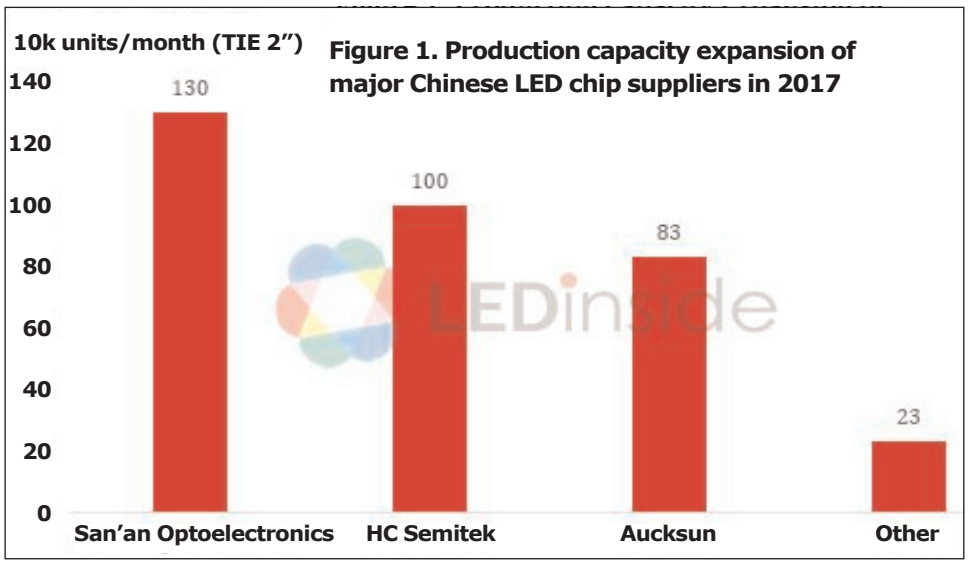


Figure 1. Production capacity expansion of major Chinese LED chip suppliers in 2017

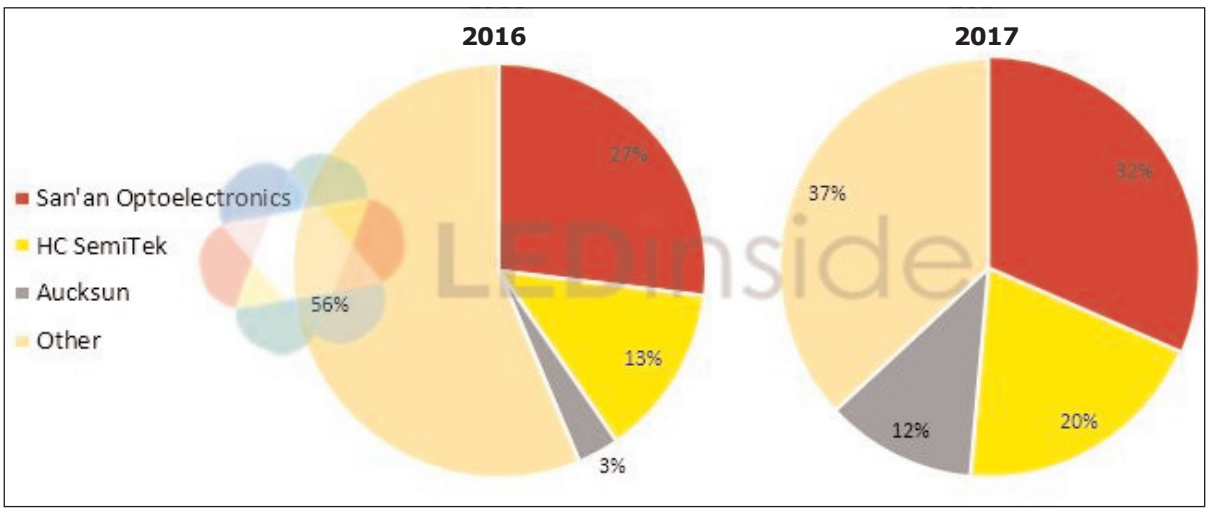
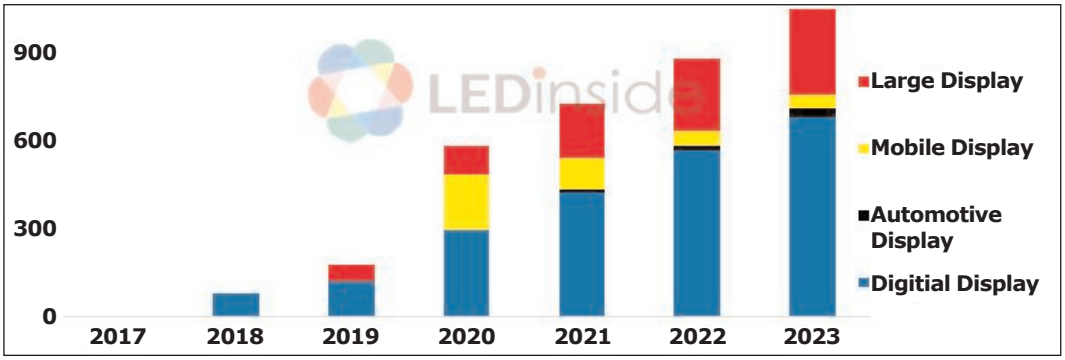


Figure 2. Distribution of production capacity for GaN-based LED epitaxial wafers in China.

Mini-LED revenue to reach $1bn in 2023, driven by digital displays and large-size TV backlighting

Due to the technological bottlenecks that make it harder to achieve commercialization of micro-LEDs in the short term (e.g. Sony's micro-LED display released in 2016, which was rather high cost), to realize mass production on a shorter time-scale LED makers have now turned to R&D on mini-LEDs, says LEDinside.



In particular, due to the larger chip size of 100–200μm, firms can develop mini-LEDs using their existing equipment, with only small changes in the manufacturing process, notes LEDinside.

Mini-LED chips can be used for self-emitting displays and backlighting, says assistant research manager Simon Yang. With the potential to be adopted for TVs, mobile phones, automotive displays, digital displays etc, revenue is expected to reach $1bn in 2023. In particular, LED digital displays and large-size TVs will be the mainstream applications, it is reckoned.

For consumer electronics products, the cost of using mini-LED chips for a self-emitting display is too high, and the resolution may not meet the requirements of existing products. Companies hence aim to use mini-LEDs as backlights to replace traditional backlighting in LCD panels. Mini-LED backlighting can be used in TVs, mobile phones, automotive displays etc. LEDinside estimates that mini-LED backlighting demos could be released in 2018.

Due to advantages such as high brightness and higher-dynamic-range imaging, it is possible for high-end TV products to adopt mini-LEDs. In terms of applications in mobile phones, mini-LED-equipped products can realize high contrast and high brightness similar to organic light-emitting diode (OLED) products, notes LEDinside. Together with local dimming, mini-LEDs are likely to compete with OLEDs in terms of performance and price.

Companies worldwide actively involved in developing mini-LED products include chip makers such as Epistar, Lextar, San'an Optoelectronics and HC SemiTek; packaging firms such as Everlight Electronics, Advanced Optoelectronic Technology, Harvatek, and Seoul Semiconductor; IC designers such as Macroblock and Radium Semiconductor; and Taiwan-, China- and South Korea-based LCD panel makers such as AU Optronics and Innolux Corp. China-based LED fine-pixel-pitch display maker Leyard Optoelectronic is also interested in adopting mini-LED chips.

However, there are still challenges for the development of mini-LEDs. High cost is a major concern, since mini-LED products use more chips, leading to higher cost in pick & place and bonding processes, as well as longer processing time and higher risks of a low yield rate. Also, a mini-LED needs greater optical distance, adding to the difficulty in making the products thinner.

www.ledinside.com

Prices of packaged LED products in China to fall in Q1

Suppliers focused on developing higher-growth markets

Prices of mainstream packaged LED products in China were generally stable in December, with no obvious fluctuation in either the high-power or mid-power segments, but prices are expected to fall in first-quarter 2018, reports LEDinside.

The major suppliers in China have successively reduced the prices of their LED chips over the past few months, but prices of packaged LED products have not been immediately lowered due to the long purchase cycle, notes analyst Terri Wang.

Although some authorized agents of packaged LED products have cut prices for certain orders, the average price in the market did not see obvious fluctuations in December.

As prices remain stable, suppliers keep upgrading product performance, and are focusing development on higher-growth segments such as industrial lighting and outdoor lighting, e.g. Cree has launched a new extreme-density high-power LED that delivers 284lm/mm^2.

In addition, Chinese manufacturers have expanded their business to the automotive lighting market through investment and acquisition. For example, CEC–Kaistar has obtained chip and phosphor patents through the acquisition of Bridgelux and Intematix. Kaistar has also invested in automotive lighting modules and hence completed the vertical integration from LED wafer through to automotive lighting modules, entering the automotive optoelectronics market.

www.ledinside.com

UV LED market growing at 24.8% CAGR to $1312m in 2025

The ultraviolet light-emitting diode (UV LED) market is growing at a compound annual growth rate (CAGR) of 24.8% from $178.4m in 2016 to $1311.7m by 2025, reckons market research firm The Insight Partners in a new report.

Over the past decade the UV LED market has expanded more than five-fold while it has seen a dramatic transformation in technology as well as adoption patterns, notes the firm. UV LEDs initially were restricted to specific application such as curing, counterfeit detection and sterilization, but over the years they have reached the technical specifications demanded for other applications including medical, water treatment and electronic devices.

A key trend that is expected to predominantly influence the market in the coming years is the evolution of new applications. R&D teams in various companies are working on further developing UV LEDs to cater for next-generation industries. UV light has widespread application in multiple industries, including agriculture, solar products and the food & beverages industry, but implementation of UV LEDs is very limited in these industries, as existing UV LED technology is unable to provide the desired performance. However, there is intensive effort worldwide to develop UV LED technology that is more flexible and reliable as well as cost effective. This trend should drive demand for UV LEDs in other novel industries.

The UV LED market is segmented by application into curing, medical, electronic devices, water treatment (purification & waste water management), security and others (mineralogy, astronomy, pest control and home cleaning). The UV curing segment accounts for the largest share of the market, but water treatment is expected to grow at the highest CAGR during the forecast period, driven mainly by the ability of LED technology to enable UV water treatment to be used in applications that were not feasible using conventional UV lamps. This has further allowed remote regions to use UV LEDs for waste water treatment and purification.

The Asia Pacific is currently one of the most prominent regions in the UV LED market and is expected to contribute the most revenue due to the prevalence of UV LED packaging firms as well as UV LED applications in countries such as Taiwan, South Korea and China. However, rapidly growing UV LED applications in North America in the coming year will make it the fastest-growing region during the forecast period, it is reckoned. South America is another region that is expected to offer promising growth opportunities.

www.theinsightpartners.com/reports/uv-led-market

LED lighting cuts CO_2 emissions by 570 million tons in 2017

The use of LEDs to illuminate buildings and outdoor spaces reduced the total carbon dioxide (CO_2) emissions of lighting by an estimated 570 million tons in 2017 (equivalent to shutting down 162 coal-fired power plants), according to analyst firm IHS Markit. LED lighting uses an average of 40% less power than fluorescents, and 80% less than incandescents, to produce the same amount of light.

"The efficiency of LEDs is essentially what makes them environmentally friendly," comments Jamie Fox, principal analyst, lighting & LEDs group. "Therefore, LED conversion is unlike other measures, which require people to reduce consumption or make lifestyle changes."

LED component and lighting companies were responsible for reducing the global carbon (CO_2e) footprint by an estimated 1.5% in 2017, and that is likely to continue to grow as more LEDs are installed worldwide, says IHS Markit.

Another environmental benefit is that LEDs have a longer life span than traditional bulbs and fewer are produced, so the emissions and pollution associated with the production, shipping, sale and disposal of the products is reduced. Secondly, unlike fluorescents, LEDs do not contain mercury. LEDs also decrease air pollution, since most electrical energy is still generated by burning fossil fuels. "While other activities affect climate change more than lighting does, it is still a very strong contribution from a single industry sector," Fox says.

IHS Markit has tracked the market share for top LED component suppliers for many years. Based on an analysis of this data, Nichia can claim credit for having saved the most carbon overall — accounting for 10% of all LED lighting reduction achieved in 2017, which translates into 57 million tons of CO_2 (about the same as 16 coal plants). Cree followed Nichia with 8%, while Lumileds, Seoul Semiconductor, MLS, Samsung and LG Innotek each have a share of 4–7%.

Savings achieved by each company relate to the energy saved by the use of its components while installed in lighting applications. It does not include a whole lifecycle analysis, which would likely lead to a small additional positive benefit, due to the longer life of LEDs.

"LED component companies and lighting companies have transformed their industry," Fox comments. "They are fighting climate change much more effectively than other industries, and they should be given credit for it. Unlike in other industry sectors, workers at LED companies can honestly say that by selling more of their products, they are helping to reduce global warming."

www.ihsmarkit.com

LED packaging market to grow at 6.2% CAGR from $18.41bn in 2017 to $26.39bn in 2023

General lighting to drive market, with APAC remaining dominant

The LED packaging market will rise at a compound annual growth rate (CAGR) of 6.2% from $18.41bn in 2017 to $26.39bn in 2023, forecasts a report 'LED Packaging Market — Global Forecast to 2023' from MarketsandMarkets. The key driving factors are increased government initiatives and regulations to adopt energy-efficient LEDs, growing demand for smart lighting solutions and growing demand from horticulture markets.

Advanced packaging technologies such as COB and CSP driving growth

The market for chip-on-board (COB) packages is expected to increase due to its growing use for lighting applications, and increased focus on smart lighting and building technologies. Strong growth is projected for COB LED packages in the long run, driven by the technologies delivering superior flexibility and versatility.

Chip-scale package (CSP) development in silicon ICs is driven by miniaturization, improved thermal management, higher reliability, and the need to connect to an ever-increasing pin-count on an ever-shrinking die. CSP also enables a reduction in device parasitic and ease of integration into level 2 packaging. The increased adoption of CSP packages is mainly due to advantages such as reduced package footprint, thin profile, reduced weight and better electrical performance and area array distribution of connections.

General lighting to drive market

General lighting applications are likely to continue to hold the largest share of the LED packaging market during 2017–2023. The potential to save energy on a large scale is one of the most attractive aspects of LED technology, notes the report. General lighting is experiencing high growth, driven by reduced energy consumption. Considering that governments and other bodies are focusing on cutting energy consumption through schemes and regulations (especially in residential and industrial use), the market is expected to see high growth during the forecast period.

APAC to be largest market region and to see fastest growth

APAC is expected to dominate the LED packaging market between 2017 and 2023. Growth is driven mainly by China, Japan, Taiwan and South Korea, as these countries account for the largest market share in the region.

Demand in China has increased exceptionally and is expected to see growth in the near future due to continuous Chinese government effort by introducing subsidies and incentives to boost domestic LED production capacity.

The market in Taiwan is also expected to grow faster than other countries in the region because of the rise in demand for backlighting applications.

www.marketsandmarkets.com/Market-Reports/led-packaging-market-217522990.html

Market for 405nm laser diodes growing at 8.5% CAGR to $1857.29m in 2025

The 405nm laser diode market was $904.46m in 2016, and will increase at a compound annual growth rate (CAGR) of 8.5% to $1857.29m in 2025, forecasts a new report from Research N Reports.

By product type, the market is segmented into: below 30mW; 30–60mW; 60–90mW; 90–200mW; and more than 200mW. Of these, the sub-30mW segment is expected to comprise the largest share. By application, the communications & optical storage segment is expected to be dominant throughout the forecast period. By mode, the single-mode segment is expected to comprise the largest share for the next few years.

Demand for 405nm laser diodes in dentistry is expanding and is expected to demonstrate notable development during the forecast period. Laser gadgets have been costly and previously had select clinical applications. But lately the enthusiasm for dental laser gadgets has expanded massively, and now laser diodes are thought to be valuable in many aspects of surgery, conservative/operative dentistry, endodontics, dental bleaching, and photodynamic treatment.

By geography, the Asia-Pacific (APAC) comprises the biggest region of the 405nm laser diode market and is expected to grow at a CAGR of over 13% during the forecast period, driven by nations such as Australia, China, India, Japan and South Korea. In particular, the prevalence of consumer electronics buyers in South Korea, Taiwan and China should boost market development.

Key players in the 405nm laser diode market covered in the report include Arima Lasers Corp, DILAS, Egismos Technology Corp, Hamamatsu Photonics K.K., Integrated Optics, Laser Components GmbH, Nichia Corp, Ondax Inc, Osram Opto Semiconductors GmbH, ProPhotonix, Sanyo Electric Co Ltd, Sharp Corp, Sony Semiconductor Solutions Corp, The Optoelectronics Co Ltd, Toptica Photonics Inc and Ushio Inc.

www.researchnreports.com/semiconductor-electronics/Global-405nm-Laser-Diodes-Market-2017-193819

Infrared laser projector market for mobile 3D sensing to grow from $246m in 2017 to $1.953bn in 2020

VCSEL/edge-emitting laser wafer & chip foundries raising capacities

As many smartphone companies have been developing 3D sensing embedded devices since Apple launched the iPhone X featuring a 3D sensor, the infrared laser projector market for mobile 3D sensing will reach US$246m in 2017 then grow to about US$1.953bn in 2020, forecasts LEDinside (a division of TrendForce) in its '2018 Infrared Sensing Application Market Report'.

An infrared laser projector has three major components, including a vertical-cavity surface-emitting laser (VCSEL) or edge-emitting laser (EEL), wafer-level optics (WLO) and diffractive optical elements (DOE). The current cost of an infrared laser projector is about US$3.5-6, but this is expected to decrease as the technology advances and supply chain strategy improves, boosting market demand as a result, says LEDinside research manager Joanne Wu.

Existing solutions for mobile 3D sensing include structured light and time of flight (ToF). The iPhone X uses structured light and its dot projector produces more than 30,000 dots of infrared lights on the face. Then the infrared camera receives the light reflected back from the face to create a 3D facial landscape.

In addition to 3D face sensing, branded smartphone makers also actively integrate 3D sensing with augmented reality (AR). LEDinside therefore forecasts that 3D sensor may be incorporated either in the front camera or in the rear camera. Manufacturers are expected to use ToF for the rear camera, as ToF can scan a larger area with better performance in computing and data processing. Moreover, ToF corresponds to the patent strategies of 3D sensing technology providers.

Regarding the supply chain for 3D sensing, LEDinside notes that algorithms, the emission pattern and patents will be the three key elements for 3D sensing development in the future.

VCSEL/EEL wafer and chip foundries (e.g. IQE, VPEC, WIN Semiconductor, II-VI Inc, Epistar, HLJ, AWSC) have increased their production capacity. Major VCSEL/EEL packaging companies include Lumentum, Finisar, Princeton Optronics, NeoPhotonics, Philips Photonics, and Osram Opto Semiconductors.

In addition to Apple, Samsung and ASUS, Chinese smartphone brands such as Xiaomi, Lenovo, Huawei and OPPO all plan to release new phones with 3D sensing,

Smartphone brands are now deploying in the market and seeking cooperation within the supply chain. However, obstacles still remain for the future development of the 3D sensing market, cautions LEDinside, including obtaining patents, developing third-party application, and increasing the performance–price ratio.

www.trendforce.com

RF power semiconductor device market growing at CAGR of nearly 12% to 2021

Asia-Pacific dominates with over 42% share

The global market for radio-frequency (RF) power semiconductor devices — spanning silicon (LDMOS), gallium arsenide (GaAs) and gallium nitride (GaN) — will increase at a compound annual growth rate (CAGR) of nearly 12% during 2017–2021 to about $1333.2m, forecasts a report by Technavio.

The leading players in the market are currently Infineon Technologies, Ampleon, Qorvo and Wolfspeed. Other vendors covered include Broadcom, EPC, Fujitsu Semiconductor, Integra Technologies, MACOM, Microsemi, RFHIC, Sumitomo Electric Device Innovations (SEDI), Toshiba and WIN Semiconductors.

In 2016, the telecom segment dominated the market, with a share of more than 41%. A major driver is the increased proliferation of smartphones and tablets. Because of the increased popularity of mobile computing devices, network traffic is growing at an exponential rate. As a result, there is the continued deployment across the globe of next-generation wireless standards such as 4G and 5G. Integration of progressive wireless technologies such as long-term evolution (LTE) and Wi-Fi into smartphones and tablets has generated an increased need for new RF features in these devices. The proliferation of mobile computing devices such as smartphones and tablets is expected to encourage RF device makers to develop high-performance RF filters that meet the requirements of OEMs.

APAC dominates market

With a dominant share of more than 42% of the RF power semiconductor devices market in 2016, the Asia-Pacific (APAC) region is expected to grow rapidly during the forecast period. There is high demand for improved cellular networks from developing countries such as China and India as well as South Korea, Taiwan and Malaysia. Most of these have almost reached saturation for 3G services and have begun offering 4G as well as LTE services. The high population density of nations such as India and China, along with the economic growth, has increased demand for power applications in network infrastructure to offer better services.

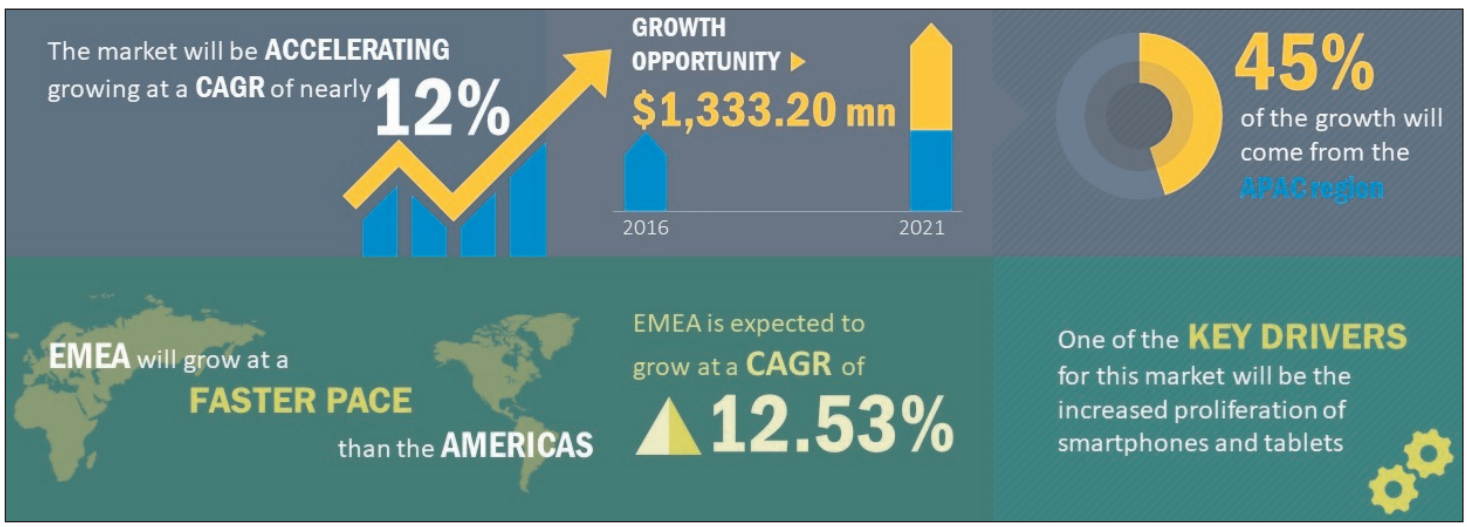
"Taiwanese manufacturers are developing RF devices for smartphones and wireless communications," notes Rohan Joy Thomas, a lead analyst for research on embedded systems. "Companies such as WIN Semiconductors and Visual Photonics Epitaxy Co (VPEC) are competing in the optic fiber telecommunication markets using their advanced technology to raise their product value and gross margins. WIN Semiconductors utilizes its production facilities at 90% of overall capacity," he adds. "These positive developments are expected to push the overall market to gain traction in the forecast period."

Meanwhile, the Europe, Middle East & Africa region (EMEA) is expected to grow at a CAGR of 12.53% (faster than the Americas).

Competitive vendor landscape

Like most emerging compound semiconductor technologies, the theoretical benefits of wide-bandgap (WBG) materials are well known. However, the practical realization of this technology in microelectronic devices remains at its nascent stage, says Technavio. The strong supply chain for RF devices can help to promote the use of this technology for RF infrastructure. In 2015, the RF power industry saw growth driven by the large-scale adoption of LTE networks in China and increased demand for cellular infrastructure. Many device makers are equipped with the requirements to make gallium nitride (GaN) commercially successful. Technavio therefore anticipates a speedy increase in product development towards mass manufacturing.

www.technavio.com



Qualcomm announces RF front-end design wins with Google, HTC, LG, Samsung and Sony Mobile

Qualcomm Technologies Inc, a subsidiary of Qualcomm Inc of San Diego, CA, USA, has announced radio-frequency front-end (RFFE) design wins with leading original equipment manufacturers (OEMs) including Google, HTC, LG, Samsung and Sony Mobile.

Qualcomm Technologies says that its portfolio of RF front-end platform solutions is designed to help OEMs deliver advanced mobile devices at scale and with accelerated time to commercialization, and that its design pipeline supports the value of its modem-to-antenna solutions. Qualcomm Technologies claims to be the first technology provider to produce the hardware and software needed to deliver a comprehensive modem-to-antenna system solution to OEMs. This includes new QPM26xx series gallium arsenide (GaAs)-based power amplifier modules incorporating duplexers (PAMiDs), envelope tracker, antenna tuners, antenna switches and discrete and integrated filter modules.

"Only Qualcomm Technologies is delivering robust end-to-end RFFE and modem solutions tailored for each tier of devices to address the increasingly complex RF demands of current networks in Gigabit LTE and beyond," claims Qualcomm Inc's president Cristiano Amon. "This is proven out by our extremely strong design pipeline for RF front-end," he adds. "Our advanced RF solutions deliver superior connectivity performance and flexibility in form-factor design," Amon continues.

Complementing its modem technology for next-generation mobile devices, Qualcomm Technologies' RF front-end portfolio delivers mobile solutions supporting technologies such as Gigabit LTE, 4x4 MIMO and LTE Advanced, and is crucial to the evolution and commercialization of 5G technologies in 2019.

Qualcomm Technologies' RF front-end design pipeline represents the culmination of recent steps in the firm's business strategy to develop and commercialize comprehensive mobile solutions from the digital modem to the antenna. Following the formation of the RF360 Holdings Singapore Pte Ltd joint venture between Qualcomm Inc and TDK Corp in February 2017, Qualcomm Technologies introduced a suite of comprehensive RF front-end products that added new capabilities to its portfolio. These included its first GaAs power amplifier modules, the next-generation Qualcomm TruSignal antenna tuning solution, premium-tier PAMiD modules, comprehensive 600MHz band (B71) support with a low-band PAMiD module, temperature-compensated (TC) surface acoustic wave (SAW) diversity receive filters and duplexer, the extension of B71 capability to its GaAs MMPA products and a B71-optimized aperture tuner. Also, at a groundbreaking event in Singapore last November, RF360 Holdings conducted a signing ceremony to expand production capacity at its key manufacturing production site dedicated to manufacturing RF front-end SAW structured wafers, as well as thin-film acoustic packaging.

With its core of RF front-end technologies and the ability to provide a comprehensive solution, Qualcomm Technologies reckons that it is uniquely positioned to address the rapidly expanding complexity and challenges of 4G and 5G.

www.qualcomm.com

Qualcomm's acquisition of NXP Semiconductors authorized by European Commission and Korea Fair Trade Commission

Qualcomm Inc of San Diego, CA, USA says that the European Commission and the Korea Fair Trade Commission (KFTC) have authorized the acquisition by indirect subsidiary Qualcomm River Holdings B.V. of NXP Semiconductors N.V. of Eindhoven, The Netherlands. The acquisition has now received 8 of the 9 approvals around the world, with China remaining.

Qualcomm says that it cooperated with the Commission and the KFTC and agreed to all conditions required by the agencies to obtain their authorization. The company committed to exclude certain near-field communication (NFC) patents from the proposed transaction and to ensure that NXP licenses those patents to third parties. Qualcomm also committed not to assert the NFC patents it will acquire from NXP and maintain interoperability between Qualcomm's baseband chipsets and NXP's NFC chips and rivals baseband chipsets and NFC chips. It will also continue to offer a license to MIFARE on terms commensurate with those offered by NXP currently.

"We are optimistic that China will expeditiously grant its clearance," says Qualcomm's CEO Steve Mollenkopf. "Acquiring NXP is complementary to Qualcomm's global portfolio, providing tremendous scale in automotive, IoT [Internet of Things], security and networking and will greatly accelerate our ability to execute and create value in new and adjacent opportunities," Mollenkopf believes.

www.nxp.com
www.qualcomm.com

Skyworks launches Sky5 platform for 5G global comms

Skyworks Solutions Inc of Woburn, MA, USA has introduced Sky5, its suite of solutions that supporting 5G wireless communications and enabling new applications across mobile and Internet of Things (IoT) ecosystems.

Skyworks says that, with decades of experience in developing connectivity platforms for each previous generation of wireless standards, it is leveraging its technology portfolio, systems expertise, leadership scale and customer relationships to accelerate the deployment of 5G. Specifically, Sky5 solutions encompass Skyworks' transmit and receive systems targeting the world's most demanding wireless end markets.

"5G is a macro-economic game changer that will revolutionize the global communication landscape with significantly more powerful and complex connectivity engines," says president & CEO Liam K. Griffin. "Skyworks is well positioned to capitalize on the demand for robust and dramatically increased data transmission speeds with near zero latency — key features that are mission critical in powering new usage cases from autonomous vehicles to emerging segments in artificial intelligence, robotics and virtual reality," he reckons. "Our Sky5 solutions will address new 5G waveforms and spectrum, enhanced carrier aggregation, dual connectivity (4G/5G) and massive MIMO requirements while delivering unmatched levels of integration and performance, all underpinned by Skyworks' intellectual property, operational scale and financial strength."

According to a May 2017 report by Research and Markets, the first standardized deployments of the technology are expected to be commercialized as early as 2019, with the 3GPP's standards organization initial 5G specifications set to be implementation-ready by March. Between 2019 and 2025, the 5G network infrastructure market is expected to grow at a compounded annual growth rate of nearly 70%, accounting for $28bn in annual spending by the end of 2025.

5G networks are expected to use a variety of spectrum bands ranging from established sub-6GHz cellular bands to millimetre-wave frequencies. The 3GPP organization is the mobile industry standards group that will submit a proposed specification to the International Telecommunications Union (IYU), or the standards body that sets the final specification. Skyworks is a key contributor to the 3GPP body on the Radio Access Network (RAN4) technical specifications.

All of Skyworks' devices and system solutions supporting 5G will be included in the Sky5 family. This will include a suite of highly flexible and customizable architectures and devices providing what is reckoned to be breakthrough performance, footprint and power efficiency.

www.skyworksinc.com/Sky5

Resonant signs fourth foundry partner agreement

Resonant Inc of Goleta, CA, USA, a designer of filters for radio-frequency front-ends that specializes in difficult bands and complex requirements, has signed its fourth non-captive Infinite Synthesized Network (ISN) foundry agreement with an established surface acoustic wave (SAW) foundry serving the RF market.

Resonant says that the new agreement increases the robustness of its fabless SAW eco-system, offering more choices for customers in the emerging module market. The new vendor provides full foundry services and capabilities as a pure-play gallium arsenide foundry, and will be able to leverage its GaAs customers by offering SAW filters. The firm is part of a new business group of a tier-1 CMOS fab company.

"This agreement with our fourth foundry partner further validates our fabless SAW eco-system model," says CEO George Holmes. "We continue to expand the offerings for our clients through this unique business model, which is fast tracking our expansion plans and increasing value for our shareholders," he adds.

"Moving to a fabless business model revolutionized CMOS, allowing a stable supply chain and increasing competition dramatically," Holmes continues. "Resonant is enabling a similar model for RF filters, which have become the key strategic element of the RF front-end."

Resonant claims that it can create designs for difficult bands and complex requirements that have the potential to be manufactured for half the cost and developed in half the time of traditional approaches. A large suite of proprietary mathematical methods, software design tools and network synthesis techniques enables it to explore a much bigger set of possible solutions and quickly derive the better ones, the firm adds. These improved filters still use existing manufacturing methods (i.e. SAW) and can perform as well as those using higher-cost methods (i.e. BAW), claims Resonant. While most of the industry designs SAW filters using a coupling-of-modes model, Resonant uses circuit models and physical models. Circuit models are computationally much faster, and physical models are highly accurate, based entirely on fundamental material properties and dimensions. Resonant claims that its method delivers excellent predictability, enabling achievement of the desired product performance in roughly half as many turns through the fab. Because Resonant's models are fundamental, integration with its foundry and fab customers is eased because its models speak the 'fab language' of basic material properties and dimensions, the firm adds.

www.resonant.com

Imec achieves record low contact resistivity on Ga-doped Ge-rich source/drain contacts

Nanosecond laser activation promising for suppressing parasitic source/drain resistance in advanced pMOS transistors

At the 63rd IEEE International Electron Devices Meeting (IEDM 2017) in San Francisco (4–6 December), nanoelectronics and photovoltaics research centre Imec of Leuven, Belgium has reported ultralow contact resistivity of $5x10^{-10}\Omega cm^2$ on gallium (Ga)-doped p-germanium (Ge) source/drain contacts. The low contact resistivity and high level of Ga activation were achieved after nanosecond laser activation (NLA) at low thermal budget. The results show that highly Ga-doped Ge-rich source/drain contacts provide a promising route for suppressing parasitic source/drain resistance in advanced pMOS devices.

Imec says that the results are important for further downscaling of the CMOS source/drain contact area, which is challenged by a parasitic source/drain resistance and results in suboptimal transistor functioning. High dopant activation is known to be an attractive approach for lowering source/drain contact resistance. Traditionally in pMOS devices, silicon (Si) source/drain contacts with high boron (B) activation are used. But in more advanced pMOS devices, Ge- and SiGe(Sn)-based source/drain are a promising alternative since they introduce beneficial strain. However, the higher the germanium content, the lower the boron activation and solubility in Ge or Ge-rich SiGe.

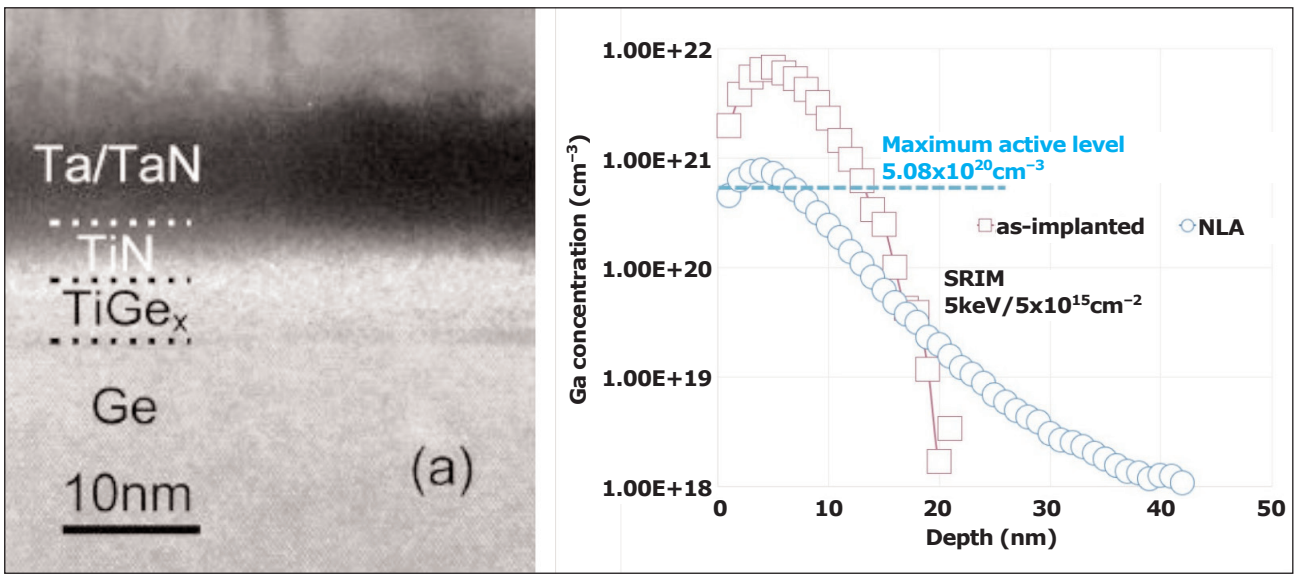
The new findings result from a comprehensive study of Ga dopant activation in Si, $Si_{0.4}Ge_{0.6}$ and Ge conducted by imec, KU Leuven in Belgium and Fudan University in Shanghai, China. In the study, either rapid thermal annealing (RTA) or Applied Materials' nanosecond laser activation were used as dopant activation technologies, after Ga ion implantation. A record low contact resistivity of $5x10^{-10}\Omega cm^2$ and a high dopant activation level of $5x10^{20}cm^{-3}$ were obtained for Ga-doped Ge source/drain contacts after NLA. The low contact resistivity can be attributed to a beneficial Ge/Ga surface aggregation following the NLA process. With RTA activation at 400°C, a contact resistivity as low as $1.2x10^{-9}\Omega cm^2$ was reported. The study shows that Ga might be preferred over B as a dopant for Ge or high-Ge content source/drain contacts in pMOS devices.

"For the first time, we have achieved contact resistivities far below $10^{-9}\Omega cm^2$ for high-Ge content source/drain contacts," says Naoto Horiguchi, distinguished member of the technical staff at imec. "This proves that Ga doping and activation by NLA or RTA are an attractive alternative to boron doping for these source/drain contacts," he adds. "It provides a possible path for further performance improvement using the current source/drain schemes in next-generation technology nodes."

The results were obtained at low thermal budget activation, making Ga doping particularly attractive for devices that require low-thermal-budget processing.

Imec's research into advanced logic scaling is performed in cooperation with key CMOS program partners including GlobalFoundries, Huawei, Intel, Micron, Qualcomm, Samsung, SK Hynix, SanDisk/Western Digital, Sony Semiconductor Solutions, TOSHIBA Memory and TSMC.

www.ieee-iedm.org
www.imec.be



Ga implanted in Ge and activated by NLA: (left) TEM image and (right) SIMS profile and calculated active carrier concentration level.

GlobalFoundries delivering 45nm RF SOI customer prototypes for 5G front-end modules

300mm RF SOI foundry process ready for volume production

GlobalFoundries of Santa Clara, CA, USA (one of the world's largest semiconductor foundries, with operations in Singapore, Germany and the USA) says that its 45nm radio-frequency silicon-on-insulator (45RFSOI) technology platform has been qualified and is ready for volume production at its 300mm production line in East Fishkill, NY, USA. Several customers are currently engaged for the advanced RF SOI process, which is targeted at 5G millimeter-wave (mmWave) front-end module (FEM) applications, including smartphones and next-generation mmWave beam-forming systems in future base stations.

GlobalFoundries says that, as next-generation systems move to frequencies above 24GHz, higher-performance RF silicon solutions are required to exploit the large available bandwidth in the mmWave spectrum. The firm's 45RFSOI platform is optimized for beam-forming FEMs, with features that improve RF performance through combining high-frequency transistors, high-resistivity SOI substrates and ultra-thick copper wiring. Moreover, the SOI technology enables easy integration of power amplifiers, switches, low-noise amplifiers (LNAs), phase shifters, up/down converters and voltage-controlled oscillators (VCO)/phase-locked loops (PLLs), which lowers cost, size and power compared with competing technologies targeting future multi-gigabit-per-second communication systems, including internet broadband satellite, smartphones and 5G infrastructure.

"GlobalFoundries' leadership in RF SOI solutions makes the company a perfect strategic partner for Peregrine's next generation of RF SOI technologies," comments Jim Cable, chairman & chief technology officer of Peregrine Semiconductor Corp of San Diego, CA, USA — a fabless provider of SOI-based RFICs. "It enables us to create RF solutions that provide our customers with new levels of product performance, reliability and scalability, and it allows us to push the envelope of integrated RF front-end innovation for evolving mmWave applications and emerging 5G markets," he adds.

"To bring 5G into the future, mmWave innovations are needed for allocating more bandwidth to deliver faster, higher-quality video and multimedia content and services," says Bob Donahue, CEO of 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. "GlobalFoundries' RF SOI technology leadership and 45RFSOI platform enables Anokiwave to develop differentiated solutions designed to operate between the mmWave and sub-6GHz frequency band for high-speed wireless communications and networks," he adds.

"GlobalFoundries continues to expand its RF capabilities and portfolio to provide competitive RF SOI advantages and manufacturing excellence that will enable our customers to play a critical role in bringing 5G devices and networks to real-world environments," says Bami Bastani, senior VP of GlobalFoundries' RF business unit. "Our 45RFSOI is an ideal technology for customers that are looking to deliver the highest-performing mmWave solutions that will handle demanding performance requirements in next-generation mobile and 5G communications."

www.globalfoundries.com

RFMW to distribute Keysight's MMIC portfolio

Keysight Technologies Inc of Santa Rosa, CA, USA has announced a distribution agreement with RFMW Ltd.

Keysight designs and makes high-frequency indium phosphide (InP) and gallium arsenide (GaAs) monolithic microwave integrated circuit (MMIC) devices providing broadband performance from DC to 110GHz. Product families include switches, attenuators, amplifiers, mixers, limiters, frequency doublers, detector diodes and pre-scalers.

RFMW is a specialized distributor providing customers and suppliers with focused distribution of RF and microwave components as well as specialized component-engineering support. Under the agreement, RFMW is franchised worldwide for Keysight's MMIC portfolio.

"Keysight's MMIC portfolio offers designers an optimized tradeoff of performance, power, size and cost," comments Keysight's business development manager Dave Savage. "The broadband performance of our devices allows full bandwidth designs and eliminates narrow band, switched path architectures that are complex, power hungry and ultimately, expensive. RFMW's worldwide organization of RF experienced sales people are uniquely positioned to understand the benefits Keysight brings to the market and can engage appropriate customers early in their design process to help them realize their broadband designs with the quickest time-to-market."

"Keysight products offer some unique and technically advanced solutions for customers developing broadband product for applications such as aerospace and defense," comments RFMW's president & CEO Joel Levine. "The diversity of products can also populate many of the blocks in a transceiver front end," he adds. "With current and future radio development, these devices will find homes in a wide range of applications and complement other devices in our supplier's portfolios, enabling the RFMW sales team to better support new product designs."

www.rfmw.com
www.keysight.com
www.ixiacom.com

ST showcases solutions for smart driving

With the automotive industry is seeing rapid advances in the development of technologies such as autonomous driving, advanced driver-assistance systems (ADAS), vehicle-to-everything (V2X) communication, and power management in electric vehicles (EVs), at Automotive World 2018 in Tokyo, Japan (17–19 January) STMicroelectronics of Geneva, Switzerland exhibited its latest semiconductor solutions for smart driving.

ST highlighted its silicon germanium (SiGe)-based transceiver ICs for long-range (77/81GHz) and short-range (24/26GHz) radar, which can measure the distance between automobiles or between automobiles and objects: 77GHz radar systems are suitable for next-generation features such as high-speed adaptive cruise control (ACC) that require high power output; 24GHz systems are suitable for blind-spot detection, collision avoidance, and lane-departure warning applications.

ST also exhibited an automotive power semiconductors based on silicon carbide (SiC). The firm says that its automotive SiC power MOSFET is characterized by low power loss during switching — about 1/4 the loss compared with existing mainstream silicon-based insulated-gate bipolar transistors (IGBTs) — as well as operation across a wide temperature range. ST also highlighted an automotive SiC diode with reverse recovery properties superior to those of silicon bipolar diodes. The firm says that its SiC can be used in hybrid, electric and other automotive systems, as well as in railway, industrial and solar-power applications.

www.st.com

Infineon's 77GHz radar ICs used in first series production car with autonomous driving features

Infineon Technologies AG of Munich, Germany says that it is supplying key components for the Audi A8, the first series production car featuring level 3 automated driving.

With level 3, drivers can temporarily take their hands off the steering wheel under certain conditions. For example, the A8 allows this when parking and exiting, in slow-moving traffic or in traffic congestion.

"Around 90% of innovations in the car are driven by electronics and hence by semiconductors," says Peter Schiefer, president of Infineon's Automotive Division. "We have been a recognized semiconductor partner of Audi for many years."

For safe automated driving, the A8 uses sensors, microcontrollers and power semiconductors from Infineon. Specifically, silicon germanium (SiGe)-based radar sensor chips from the RASIC family are installed in the front and corner radar, sending and receiving 77GHz signals and forwarding these onto the central driver assistance controller.

www.infineon.com/rasic

Peregrine changes name to pSemi, as it celebrates 30th anniversary and ships 4 billionth chip

Expanded engineering team to boost product portfolio, supporting Murata's move into more advanced and intelligent modules

Peregrine Semiconductor Corp of San Diego, CA, USA — a fabless provider of radio-frequency integrated circuits (RFICs) based on silicon-on-insulator (SOI) — has announced its corporate name change to pSemi Corp, a Murata company focused on semiconductor integration.

Peregrine was acquired in December 2014 by Japan's Murata Manufacturing Co Ltd, which designs and manufactures ceramic-based passive electronic components & solutions, communication modules and power supply modules.

In March 2017, Peregrine acquired Arctic Sand Technologies of Burlington, MA, USA (a designer and manufacturer of low-power semiconductors for DC–DC power conversion) to accelerate Murata's aim to provide the smallest, most efficient power solutions.

The name change will be rolled out across new products. Legacy products will remain branded under the Peregrine Semiconductor name and logo and will be supported by the same sales teams, distributors and applications engineers.

The name change coincides with two major milestones: the company's 30-year anniversary and the shipment of its 4 billionth chip. pSemi will serve as Murata's semiconductor arm and is tasked with growing rapidly to support its expanding product portfolio and the hiring of engineers and professionals globally.

pSemi will have a broader scope and an expanded product portfolio which, building on its foundation in RF integration, will span power management, connected sensors, optical transceivers, antenna tuning and RF front-ends.

"We've challenged the pSemi team to broaden their scope, increase their intellectual property (IP) portfolio and grow on a global scale to support more semiconductor innovations," says Norio Nakajima, senior executive VP, module business unit at Murata. "pSemi will leverage the breadth of Murata's manufacturing and technology leadership, while maintaining a level of autonomy that accelerates its path to semiconductor integration," he adds. "pSemi will serve as the hub for Murata's semiconductor activities, and we are investing in its aggressive growth strategy to fuel our move into more advanced and intelligent modules."

The 4 billionth chip was shipped in an order to Samsung. Also, in January the firm's founders published a research paper that served as the foundation for Peregrine's UltraCMOS technology platform. "Over a span of three decades, many industry firsts were achieved, such as CMOS switches, SOI power amplifiers and mmWave beam-forming," notes CEO Stefan Wolff. "Our patent portfolio continues to grow and is now ranked as one of the technology world's most valuable patent portfolios, and finally we became a Murata company," he adds. "The launch of pSemi is the next chapter in this company's history. I am grateful to Murata for selecting us for this important growth strategy... With pSemi, we are building the 'dream team' of engineers, and we need more talented people to join us."

www.psemi.com
www.murata.com

pSemi ranked for second consecutive year on 'IEEE Spectrum' Patent Power Scorecard

Murata company pSemi Corp of San Diego, CA, USA (formerly Peregrine Semiconductor Corp) — a fabless provider of radio-frequency integrated circuits (RFICs) based on silicon-on-insulator (SOI) — has been ranked for the second consecutive year on the 'IEEE Spectrum' Patent Power Scorecard.

This annually published benchmark identifies the technology world's most valuable patent portfolios and ranks companies by a Pipeline Power score. Based on an analysis of US Patent and Trademark Office records through the end of 2016, the 2017 scorecard ranks the pSemi patent portfolio among the top 10 in the semiconductor manufacturing sector.

The firm's patent portfolio now exceeds 500 issued and pending patents and continues to grow. On 17 January, the firm celebrated its 30th anniversary and announced its corporate name change from Peregrine Semiconductor to pSemi.

"Our top-10 ranking within semiconductor manufacturers demonstrates our team's commitment to innovation and our patent portfolio's strength," says Dan Nobbe, VP of corporate research & IP development. "We are even more proud of the quality of our patents. It is a testament to our forward-thinking engineers and the groundbreaking role our team has played in advancing semiconductor technology for the last 30 years," he adds.

www.spectrum.ieee.org

University of Tokyo and Mitsubishi quantify factors for reducing SiC power semiconductor resistance by two-thirds

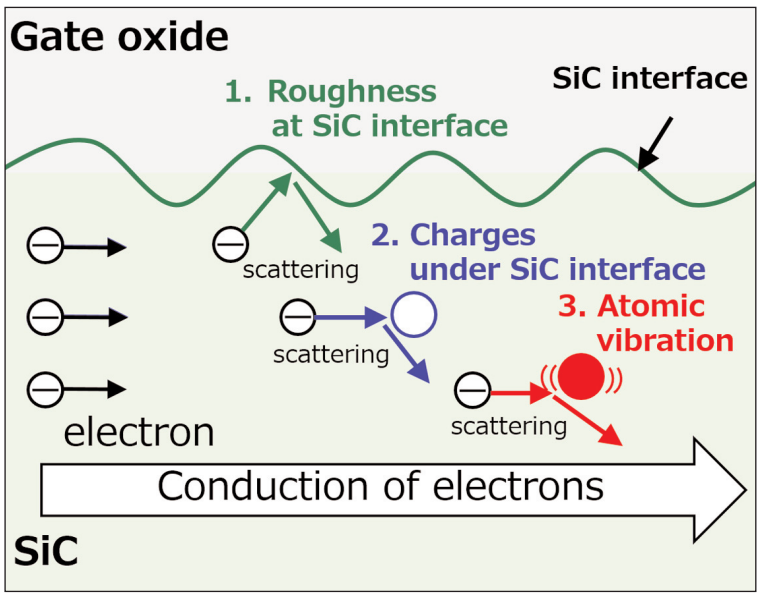
Electron scattering dominated by charge under SiC interface and atomic vibration rather than SiC interface roughness

At the 63rd IEEE International Electron Devices Meeting (IEDM 2017) in San Francisco on 4 December, a university–industry team at the University of Tokyo and Mitsubishi Electric Corp in Japan reported that it has quantified for the first time the impacts of three electron-scattering mechanisms for determining the resistance of silicon carbide (SiC) power semiconductor devices in power semiconductor modules. They found that resistance under the SiC interface can be reduced by two-thirds by suppressing electron scattering by the charges. This is expected to help to reduce energy consumption in power equipment by lowering the resistance of SiC power semiconductors.

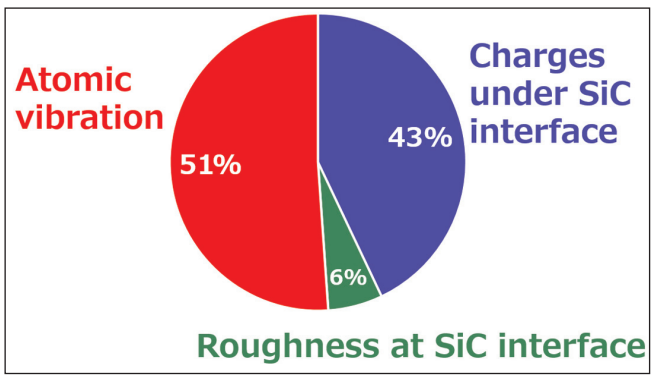
SiC power devices offer lower resistance than conventional silicon power devices, so to further lower their resistance it is important to understand correctly the characteristics of the resistance under the SiC interface.

"Until now, however, it had been difficult to measure separately resistance-limiting factors that determine electron scattering," says Satoshi Yamakawa, senior manager of the SiC Device Development Center at Mitsubishi Electric's Advanced Technology R&D Center.

Electron scattering focusing on atomic vibration was measured using technology from the University of Tokyo. In Mitsubishi Electric's analyses of fabricated devices, the impact that charges and atomic vibration have on electron scattering under the SiC interface was revealed to be dominant. Although it has been recognized that electron scattering under the SiC interface is limited by three factors — namely the roughness of the SiC interface, the charges under the SiC interface, and the atomic vibration — the contribution of each factor had been unclear. A planar-type SiC metal-oxide-semiconductor field-effect transistor (SiC-MOSFET), in which electrons conduct away from the SiC interface to around several nanometers, was fabricated to confirm the impact of the charges.



Electron scattering under the SiC interface is limited by three factors: roughness of the interface, charges under the interface, and atomic vibration.



SiC interface roughness has little effect in limiting resistance, while charges under the SiC interface and atomic vibration are dominant factors.

"We were able to confirm at an unprecedented level that the roughness of the SiC interface has little effect while charges under the SiC interface and atomic vibration are dominant factors," says Koji Kita, an associate professor in the University of Tokyo's Graduate School of Engineering.

Using an earlier planar-type SiC-MOSFET device for comparison, resistance was reduced by two-thirds due to suppression of electron scattering, which was achieved by making the electrons conduct away from the charges under the SiC interface. The previous planar-type device has the same interface structure as that of the SiC MOSFET fabricated by Mitsubishi Electric.

For the test, the firm handled the design, fabrication and analysis of the resistance-limiting factors and the University of Tokyo handled the measurement of electron-scattering factors.

"Going forward, we will continue refining the design and specifications of our SiC MOSFET to further lower the resistance of SiC power devices," says Yamakawa.

www.ieee-iedm.org
www.MitsubishiElectric.com/

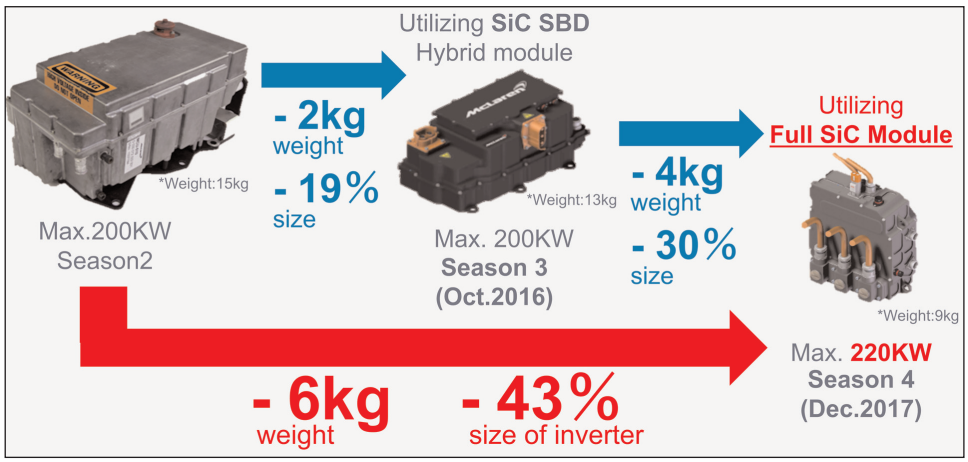
ROHM supplying full-SiC power modules to Venturi Formula E racing team

ROHM of Kyoto, Japan is providing full-SiC (silicon carbide) power modules to the VENTURI Formula E team during season 4 (2017–2018) of FIA Formula E (the world's first formula racing championship for all-electric vehicles), which started on 2–3 December in Hong Kong. The module supports further improvements in the machine's performance under racing conditions.

ROHM became VENTURI's official technology partner in season 3, and provides SiC power devices used in the inverter (the core of the electric vehicle powertrain). The inverter for season 4 features an embedded full-SiC power module, making it 43% smaller and 6kg lighter than the inverter for season 2.

After being inaugurated by the FIA (Fédération Internationale de l'Automobile) in 2014, the Formula E series has expanded to cities worldwide, including metropolises such as Hong Kong, Berlin and New York. The advances in Formula E technology are expected to filter through developments to general-use electric vehicles. Although still in its infancy, Formula E already enjoys the participation of automotive manufacturers from around the world, and major automobile manufacturers including those from Japan have declared their intention to join the championship.

"Formula E is the only motorsports event for testing the latest technology in next-generation

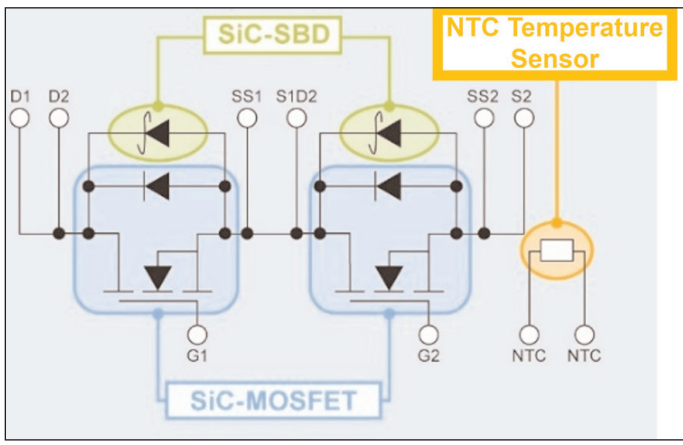


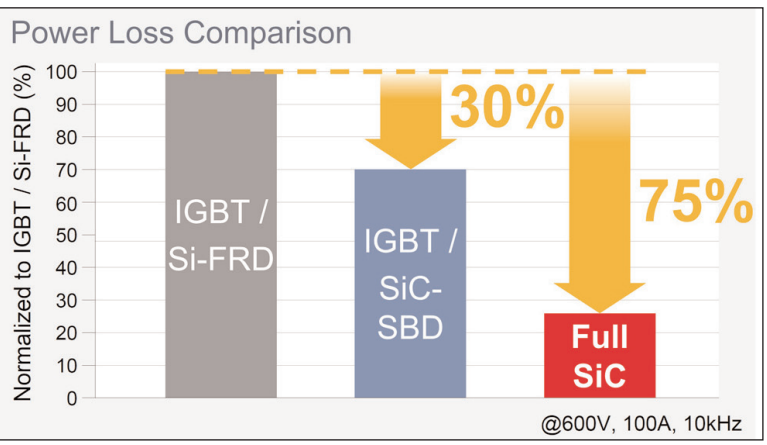
electric vehicles," comments VENTURI Formula E Team's chief technology officer Franck Baldet. "We are extremely happy about our technical partnership with ROHM in the area of power management, which is the foremost key to the Formula E race," he adds. "For season 4, by adopting a full-SiC power module, we were able to bring to reality a lightweight inverter that requires only a minimum amount of space."

"Semiconductor devices are certain to play a crucial role in recent hybrid and electric automobiles," says Kazuhide Ino, group general manager of ROHM's Power Device Production Headquarters. "The SiC power device that we are providing for the Formula E racing car is one example. We provided SiC-SBDs in season 3 last year (2016–2017), but this year we provide full-SiC power modules that combine SiC SBD and SiC MOSFET. These modules will contribute to improve vehicle performance."

The SiC power module used in the inverter of the VENTURI Formula E team racing car achieves large power throughput due to the development of a new package with an improved internal module structure, as well as an optimized thermal management. Compared to conventional insulated-gate bipolar transistor (IGBT) modules with similar current ratings, the module reduces switching losses by 75% (at a chip temperature of 150°C), aiding energy efficiency for the whole application. Also, having more compact peripheral components throughout the high-frequency drive, as well as the effect of reductions in switching losses, also contributes to a more compact cooling system.

www.rohm.com/web/global/full-sic-power-modules
http://micro.rohm.com/en/formulae





Littelfuse completes acquisition of IXYS

Littelfuse Inc of Chicago, IL, USA, which provides circuit protection technologies (including fuses, semiconductors, polymers, ceramics, relays and sensors), has completed its acquisition of IXYS Corp of Milpitas, CA, USA and Leiden, The Netherlands (which provides medium- to high-voltage power semiconductors and mixed-signal ICs for power conversion and motor control applications across the industrial, communications, consumer and medical device markets).

"Today marks a significant step forward in our company strategy to accelerate growth within the power control and industrial OEM markets," says president & CEO Dave Heinzmann. "The combination of our companies brings together a broad power semiconductor portfolio, complementary technology expertise and a strong talent pool."

The transaction is expected to be immediately accretive to adjusted earnings per share (EPS). Littelfuse expects to achieve more than $30m of annualized cost savings within the first two years after closing. The combination is also expected to create significant revenue synergy opportunities longer term, given the companies' complementary offerings and combined customer base.

In conjunction, IXYS founder Dr Nathan Zommer has been appointed to Littelfuse's board of directors, increasing its size to nine members.

Each former IXYS stockholder is entitled to receive either $23 in cash or 0.1265 of a Littelfuse share in exchange for each IXYS share held immediately prior to the closing. In total, 50% of IXYS stock was converted into cash and 50% into stock.

www.littelfuse.com

Littelfuse's expanded SiC Schottky diode line reduces switching losses, and increases efficiency and robustness

Littelfuse Inc of Chicago, IL, USA, which provides circuit protection technologies (including fuses, semiconductors, polymers, ceramics, relays and sensors), has added to its GEN2 family of 1200V silicon carbide (SiC) Schottky diodes (launched last May) by releasing four new series: the LSIC2SD120A08, LSIC2SD120A15 and LSIC2SD120A20 (offering current ratings of 8A, 15A ,20A, respectively, and provided in TO-220-2L packages) and the LSIC2SD120C08 (offering a current rating of 8A in a TO-252-2L package).

GEN2's merged p-n Schottky (MPS) device architecture is said to enhance surge capability and reduce leakage current. Replacing standard silicon bipolar power diodes with the new GEN2 SiC Schottky diodes allows circuit designers to reduce switching losses dramatically, accommodate large surge currents without thermal runaway, and operate at junction temperatures as high as 175°C, says Littelfuse, allowing substantial increases in power electronics system efficiency and robustness.

"They expand the component options available to circuit designers striving to improve the efficiency, reliability and thermal management of the latest power electronics systems," says Michael Ketterer, global product marketing manager, Power Semiconductors.

Littelfuse's new SiC Schottky diodes

Typical applications include: active power factor correction (PFC); buck or boost stages in DC–DC converters; free-wheeling diodes in inverter stages; and high-frequency output rectification. Markets include industrial power supplies, solar energy, industrial motor drives, welding and plasma cutting, EV charging stations, and inductive cooking fields.

GEN2 SiC Schottky diodes are claimed to offer the following benefits:

- best-in-class capacitive stored charge and negligible reverse recovery (ensuring switching losses are extremely low and reducing stress on the opposing switch), making them suitable for high-frequency power switching;
- best-in-class forward voltage drop (V_F), providing low conduction losses; and
- maximum junction temperature of 175°C, allowing a larger design margin and relaxed thermal management requirements.

The new LSIC2SD120A08, LSIC2SD120A15 and LSIC2SD120A20 series are available in tubes in 1000-unit quantities. The LSIC2SD120C08 series is available in tape & reel in quantities of 2500. Sample requests can be placed through authorized Littelfuse distributors worldwide.

www.littelfuse.com

AFRL uses boron nitride to demonstrate growth and lift-off of GaN for strainable RF devices

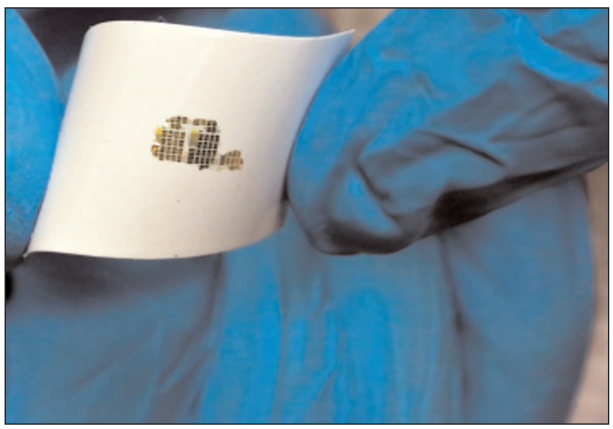
Flexible gallium nitride to enable fifth-generation, high-speed, agile wireless communications

The Air Force Research Laboratory (AFRL) says it has discovered a new way to grow and transfer gallium nitride (GaN), laying the groundwork for future fifth-generation, high-speed, agile communication systems (Glavin et al, 'Flexible GaN for High-Performance, Strainable Radio Frequency Devices', Advanced Materials (14 December 2017); DOI: 10.1002/adma.201770338).

"We demonstrated the ability to grow and place the material on a flexible substrate, enabling the potential to power wearable devices or electronic devices that are not necessarily flat," says Nicholas Glavin, a research scientist at the AFRL Materials and Manufacturing Directorate. "We are the first group ever to demonstrate a flexible RF (radio frequency) transistor device based on gallium nitride that actually performs under strain and is flexible," he claims.

Although gallium arsenide is often the material of choice for wireless devices currently, it is limited in its ability to transmit high-frequency signals at high power, which can cause data degradation or slow speeds of transfer at high range. In contrast, GaN has an exceptional ability to transmit large amounts of information at a high frequency with high power, but it has been limited in application due to the high cost of material manufacturing, which typically requires a rigid substrate such as sapphire and precise thermal and chemical stability. Also, once grown on a substrate, GaN made this way can only be used in flat, planar platforms, unable to withstand bending or strain.

AFRL's new method of GaN production takes advantage of the physical properties of boron nitride. The GaN is grown on the boron nitride and then, due to weak chemical bonds between the boron nitride and the growing surface, they can then lift and transfer the apparatus to another substrate, enabling communication capability on unique platforms and devices.



AFRL has demonstrated the growth and transfer of flexible GaN devices that can be used to amplify communication signals for next-generation wearable electronics, flexible sensors and radar systems. (courtesy US Air Force).

"It's been a big DoD [Department of Defense] priority to further develop this material. We are the first to demonstrate a flexible RF transistor device using gallium nitride that maintains high-quality performance under strain using the transfer method," claims Dr Donald Dorsey, the lead for the Agile Radio Frequency Electronic Materials and Processes Team. "We now have the potential to create high-frequency transmitters for high-power communications and radar that use gallium nitride in a more compact and versatile form."

The ability to transfer the GaN to a flexible or other arbitrary substrate has tremendous value for the Air Force as communication needs continue to grow and expand at a rapid rate.

"There are two primary applications we see this research directly benefitting the Air Force," says Glavin. "The first is in wearable systems — as we collect more information on our operators and develop more sensor technologies, we need to be able to take that information and communicate it for action. A flexible transmitter based on GaN can make this happen more efficiently," he adds. "Another area that will benefit is flexible and conformal radar technology. Typical radar systems are big and bulky, but using this technology we can create systems that can be more easily integrated into dynamic environments."

Another benefit is power amplification directly on antenna systems, says Dr Michael Snure, a senior physicist at the AFRL Sensors Directorate. "If you have a flexible power amplifier and can get it as close as possible to your radar antenna, you can improve performance simply by removing the distance a signal has to travel," he adds. "Flexible GaN gets you the ability to place the amplifier up against the antenna on the same platform and improve performance and transmission."

"We performed the demo state and are now focusing on material integration," says Glavin. However, although research continues to optimize the ability for the AFRL-developed GaN to integrate with diverse material surfaces and to find ways to improve performance and the transfer process, the team is already in the process of obtaining patents for both the material growth process and the use of GaN in flexible RF devices.

http://onlinelibrary.wiley.com/doi/10.1002/adma.201770338/full

ON Semiconductor joins CharIN Ecosystems in developing EV charging standards

ON Semiconductor of Phoenix, AZ, USA — which supplies power management, analog, sensors, logic, timing, connectivity, discrete, system-on-chip (SoC) and custom devices for automotive, communications, computing, consumer, industrial, medical, aerospace and defense applications — has joined the global Charging Interface Initiative e.V. (CharIN) ecosystem.

As a registered association founded in 2015 in Berlin, Germany and open to all interested parties (with more than 100 international members from the whole automotive value chain), CharIN aims to promote standards for charging systems in electric vehicles (EV), creating requirements for the evolution of EV charging systems and developing a certification system for manufacturers to implement charging systems into their products.

"Their broad portfolio of power, analog and communication silicon products, system design expertise, and relationships with leading companies in both the automotive and industrial markets complement and supplement the already-strong CharIN roster of members and partners," comments CharIN chairman Claas Bracklo about ON Semiconductor.

ON Semiconductor says it has all the core technologies for vehicle electrification, particularly its automotive-qualified power management portfolio including: insulated-gate bipolar transistors (IGBTs), high-voltage gate drivers, super-junction rectifiers, high-voltage MOSFETs, high-voltage DC–DC converters, as well as wide-bandgap (WBG) devices in silicon carbide (SiC) and gallium nitride (GaN) for next-generation solutions. Beyond silicon development, investments in advanced packaging include: high-power modules, single/dual-sided cooled and dual-sided direct cooled packages. With sensing, communication and analog solutions, ON Semiconductor reckons it has nearly all the components for current and future EV charging infrastructure needs.

"Our core business is power management, and we support virtually every requirement with products that range from low drop-out regulators to switched-mode power supplies to sophisticated power management ICs (PMICs), positioning the company as an unrivaled supplier of power solutions for the rapidly emerging EV and hybrid electric vehicle market," claims Ali Husain, senior manager, power conversion and motor control solutions.

"We are seeing a ramp-up of our IGBT modules and FETs for electric vehicle charger designs," he adds. "We expect next-generation semiconductor materials such as silicon carbide and gallium nitride to drive improving power density and efficiency. We look forward to bringing this expertise to the CharIN ecosystem and collaborating with other industry leaders to create a Combined Charging System [CCS, as a global standard for the charging of battery-powered electric vehicles of all kinds] and supporting the continued evolution of EV charging infrastructure."

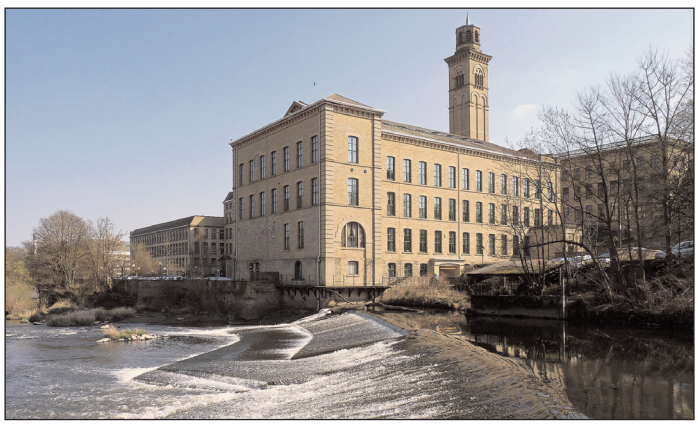
As automotive manufacturers turn to next-generation semiconductor materials to improve power density and efficiency in hybrid and electric vehicles, ON Semiconductor is providing 1200V SiC and 650V GaN power devices, offering higher power efficiency and power density while keeping weight to a minimum.

www.charinev.org
www.onsemi.com

Diamond Microwave relocates design and lab facility

Diamond Microwave Devices Ltd of Leeds, UK — which specializes in compact gallium nitride (GaN)-based microwave solid-state power amplifiers (SSPA) customized for high-reliability defence and communications applications — has relocated its design and laboratory facility to the historic Salts Mill in Saltaire, near Shipley, West Yorkshire, UK.

The firm's ultra-compact amplifiers are said to achieve high pulsed and continuous wave (CW) power output levels, and offer a viable alternative to traveling-wave tube (TWT) amplifiers, with low cost of ownership.



Salts Mill in Saltaire, near Shipley, West Yorkshire.

"Our new location offers us attractive surroundings within a UNESCO World Heritage Site, much closer to good national rail links and only 20 minutes from Leeds Bradford International airport," says managing director Richard Lang. "Saltaire and Shipley have excellent local facilities, and have a history of developing innovative electronics businesses."

www.diamondmw.com

II-VI and University of South Florida achieve research milestone in thin-film diamond on silicon technology for 5G wireless

Engineered materials and optoelectronic component maker II-VI Inc of Saxonburg, PA, USA says that, in collaboration with the University of South Florida (USF), it has achieved a key research milestone in the development of thin-film diamond on silicon technology for 5G wireless communications, adding to its portfolio of gallium arsenide (GaAs) and silicon carbide (SiC) engineered materials for high-speed wireless applications.

Mobile communications service providers are planning to enhance their high-speed broadband services with 5G wireless, which is driving the demand for devices with much higher bandwidth and power efficiency than can be achieved through existing technologies. II-VI and USF have completed the first phase of their joint research program, which was initiated in June 2016, to develop a new technology platform using thin-film diamond on silicon that can enable next-generation high-speed electronic components in 5G wireless handsets.

"Our work with USF accelerates the development timelines and will enable us to be ready in time to serve the market for 5G wireless components," says Dr. Wen-Qing Xu, general manager of Platform Technology Development and Incubation, II-VI Inc.

The joint research activities of II-VI and USF were partly funded by the Matching Grant Research Program (MGRP) from the Florida High Tech Corridor Council, which is an economic development initiative of the University of South Florida (USF), the University of Central Florida (UCF) and the University of Florida (UF) spanning a 23-county region. Activities included the design, modeling, fabrication and characterization of prototype devices.

"Our research team at USF was able to leverage our area of expertise in micro-machined thin-film diamond on silicon, to rapidly converge on a technical solution for II-VI," says Dr Jing Wang, associate professor in USF's Department of Electrical Engineering. "We acknowledge MGRP's support for this program along with a dozen others in recent years."

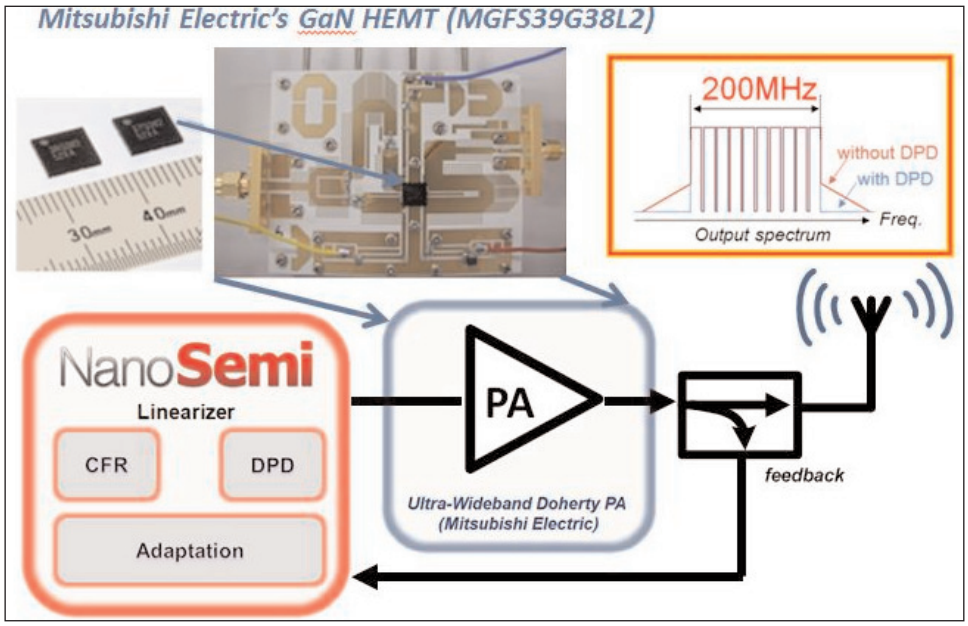
www.ii-vi.com
www.floridahightech.com

Mitsubishi Electric and NanoSemi demonstrate ultra-wideband linearized Doherty amplifier for next-generation LTE base stations

At the IEEE Radio & Wireless Week (RWW2018) in Garden Grove, Anaheim, CA, USA (15–16 January), Mitsubishi Electric US Inc of Cypress, CA, USA presented a hands-on mini lab showcasing its high-efficiency, wideband gallium nitride (GaN) Doherty amplifier.

At RWW2017 in Phoenix, AZ, USA, Mitsubishi Electric Corp and Mitsubishi Electric Research Laboratories Inc presented a paper '3.0–3.6GHz Wideband, over 46% Average Efficiency GaN Doherty Power Amplifier with Frequency Dependency Compensating Circuits' describing this wideband Doherty power amplifier design technique for next-generation LTE base stations using GaN transistor technology. The demonstration at RWW2018 further illustrated the ability to linearize an ultra-wideband signal applied to Mitsubishi Electric's GaN power amplifier using an advanced pre-distortion technique provided by NanoSemi Inc of Waltham, MA, USA, which develops digital compensators to linearize non-linear dynamic systems such as wireless radios.

"The proliferation of smartphones and tablets will require a dramatic increase in wireless capacity of base stations," says Kyle Martin, VP & general manager, Mitsubishi Electric US Inc Semiconductor Division. "To meet this demand, mobile technologies are moving to next-generation LTE in which the wireless capacities are increased by allocating multiple simultaneous frequency bands (carrier aggregation) above 3GHz," he adds. "Operating in multiple simultaneous frequency bands usually requires multiple power amplifiers to cover each frequency band, leading to an increase in the size of base stations."



Conventional base-station Doherty power amplifier design presents many challenges to simultaneously achieve both high efficiency and low distortion for wideband carrier aggregation. Using NanoSemi's digital pre-distortion (DPD) technology, Mitsubishi Electric's wideband Doherty power amplifier can achieve high efficiencies with up to 200MHz instantaneous bandwidth while maintaining adjacent channel level rejection (ACLR) of –50dBc. Base-station designers hence gain the ability to design a single flexible LTE power amplifier capable of many carrier aggregation scenarios, even above 3GHz, says the firm.

Mitsubishi Electric's full line-up of GaN devices, with frequencies in cellular, Ku, and Ka-bands at output powers of 2–100W, supports a wide variety of end-communications applications including cellular base station, satellite, ground station and point to point.

www.MitsubishiElectric.com
www.nanosemitech.com

SMI hires sales & marketing manager

Structured Materials Industries Inc (SMI) of Piscataway, NJ, USA — which provides chemical vapor deposition (CVD) systems, components, materials, and process development services — has recruited Keith Lehn as sales & marketing manager, responsible for growing commercial revenue, implementing multiple marketing strategies, and expanding SMI's presence in domestic and foreign markets.

Most notably, Lehn oversaw the business operations for 2D material supplier Graphene Laboratories. Through its e-commerce site Graphene Supermarket, he helped bring to market and manage products made from 2D materials such as graphene, boron nitride (BN), molybdenum disulfide (MoS_2) and tungsten disulfide (WS_2).

"His background aligns with SMI's trajectory, and will be invaluable to future initiatives as we seek to grow and diversify our product offerings to best meet the needs of our customers," comments president Dr Gary S. Tompa.

www.smicvd.com

DENSO and Kyoto spin-off FLOSFIA to develop α-Ga_2O_3-based power semiconductor device for EVs

DENSO invests in FLOSFIA series C funding round

Automotive supplier DENSO Corp of Kariya, Aichi prefecture, Japan, and Kyoto-based FLOSFIA Inc are partnering to develop a next-generation power semiconductor device that is expected to reduce the energy loss, cost, size and weight of inverters used in electric vehicles (EVs). Through the joint development project, the two firms aim to improve the efficiency of EV power control units (key to driving the widespread use of EVs).

Since 2007, DENSO has provided power control units (PCUs) for hybrid and electric vehicles, using an inverter to control the power supplied from the battery to the motor generator. To use electric energy more efficiently, energy losses during the DC to AC conversion by the inverter must be reduced, so DENSO is conducting R&D on low-loss power semiconductors.

FLOSFIA was spun off from Kyoto University in 2011 and specializes in R&D and commercialization of gallium oxide (α-Ga_2O_3) thin films formed by mist chemical vapor deposition (CVD). DENSO has also acquired new shares issued by FLOSFIA in its Series C funding round.

Kyoto University's professor Shizuo Fujita pioneered the application of corundum-structured α-Ga_2O_3 for use in semiconductors. With a wide bandgap of 5.3eV and high electric breakdown field strength, α-Ga_2O_3 can better withstand high-voltage applications, making it possible to replace existing silicon and silicon carbide (SiC) power semiconductors.

Making use of physical properties of α-Ga_2O_3, FLOSFIA has developed low-loss power devices including a Schottky barrier diode (SBD) with what is claimed to be the lowest specific on-resistance on the market. The firm aims to develop its own production lines, targeting commercial production in 2018.

www.flosfia.com
www.denso.com

SMI demonstrates MOCVD growth of silicon-doped gallium oxide on sapphire substrates

Structured Materials Industries Inc (SMI) of Piscataway, NJ, USA — which provides chemical vapor deposition (CVD) systems, components, materials, and process development services — says its R&D team has grown silicon-doped gallium oxide (Ga_2O_3) films on sapphire (Al_2O_3) substrates using metal-organic chemical vapor deposition (MOCVD). The demonstration proves that doped Ga_2O_3 films can be deposited uniformly on large-area substrates for device applications, says the firm.

Previously, SMI grew Si-doped Ga_2O_3 films on insulating (or unintentionally doped) bulk Ga_2O_3 substrates that were acquired from different organizations around the world, including IKZ in Germany, Tamura in Japan, and Synoptics in California.

"We chose Ga_2O_3 as a wide-bandgap semiconductor material because of its impressive properties which, for certain applications, are widely regarded as superior to silicon (Si), silicon carbide (SiC) and gallium nitride (GaN) semiconductor materials," says Dr Serdal Okur, principal investigator for SMI's Department of Energy (DOE) and National Aeronautics and Space Administration (NASA) Ga_2O_3 projects. "There is a significant amount of commercial opportunity for Ga_2O_3 on Al_2O_3. One example is a low-cost power control device based on a superior wide-bandgap semiconductor material, which could add benefits of higher-voltage, higher-power-handling, and higher-frequency capabilities," he adds. "In addition, tuning the energy bandgap of Ga_2O_3 with Al_2O_3 and In_2GaO_3 enables a broad range of applications such as photodetectors tunable through UV wavelengths, optical filters with tunable transmission range, and graded heterostructures for optoelectronic devices, as well as MOSFETs," Okur notes.

"We are very proud to offer high-quality customized solutions for new material efforts that enable researchers to meet their developmental objectives," says president & CEO Dr Gary S. Tompa. "This offering comes as an extension from our traditional line of products and the commercialization of technologies funded by the government while collaborating with notable universities and companies in the USA," he adds. "This milestone achievement executed by our research team attests to our company's strategic objectives and core competencies."

The materials were grown using two in-house SMI-fabricated Ga_2O_3 MOCVD reactors: one features a rotating disc reactor with a 13"-diameter susceptor; the other features single 2"-wafer processing through 1200°C.

SMI can provide tools to grow Ga_2O_3 on Al_2O_3 and/or the materials in research-size quantities. Ga_2O_3 film on Al_2O_3 substrates will be available for purchase on SMI's website in wafer sizes of 2"; joining the firm's already available homoepitaxy doped and undoped Ga_2O_3 films. SMI says the product is suitable for researchers and industry professionals aiming to develop power devices and sensors.

www.smicvd.com

EPC demos GaN-enabled large-area wireless power and high-resolution LiDAR at CES 2018

At the Consumer Electronics Show (CES) in Las Vegas (9–12 January), Efficient Power Conversion Corp (EPC) of El Segundo, CA, USA — which makes enhancement-mode gallium nitride on silicon (eGaN) power field-effect transistors (FETs) for power management applications — demonstrated the power of eGaN technology to enhance two consumer applications: wireless power and LiDAR for self-driving cars.

As a partner within the AirFuel Alliance booth at CES, EPC displayed a GaN-based wirelessly powered system embedded in a desktop that can power multiple devices anywhere on the surface up to a total power consumption of 300W. This level of power makes it possible to simultaneously power a computer, run a monitor, power a lamp, communicate via a talking digital assistant, and charge a cell phone — without running a single power cord to any of the devices.

In its hospitality suite, EPC had multiple wirelessly powered surfaces on display to demonstrate the myriad of consumer uses in the home such as running a blender in the kitchen, powering a radio and baby monitor while charging a wearable on a nightstand, and powering both a computer and lamp while charging a phone on a desktop.

Also on show was an eGaN FET-based LiDAR system. Since LiDAR technology is emerging as the leading technology to act as the 'eyes' for self-driving autonomous vehicles, EPC demonstrated how GaN technology is enabling such higher-resolution and lower-cost LiDAR systems.

www.epc-co.com

40V, 5mΩ GaN power transistor eight times smaller than MOSFET

EPC has launched the EPC2049 power transistor — which has a voltage rating of 40V and maximum $R_{DS(on)}$ of 5mΩ with a 175A pulsed output current — for applications including point of load (PoL) converters, light detection and ranging (LiDAR), envelope tracking power supplies, class-D audio, and low-inductance motor drives.

The chip-scale packaging of the EPC2049 handles thermal conditions far better than the plastic-packaged MOSFETs since the heat is dissipated directly to the environment with chip-scale devices, whereas the heat from the MOSFET die is held within a plastic package, says EPC. The new device measures just 2.5mm x 1.5mm (3.75mm^2) — about eight times smaller than equivalently rated silicon MOSFETs — so designers no longer have to choose between size and performance, notes the firm.

"The EPC2049 demonstrates how EPC and gallium nitride transistor technology is increasing the performance and reducing the cost of eGaN devices," says co-founder & CEO Alex Lidow. "The EPC2049 is further evidence that the performance and cost gap of eGaN technology with MOSFET technology continues to widen."

The EPC2049 eGaN FET is priced at $2.19 each in 1000-unit quantities, and is available for immediate delivery from distributor Digi-Key.

EPC launches 150A laser diode development board

EPC has made available the EPC9126HC, a 100V, 150A high-current pulsed laser diode driver evaluation board (priced at $231.25).

In a LiDAR (light detection and ranging) system, used to create 3D maps for autonomous vehicle applications, the speed and accuracy of object detection is critical. As demonstrated by the new board, the rapid transition capability of eGaN FETs provides power pulses to drive the laser up to ten times faster than an equivalent MOSFET, enhancing the quality of information that a LiDAR system can detect (including the accuracy, precision, and processing speed).

The EPC9126HC is mainly intended to drive laser diodes and features an EPC2001C ground-referenced eGaN FET driven by a Texas Instruments UCC27611 gate driver. The EPC2001C is a 100V maximum voltage device capable of current pulses up to 150A. The EPC9126HC can drive 75A pulses into a high-power triple-junction laser diode with a pulse width as low as 5ns.

The board includes multiple ultra-low-inductance connection options for mounting laser diodes and can drive these via a discharging a capacitor (as shipped) or directly from a power bus. The board does not include a laser diode, which must be supplied by the user to evaluate specific applications.

The printed circuit board is designed to minimize the power loop inductance while maintaining mounting flexibility for the laser diode. It includes multiple on-board passive probes for voltages and discharge capacitor current measurement, and comes equipped with SMA connections for input and sensing designed for 50Ω measurement systems. In addition, the user can enable an optional precision narrow pulse generator.

Finally, the board can also be used for other applications requiring a ground-referenced eGaN FET, for example in Class E or similar circuits.

http://epc-co.com/epc/Products/DemoBoards.aspx

Fuji Electric
Innovating Energy Technology

Fuji Electric Lambda Series
New, Compact, Powerful

The New Generation of Low Voltage Earth Leakage Circuit Breakers

- Compact! Ground Fault Protection Built in One Unit for Space Saving Designs
- Same Footprint! MCCBs & ELCBs Interchangeable without Panel Modifications
- 18mm Per Pole Width(2P & 3P), IEC 35mm DIN Rail Mounting
- Higher Capacity SCCR ⇒ 18kA@ 240VAC UL489

Fuji Electric Corp. of America **Distribution & Control Department**

For sales, product & distributor information, please visit http://www.americas.fujielectric.com/componentsdistribution-control

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

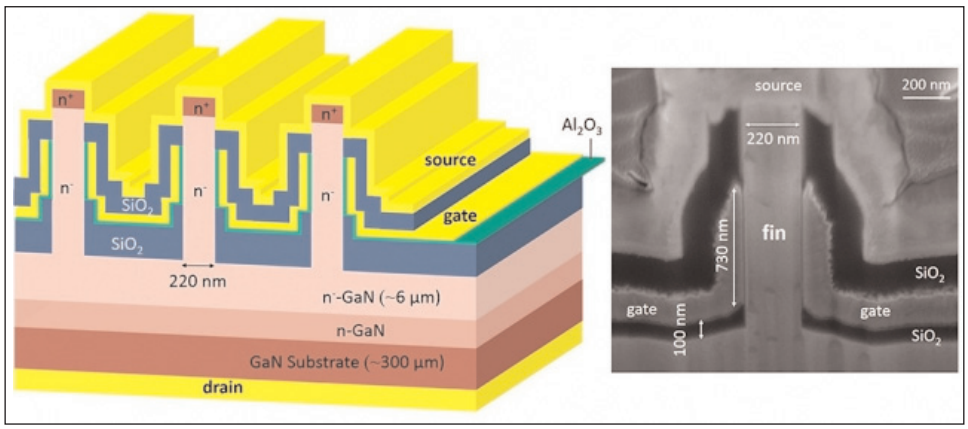
Fins boost prototype vertical GaN transistor to 1200V, sufficient for electric vehicles

Targeted 3300–5000V to extend GaN power efficiencies from household electronics to electrical grid applications

Commercial gallium nitride (GaN) power devices cannot handle voltages above about 600V, limiting their use to household electronics. But at the Institute of Electrical and Electronics Engineers' International Electron Devices Meeting (IEDM), researchers from Massachusetts Institute of Technology (MIT), epiwafer and substrate maker IQE plc, Columbia University, IBM and the Singapore–MIT Alliance for Research and Technology presented a new design that, in tests, enabled gallium nitride (GaN) power devices to handle voltages of 1200V.

That is already enough capacity for use in electric vehicles, but the device is a first prototype manufactured in an academic lab. But, since the new device uses a fundamentally different design from existing GaN power electronics, the researchers believe that further work can boost the voltage to 3300–5000V, bringing the efficiencies of GaN to the power electronics in the electrical grid itself.

"All the devices that are commercially available are what are called lateral devices," says the paper's senior author Tomás Palacios, who is an MIT professor of electrical engineering and computer science, a member of the Microsystems Technology Laboratories. "So the entire device is fabricated on the top surface of the gallium nitride wafer, which is good for low-power applications like the laptop charger. But for medium- and high-power applications, vertical devices are much better," he adds. "These are devices where the current, instead of flowing through the surface of the semiconductor, flows through the wafer, across the semiconductor. Vertical devices are much better in terms of how much voltage they can manage and how much current they control."



In the vertical GaN transistors, the narrowness of the fins ensures that the gate electrode will be able to switch the transistor on and off.

First, current flows into one surface of a vertical device and out the other, so there's more space in which to attach input and output wires, enabling higher current loads.

Secondly, when you have lateral devices, all the current flows through a very narrow slab of material close to the surface. "We are talking about a slab of material that could be just 50nm in thickness," Palacios says. "So all the current goes through there, and all the heat is being generated in that very narrow region, so it gets really, really, really hot. In a vertical device, the current flows through the entire wafer, so the heat dissipation is much more uniform."

Narrowing the field

Although their advantages are well known, vertical devices have been difficult to fabricate in GaN. For transistor switching to be efficient, the current flowing through the semiconductor needs to be confined to a relatively small area, where the gate's electric field can exert an influence on it. In the past, researchers had attempted to build vertical transistors by embedding physical barriers in the GaN to direct current into a channel beneath the gate.

But the barriers are built from a temperamental material that's costly and difficult to produce, and integrating it with the surrounding GaN in a way that doesn't disrupt the transistor's electronic properties has also proven challenging.

Palacios and his collaborators have adopted a simple but effective alternative. Rather than using an internal barrier to route current into a narrow region of a larger device, they simply use a narrower device. Their vertical GaN transistors have blade-like protrusions (fins) on top. On both sides of each fin are electrical contacts that together act as a gate. Current enters the transistor through another contact, on top of the fin, and exits through the bottom of the device. The narrowness of the fin ensures that the gate electrode will be able to switch the transistor on and off.

The idea was to say, "Instead of confining the current by having multiple materials in the same wafer, let's confine it geometrically by removing the material from those regions where we don't want the current to flow,'" Palacios says. "Instead of doing the complicated zigzag path for the current in conventional vertical transistors, let's change the geometry of the transistor completely."

https://tlo.mit.edu/technologies/new-structures-gan-vertical-transistors

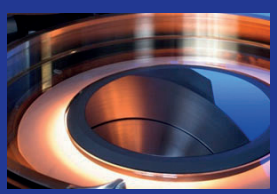
NAsP III/V

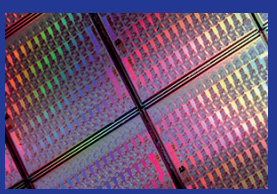
Guiding processing forward

Developing III/V integration on Si?

Speeding-up time-to-market with GaP-on-Si integration.

GaP-on-Si templates with high crystalline perfection for high-end applications





For today´s high-end applications we all strive to achieve a supreme performance. The challenging question is this: how to boost the efficiency of Si wafers to get one step ahead?

Our solution for you: NAsP III/V

Our technology has mastered the first challenge for the integration of a variety of III/V semiconductor materials and device heterostructures on 300 mm CMOS compatible (001) Si wafers. For this purpose, we have developed a proprietary nucleation process for the deposition of thin GaP layers on such Si substrates with high crystalline perfection.

Curious? For further information, please contact us at **NAsP.de**

MACOM closing Belfast center in Northern Ireland due to changing market conditions

MACOM Technology Solutions Inc of Lowell, MA, USA is shutting its base in Belfast, Northern Ireland, with the loss of around 20 jobs due to "changing market conditions", reports the Belfast Telegraph.

"MACOM, like many other companies, is continually evaluating its teams, offices and skill mix to align with the company's broader business requirements and market changes," says a spokesman for the firm. "Over the last 12 months there have been a number of changes in business conditions, which has unfortunately resulted in changes to the team in Belfast."

Last year, MACOM announced a move from its offices at Newforge Lane in the south of the city to City Quays 1 at Belfast Harbour, aiming to double its team of 22 staff. But now the firm is said to be moving out of its City Quays offices this month.

In 2012, the firm said it was investing £2.5m in a major R&D project at its Belfast center, and received backing of £700,000 from Invest NI. "We continue to liaise with the company to leverage the best possible outcome for Northern Ireland, including minimizing the impact on Belfast-based staff who may be affected by potential redundancies," says a spokeswoman for the economic development agency.

"Our design business locally is working with gallium nitride on silicon," said Dr Andrew Patterson (who headed up the business in Northern Ireland) to the Belfast Telegraph last year. "This is a technology which the company has acquired and they are growing," he added. In 2012, he said the firm's decision to invest in R&D demonstrated its loyalty to Northern Ireland. "The Belfast center has been a key research and development operation for the company, successfully developing a number of specialist components for the semiconductor market."

For the fiscal year ended 29 September 2017, MACOM reported an operating loss of $16.1m compared with an operating income of $13.2m the prior year, despite revenue growing by 28.4% from $544.3m to $698.8m. The latest three months had been "very challenging", said president & CEO John Croteau.

www.macom.com

GaN-on-Si portfolio and MMICs & diodes showcased in India

At the International Radar Symposium India 2017 (IRSI-17) in Bangalore (14–16 December), MACOM showcased its RF product and technology portfolio optimized for civil and defense radar, public and military radios and satellite communication applications.

This includes:

- high-power gallium nitride (GaN)-on-silicon;
- RF small-signal portfolio, featuring high-performance monolithic microwave integrated circuits (MMICs) and base-station and mobile backhaul devices; and
- high-performance diodes and application-specific solutions.

Also at IRSI, MACOM's Tim Boles participated in a conference session 'Microwave and mmW Switch Technologies'.

www.radarindia.com
www.macom.com

Navitas demonstrates GaN Power IC at CES 2018

At the Consumer Electronics Show (CES) in Las Vegas (9–12 January), Navitas Semiconductor Inc of El Segundo, CA, USA demonstrated how gallium nitride power ICs are creating a new class of mobile and consumer power solutions. The firm gave live demonstrations showcasing five different applications enabled by GaN power IC technology that are up to 5x faster, smaller or more energy efficient than existing solutions.

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

"GaN power adoption has been accelerating throughout the industry and CES provides the perfect opportunity for innovators to see why," says Stephen Oliver, VP of sales & marketing. "Our high-performance, easy-to-use GaN power ICs are generating significant interest from innovators in next-generation applications that include ultra-thin TVs, fast mobile chargers, drones, AR/VR devices, gaming systems etc."

In September, Navitas introduced what it claimed to be the smallest 65W USB-PD laptop adapter reference design, supporting the dramatic size and weight reductions demanded by consumers. The NVE028A utilizes Navitas' high-frequency, high-efficiency AllGaN GaN power ICs to deliver 65W in a package up to five times smaller and lighter than traditional silicon-based designs. Since introducing the AllGaN platform at APEC'16, Navitas has announced single- and half-bridge GaN power ICs, plus the world's smallest 150W adapter.

www.ces.tech

Transphorm receives $15m investment from servo motor firm Yaskawa

Funds to be used in GaN product development

Transphorm Inc of Goleta, near Santa Barbara, CA, USA — which designs and manufactures JEDEC- and AEC-Q101-qualified 650V gallium nitride (GaN) field-effect transistors (FETs) for high-voltage power conversion applications — has received a $15m investment from Yaskawa Electric Corp of Kitakyushu, Japan.

This follows Yaskawa revealing as recently as late September that its integrated Σ-7 F servo motor was using Transphorm's high-voltage (HV) GaN. Transphorm intends to allocate the funds to various areas of its GaN product development.

"We've seen the benefits of working with gallium nitride from the R&D phases through to the application development phases of our products, such as photovoltaic converters and the integrated Σ-7 F servo motor," says Yukio Tsutsui, general manager of Yaskawa's Corporate R&D Center. "We look ahead to further developments from Transphorm."

The integrated Σ-7 F products resulting from the companies' co-development serves one of the core target markets that can benefit most from HV GaN: servo motors. The technology is also said to be an optimal solution for automotive systems, data-center and industrial power supplies, renewable energy and other broad industrial applications.

"Transphorm has consistently prioritized the quality and reliability of our GaN platform," says Transphorm's chairman, chief technology officer & co-founder Dr Umesh Mishra. "That focus leads to strong customer relationships with visionaries such as Yaskawa and companies that not only innovate, but also influence market growth by demonstrating GaN's real-world impact," he adds. "Receiving Yaskawa's recent support illustrates the rising confidence in GaN while underscoring its reliability."

www.transphormusa.com
www.yaskawa.co.jp/en

Transphorm enters PC gaming market via CORSAIR's power supply

Transphorm's GaN FETs are being used in CORSAIR's new AX1600i power supply unit (PSU).

CORSAIR supplies the gaming community with high-performance products used in custom PCs. Its latest product establishes a new class of AC-to-DC PSUs, as it is the first to use GaN and achieves 99% efficiency. Transphorm's GaN is said to increase the PSU's power output by 6.5% in an 11% smaller package at the same temperature.

The AX1600i uses Transphorm's TPH3205WS 650V FETs in a bridgeless totem-pole power factor correction (PFC) topology (the topology that complements GaN's performance and efficiency potential). With an increase of 6% within this topology, CORSAIR's PSU efficiency now earns a better-than 80 PLUS Titanium rating. Previous CORSAIR power supplies used silicon superjunction (SJ) MOSFETs in a 2-phased interleaved PFC, reaching 93% efficiency.

"Our objective was to take an already award-winning PSU and make it better," says CORSAIR's PSU R&D manager Jon Gerow. "We aimed to maximize output from any PC running on a 115V mains. To do this was, we had to adopt innovative methods and materials," he adds. "Transphorm's GaN ultimately gave us the boost in performance, efficiency and size we wanted along with the high quality and reliability we needed to confidently release the AX1600i to our customers."

After researching market-available GaN devices, CORSAIR chose Transphorm's FETs as they enabled the AX1600i to deliver new benchmarks compared to the previous AX1500i, i.e. a 6.5% increase in power output to 1600W; a 11% reduction in size (20mm shorter); a thermal impact equivalent to 50°C continuous output; and an audible noise impact (slower fan speed, less noise at full load).

CORSAIR says that Transphorm's packaging also played a role in its selection process. The TPH3205WS comes in a commonly used TO-247 package, reducing some design complexity.

"CORSAIR's brand is built on products that give our customers a competitive edge, inside and outside of the gaming PC," says Gerow. "Transphorm's GaN presented an invaluable opportunity to advance the PSU — to make it smaller, quieter, cooler, and, most importantly, more powerful."

Since GaN devices are higher frequency, they sometimes requiring different design techniques than previously used with silicon. Transphorm says that its GaN experts collaborate regularly with customers to provide guidance as well as to identify areas of opportunity for future platform innovation and customer design resources. Regarding the AX1600i project, Transphorm supported CORSAIR during both the prototyping and the design validation testing phases. CORSAIR tapped Transphorm's teams on the ground in both Shenzhen, China, and California, USA.

www.corsair.com/en-us/ax1600i-psu
www.transphormusa.com/products

Delta joins BMW i Ventures as investor in GaN Systems

Funds to aid global sales expansion and accelerate product innovation

GaN Systems Inc of Ottawa, Ontario, Canada — a fabless developer of gallium nitride (GaN)-based power switching semiconductors for power conversion and control applications — says that power systems firm Delta has joined BMW i Ventures in participating in a strategic investment.

GaN Systems plans to use the funding to expand global sales and accelerate product innovation. The latest announcement follows previous investments from backers including BMW i Ventures, BDC Capital, Chrysalix Venture Capital, Cycle Capital Management, RockPort Capital and Tsing Capital.

"This investment reaffirms GaN Systems' continued accomplishment in creating the future of the most energy-efficient power electronics," comments BMW i Ventures' managing director Uwe Higgen. "GaN Systems' is pioneering a new approach to the design and creation of power systems that are smaller and lighter, while simultaneously providing more efficient and reliable power conversion," he adds.

"GaN Systems' is pioneering a new approach to the design and creation of power systems that are smaller and lighter, while simultaneously providing more efficient and reliable power conversion," says BMW i Ventures' managing director Uwe Higgen

"It's a huge vote of confidence, both in GaN as a technology and GaN Systems' approach to GaN transistors, to have investment partners such as Delta and BMW i Ventures," says GaN Systems' CEO Jim Witham.

GaN Systems says that this year it has is experienced a rapid increase in customer growth and increasingly strong demand for GaN transistors, especially in notebook travel adapters, computer server and industrial motor power applications.

www.bmwiventures.com

GaN Systems honors China Power Supply Society competition winners

Winners from the annual China Power Supply Society (CPSS) competition were honored at the organization's annual meeting on 22 November by sponsor GaN Systems Inc of Ottawa, Ontario, Canada (a fabless developer of gallium nitride-based power switching semiconductors for power conversion and control applications) alongside CPSS, China Power Society Science Popularization Committee, and Nanjing University of Aeronautics and Astronautics. This year's theme focused on the application of power electronics technology for innovation, energy savings, and new energy use.

Thirty-one teams participated from 29 universities throughout China. The teams were challenged to create a single-phase DC–AC inverter with 400V DC input, 500VA output power, and 95% minimum efficiency, in a small form factor. The final 10 teams competed at the CPSS meeting. Entries were evaluated based on performance criteria, including inverter efficiency, power density, and output stability across various load conditions. Cash awards of 20,000-yuan, 10,000 yuan, and 5000 yuan were given to Top grade prize, Number 1 prize, and Number 2 prize finishers.

Six power design engineering teams were awarded for their high-efficiency, high-power-density GaN-based inverter designs. The Top Grade Prize was given to NUAA (Nanjing University of Aeronautics and Astronautics), Number 1 Prize to Xi'an Jiaotong University and Shanghai University of Electric Power, and Number 2 Prize to Chongqing University of Technology, Heilongjiang Institute of Science and Technology, and Zhejiang University. The team from NUAA demonstrated good operating performance, high level power density and thermal performance, and a compact and inexpensive system design.

"We're continually inspired by these young engineers and their approach and use of GaN transistors to solve current and future power system challenges," said GaN Systems' Jim Witham. "Solutions developed from the award recipients demonstrate the advantages GaN transistors enable to make designs smaller and more efficient."

GaN Systems has supported this annual competition for several years, helping to accelerate and proliferate the learning of system development with GaN transistors to address the applications needs of the most demanding industries, including data centers, renewable energy systems, automotive, industrial motors, and consumer electronics.

In addition, GaN Systems had an educational role at the China Power Supply Society Conference 2017, which drew more than 1000 researchers and scholars in power electronics. The firm presented a 3.5 hour technical seminar providing continuing education of GaN power transistors and applications, and an industrial paper, which provided an in-depth industry overview of the GaN technology market as well as GaN use cases in several industries.

www.cpss.org.cn/en
www.gansystems.com

GaN Systems releases high-power Insulated Metal Substrate evaluation platform

GaN Systems Inc of Ottawa, Ontario, Canada (a fabless developer of gallium nitride-based power switching semiconductors for power conversion and control applications) has launched its Insulated Metal Substrate (IMS) Evaluation Platform, which provides a flexible, low-cost, high-power development platform for high-efficiency power systems with 3kW-or-higher applications.

In combination with GaNPX packaging technology and smart design techniques, the IMS evaluation platform enables power engineers to quickly take full advantage of GaN power transistors in designing smaller, lighter, lower-cost, and more efficient power systems for data-center, automotive, and energy-storage system applications.

The platform consists of a high-power motherboard (GSP65MB-EVB) and two variants of IMS evaluation modules configured in half-bridge (single IMS module) and full-bridge (two IMS modules). IMS evaluation modules are available in two power levels: 3kW (GSP65R25HB-EVB) and 6kW (GSP65R13HB-EVB). Each module includes GaN E-HEMTs, gate drivers, isolated DC/DC supply, DC bus decoupling capacitors, and a heatsink to form a fully functional half-bridge power stage.

Benefits of the platform are said to include:

- Low thermal resistance & optimized layout: The IMS platform enhances the thermal and electrical performance benefits of GaNPX E-HEMTs. The drive board is tightly coupled with the IMS board to minimize power commutation and gate driver loops to optimize performance.
- Greater flexibility: The platform enables 12 different configurations, architectures and operating modes. IMS evaluation modules can be used independently as a high-power GaN intelligent power module with developers' own system boards for in-system prototyping.
- Greater power density: Using IMS boards for transistor mounting takes advantage of the vertical space available in larger-power applications. The optimized driver board not only minimizes both power and gate driver loops, it also increases the power density of the electronics.

"The power level that the new IMS platform provides is unrivaled," claims Peter Di Maso, director, product line management. "Higher power density, at a low cost, makes possible new applications and new revenue streams of power systems in existing markets and applications."

www.gansystems.com/gsp65rxxhb-evb.php

University of Bristol's Kuball elected as SPIE Fellow

Professor Martin Kuball, who heads the University of Bristol's Centre for Device Thermography and Reliability (CDTR) — a research centre focusing on improving the thermal management, electrical performance and reliability of semiconductor devices, circuits and their packaging — has been elected as a new Fellow of the International Society for Optics and Photonics (SPIE).

Each year, SPIE promotes members as new Fellows of the Society, and Kuball is one of 73 new Fellows for 2018. Fellows are Members of distinction who have made significant scientific and technical contributions in the multi-disciplinary fields of optics, photonics, and imaging. They are honoured for their technical achievement, for their service to the general optics community, and to SPIE in particular.

Martin Kuball.

Kuball leads a team of 20 international researchers and PhD students and works with industry and academia worldwide to develop next-generation technology for communications, microwave and power electronics enabling the low carbon economy.

"Our research continues to be internationally recognized and we are leading the field in this area," says Kuball.

This is the second major recognition for Kuball and his CDTR team after they won the University Research Group of the Year at TechWorks Awards in November. The awards celebrated the year's key electronics innovations, people and companies from across the UK and Ireland. Although these were the inaugural TechWorks Awards, they followed on from the NMI Awards, which ran from 2001 to 2016.

The Research Group of the Year category specifically promotes teams that demonstrate excellent liaison and partnership with industry. The award was given for the group's very strong research portfolio in gallium nitride (GaN) device reliability for next-generation communications and power applications and its excellent and broad-ranging relationship with industry, working with companies such as MACOM, Airbus, MBDA and Plessey. The judges were also impressed by the group's attention to equality and diversity as an integral part of capability development.

www.bristol.ac.uk/physics/research/cdtr

http://spie.org/about-spie/fellows-and-senior-members/fellows

SPTS's Omega plasma etch system chosen by HiWafer for new 6" GaN-on-SiC high-power RF device production line

Chinese GaAs pHEMT and HBT RF device foundry extending to GaN-on-SiC for 5G

SPTS Technologies Ltd of Newport, Wales, UK (an Orbotech company that manufactures etch, PVD and CVD wafer processing solutions for the MEMS, advanced packaging, LED, high-speed RF on GaAs, and power management device markets) has won an order for its Omega plasma etch system from China's first pure wafer foundry, Chengdu HiWafer Semiconductor Co Ltd, to establish their new 6-inch gallium nitride on silicon carbide (GaN-on-SiC) production line.

The Synapse and ICP process modules on the Omega c2L platform will etch SiC backside vias (BSV) and GaN epitaxial layers to manufacture high-power radio frequency (RF) devices. The high-rate Omega system was selected over the competition because the Synapse provided superior SiC etch rates while the ICP module delivered improved selectivity for GaN etch, says SPTS.

"HiWafer is already a well established Chinese foundry producer of gallium arsenide (GaAs)-based pHEMT and HBT RF devices currently used in 4G communication, and they are an early adopter of SiC and GaN materials for use in high-end RF devices that target the worldwide 5G protocol," notes Kevin Crofton, president of SPTS Technologies and corporate executive VP at Orbotech. "This leadership position is important as power and RF applications are high on the 'Made in China 2025' agenda for promoting domestic production of semiconductor devices, and companies like HiWafer are well-positioned to contribute to realizing this national initiative. Our leadership in high-rate etching of SiC and other dielectric materials will support HiWafer to provide manufacturing solutions for the coming 5G wave," he adds.

"Orbotech's SPTS Technologies is a recognized leader in compound wafer processing solutions to the global power and RF device industries. The addition of SPTS's Omega plasma etch system gives us the tools to compete in GaN-on-SiC RF technology in telecoms and transportation applications, including railway systems," says HiWafer's genera manager Nengwu Gao. "Acquiring this capability enables us to explore new applications and supports our ambitions to become a highly profitable and successful semiconductor foundry."

www.hiwafer.com/en
www.spts.com

JEDEC's new committee for wide-bandgap power semiconductors invites industry participation

The JEDEC Solid State Technology Association (which develops standards for the microelectronics industry) has announced the launch of its newest committee: JC-70 Wide Bandgap Power Electronic Conversion Semiconductors.

JC-70 held its first meeting in late October with 23 member companies, led by committee and subcommittee chairs from Infineon Technologies, Texas Instruments, Transphorm, and Cree company Wolfspeed. Committee members include industry leaders in power gallium nitride (GaN) and silicon carbide (SiC) semiconductors as well as prospective users of wide-bandgap (WBG) power semiconductors and test & measurement (T&M) equipment manufacturers. Global multi-national corporations and technology startups from the USA, Europe and Asia are working together to bring to the industry a set of standards for reliability, testing and parametrics of WBG power semiconductors.

JC-70 has two subcommittees, focusing on Silicon Carbide (SiC) and Gallium Nitride (GaN) as the most mature wide-bandgap (WBG) power semiconductor materials. Both SiC and GaN offer immense potential for enabling higher-performance, more compact and energy-efficient power systems. JEDEC says that industry interest in JC-70 has been high, with several new members joining the committee after the first meeting, underscoring the importance of creating universal standards to help advance the adoption of WBG power technologies.

"I am delighted by the initial response to the JC-70 committee, and look forward to welcoming additional companies to participate in developing standards for wide-bandgap power technology," says JEDEC president John Kelly. "Broad industry participation will help ensure the resulting documents meet the needs of product designers as they create systems to enable a more energy-efficient future."

Four committee meetings are planned for 2018, including a web conference on 25 January and a meeting on 5 March co-located with the Applied Power Electronics Conference (APEC 2018) in San Antonio, TX, USA. JEDEC welcomes interested companies worldwide to join it to participate in the standardization effort. Contact Emily Desjardins (emilyd@jedec.org) for more information.

www.jedec.org

KAUST/Georgia Tech team determines band alignment at BAlN/AlGaN heterojunction

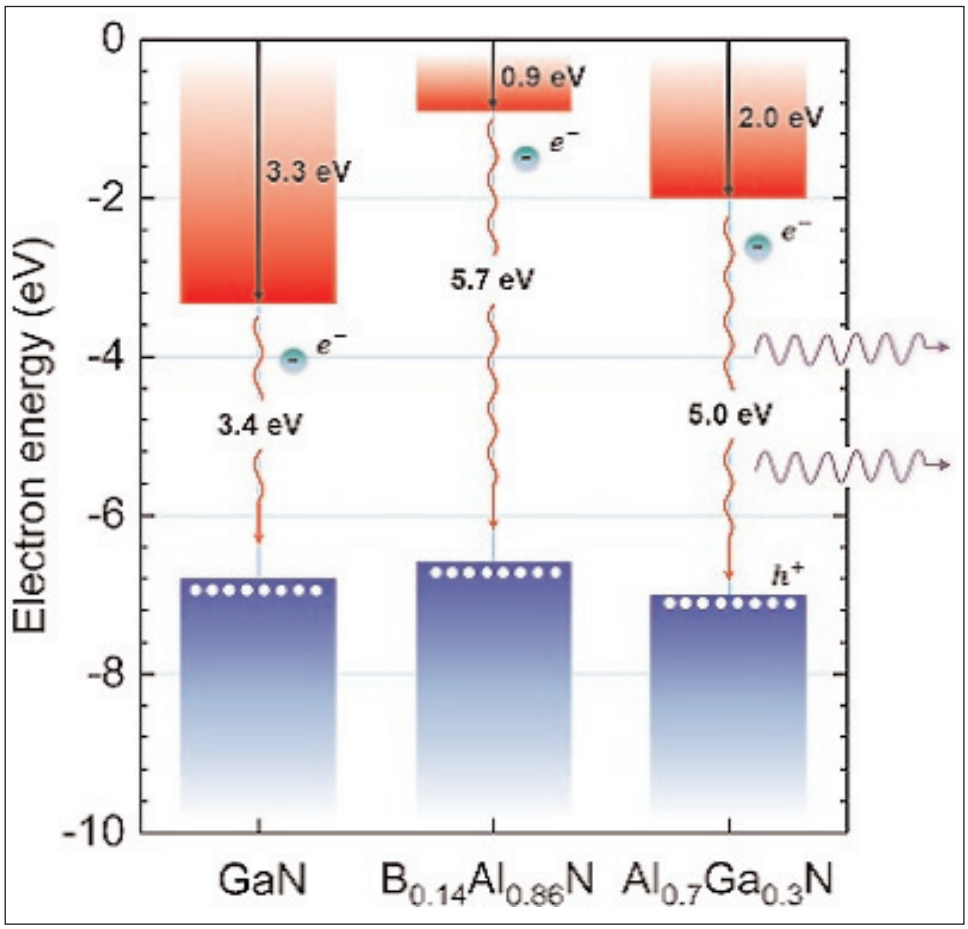
Insight could help boost efficiency of wide-bandgap light-emitting and high-power electronic devices

Haiding Sun and principle investigator Xiaohang Li of Saudi Arabia's King Abdullah University of Science and Technology (KAUST) and coworkers at the Georgia Institute of Technology in the USA have experimentally measured the alignment of the two large-bandgap materials boron aluminum nitride and aluminium gallium nitride (Sun, H., Park, Y. J., Li, K.-H., Torres Castanedo, C. G., Alowayed, A., Detchprohm, T., Dupuis, R. D. & Li, X. 'Band alignment of $B_{0.14}Al_{0.86}N/Al_{0.7}Ga_{0.3}N$ heterojunction'. Applied Physics Letters 111, 122106 (2017)).

Compared with 3.4eV for gallium nitride (GaN), aluminum nitride (AlN) has a much larger bandgap of 6.1eV. Materials with a large bandgap are useful in high-power electronics because they have larger breakdown voltage for energy-efficient transistors compared with narrow-bandgap materials, such as silicon. They can also produce light deep into the ultraviolet part of the spectrum, making them useful for disinfection and water purification.

The electronic properties of aluminum nitride can be tuned by replacing some of the aluminium atoms in the crystal with either boron or gallium. Such materials can be tailored to a specific application by layering different semiconductors to create a heterostructure with the desired properties. However, it is vital to understand how the bandgaps of two semiconductors align when they are brought together in this way.

The KAUST/GeorgiaTech team created an interface between boron aluminium nitride (with a boron to aluminium atom ratio of 14:86) and aluminium gallium nitride (with a gallium to aluminium ratio of 30:70) on an AlN-covered sapphire substrate.



Bandgaps and band alignments of $B_{0.14}Al_{0.86}N$ and $Al_{0.7}Ga_{0.3}N$ compared with GaN.

They used high-resolution x-ray photoemission spectroscopy (XPS) to measure the offset between the top and the bottom of the two material's bandgaps. They show that the bandgaps have a staggered alignment, with both the top and bottom edge of the bandgap of the $Al_{0.7}Ga_{0.3}N$ lower than the respective edge in $B_{0.14}Al_{0.86}N$ (pictured).

Based on the experimental results, we can achieve a much higher amount of two-dimensional electron gas sheet carrier concentration in such junctions

"Based on the experimental results, we can achieve a much higher amount of two-dimensional electron gas sheet carrier concentration in such junctions," notes Sun. "Determination of the band alignment of $B_{0.14}Al_{0.86}N/Al_{0.7}Ga_{0.3}N$ heterojunction provides valuable support in the design of optical and electronic devices based on such junctions," he adds. Insight could help to improve the efficiency of light-emitting optoelectronic and high-power electronic devices, it is reckoned.

http://aip.scitation.org/doi/10.1063/1.4999249

www.kaust.edu.sa

IQE's full-year revenue to exceed market expectations

Photonics revenue doubling, driven by VCSELs entering mass-market production in June

In a pre-close trading update for 2017, epiwafer foundry and substrate maker IQE plc of Cardiff, Wales, UK says that it expects full-year revenue to be ahead of market expectations, and not less than £150m (up from £132.7m in 2016). In particular, wafer sales are on track to deliver strong double-digit growth and to continue to diversify. The three primary markets are Photonics, InfraRed and Wireless.

Over the past few years the Photonics business has seen strong double-digit growth, driven largely by new product development and pilot production for a wide range of applications. This growth continued to accelerate sharply in second-half 2017 as a vertical-cavity surface-emitting laser (VCSEL) product development program moved to mass-market production in June. As a result, the Photonics division is on track to achieve about 100% growth in 2017 over 2016. IQE believes it has created a sustainable lead in this market through its intellectual property, its ability to scale this complex technology into the mass market, and its dual-site supply strategy. This is further underpinned over the next few years by several, multi-year supply contracts.

The InfraRed business is the global leader in supplying antimonide wafer products, claims IQE, with a history of delivering steady growth and on track to deliver growth in 2017 of about 10%. This business has historically focussed on advanced 'see in the dark' technologies in the defence sector, but it is now engaged with major OEM and device companies in product development programs targeting mass-market consumer applications.

Wireless sales are expected to be broadly flat year on year, with a forex (foreign exchange) tailwind mitigated by a reduction in inventories downstream. IQE managed this inventory reduction to enable it to focus capacity on the rapidly expanding photonics division. This was achievable through supplier-managed inventory (SMI) relationships with its customers. These inventory levels will normalize in 2018 as IQE replenishes normal SMI levels.

License income from joint ventures will (as expected) decline from 2016 (which included significant upfront amounts) to no more than £2m for 2017.

Most of IQE's revenue is denominated in foreign currency. A forex tailwind of about 5% in 2016 turned into an approximate 5% headwind in second-half 2017. However, this is largely presentational as the majority of IQE's costs are also in foreign currency.

The increase in wafer sales will continue to drive an expansion of wafer margins in 2017. As a result, profit before tax is expected to be ahead of current market expectations. In particular, wafer sales are expected to be materially higher, partially mitigated by lower license income.

This margin expansion is after upfront investment in overheads to establish the new foundry that will begin operations in 2018. Progress with the new foundry is on track, with the first five new tools ordered being scheduled for installation in early 2018, and generating revenue by mid-year. In addition, IQE has agreed terms for a further ten production tools, and is in the process of agreeing the specification for the first five of these.

Net funds are expected to be in the range of current market expectations.

As reported in October, a prior-year tax liability estimated to be £4.2m was identified and settled in full. The firm's tax advisors have now completed their review of the tax computations and the tax return has been filed. While there were no indications of any further potential omissions, the board commissioned an international independent tax firm to complete a comprehensive review of IQE's tax compliance in the UK, the USA and Asia. This review is ongoing and has not identified any further unrecorded liabilities. This review is scheduled for completion during Q1/2018.

Additionally, the US Government's plan to reduce the corporation tax rate from 35% to 21%, if passed, would have a positive long-term financial benefit for IQE, which has operations in the USA. However, this change would give rise to an upfront non-cash deferred tax charge relating to a reduction in the associated deferred tax asset. The size of the potential reduction has not yet been evaluated.

IQE is scheduled to report its full-year results for 2017 on 20 March.

"IQE is on track to achieve record financial results in 2017," says IQE's chief executive Dr Drew Nelson. "The adoption of VCSELs in the mass market has been a key revenue driver in the year. IQE has built a strong and sustainable lead in this complex materials technology. We see VCSELs being a long-term growth driver for the group across a diverse range of applications including sensing, LiDAR, optical communications, industrial heating, machine vision and heat-assisted magnetic recording," he adds.

"VCSEL is just one of many advanced materials technologies that IQE has developed which will drive continuing growth in the near and mid term," Nelson continues. "IQE has created strong differentiation in the industry through its broad portfolio of materials technologies and its ability to scale and supply reliably in the mass market," he adds. "Combined with our recent fundraising to pump prime our expansion, IQE's outlook is for strong, diverse and sustainable growth."

www.iqep.com

InnovateUK funding project QBARKA for microstructural characterization using quantum-enabled Burkhouse noise analysis

AHS, CSC, Microsemi and TWI consortium to use quantum-well Hall-effect magnetic sensing technology

The Quantum Technology program of UK Government agency InnovateUK has awarded funding to support the project QBARKA ('Microstructural characterization using Quantum enabled Burkhouse noise Analysis'), which will focus on developing a new technique to enable ultra-high-resolution magneto-imaging of metallic microstructure by exploiting the Barkhausen effect in ferro-magnetic materials.

The project consortium includes the Compound Semiconductor Centre (CSC) — a joint venture founded in 2015 between Cardiff University and epiwafer foundry and substrate maker IQE plc of Cardiff, Wales, UK — together with Advanced Hall Sensors Ltd (AHS) of Manchester, UK (which makes magnetic sensor products based on quantum effects in gallium arsenide materials), Microsemi Corp Aliso Viejo, CA, USA (which has a packaging business in South Wales that makes modules for high-reliability, harsh-environment datacoms, medical implant and aerospace applications), and independent research and technology organization TWI of Cambridge, UK.

Magnetic Barkhausen noise (BHN) measurements are currently used in non-destructive inspection of stress/strain and microstructures in a range of materials. BHN occurs when a magnetic field is applied to a ferromagnetic material, and is generated by the sudden irreversible motion of magnetic domain walls as they are released from microstructural obstacles such as dislocations and grain boundaries. It can provide high-resolution microstructure-related information, but existing detection techniques do not have the resolution (spatial or magnetic) to extract the wealth of data available.

The project will leverage core technology based on compound semiconductor quantum-well Hall-effect (QWHE) magnetic sensing technology developed by AHS.

"These sensors have several advantages over incumbent technology: miniaturized size, sensitivities independent of frequency, and a very wide dynamic range," says AHS founder Mohamed Missous, a professor of semiconductor devices & materials at the University of Manchester and inventor of the technology. "The technology offers a novel solution to enable a new paradigm in high-resolution microstructural analysis of materials," he adds.

"Magnetic field sensors are key enabling technologies for a wide range of metrology, imaging, industrial and automotive sensing applications where demand is proliferating rapidly," comments CSC director Wyn Meredith. "The consortium (AHS, CSC, Microsemi and TWI) has been constructed to address both the key markets and the development and manufacturing supply chain.'

www.compoundsemiconductorcentre.com

NanoGaN purchases quasi photonic crystal patents

IQE's subsidiary NanoGaN Ltd has (in exchange for a one-off payment of $0.5m) secured the purchase and assignment of a portfolio of 54 patents from LED epiwafer and chip maker Luxtaltek Corp of Miaoli County, Taiwan, spanning a range of novel technologies and applications based mainly on quasi photonic crystals (QPC).

The advanced materials technology complements the IQE's organic development of nano-imprint lithography (NIL) and broadens the potential application of NIL beyond IQE's current focus on advanced distributed feedback (DFB) lasers. The patents acquired have applications in optical components including vertical-cavity surface-emitting lasers (VCSELs) and edge-emitting lasers, modulators, silicon photonics, fiber-optic systems, micro-LED displays, image sensors including diffractive optical elements (DOE) and biosensors.

IQE's board believes that, due to its existing in-house nano-imprint lithography capability, the firm is well positioned to commercialize the new technology.

"Over the last few years, IQE has developed an exciting and strong IP portfolio which, coupled with the expertise and manufacturing capability to commercialize these new materials technologies, has uniquely positioned IQE as the clear global leader in providing advanced compound semiconductor technology solutions," says IQE's chief executive Dr Drew Nelson. "This significant addition to our IP portfolio provides the group with additional competitive advantages that will secure our entry and maintain our leadership across a range of new and emerging technology applications, and offer our customers access to a unique portfolio of materials expertise," he adds.

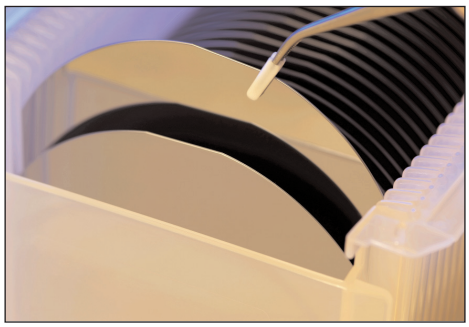
www.iqep.com

Inseto expands Semiconductor sector products and services by acquiring substrate supplier IDB Technologies

Inseto (UK) Ltd of Andover, UK, a distributor of equipment and related materials to the semiconductor, microelectronic & advanced technology sectors (as well as adhesives for electronics, automotive and industrial manufacturing), has acquired semiconductor wafer and substrate supplier IDB Technologies. The two firms have worked together for several years and share many of the same customers.

"IDB Technologies worked primarily with universities in the UK and mainland Europe," notes Inseto director Matt Brown. "Many spin-off companies have emerged from these universities and are now scaling for volume production, which is where Inseto can help."

IDB's materials stock and service offerings have added to Inseto's Consumables Division, which already represents 12 OEMs, including semiconductor assembly materials and machine consumable tooling.



IDB's founder Ian Burnett has joined Inseto to provide support to customers. "This is a win-win for all parties concerned, and especially our customers," reckons Burnett. "Inseto is ISO 9001:2015 certified, has invested in an impressive storage and handling facility, and has automated many of its processes to assure as fast a turnaround as possible on all orders."

Inseto can now supply a wide range of wafers, with next day delivery, from an extensive UK stock, and many other wafers can be provided on short lead-times. The firm also processes wafers including oxidized and nitride coating, patterned and diced wafers.

"As users' projects become more complex, and as they scale their manufacturing processes to serve their target markets, it is essential to have a streamlined supply chain plus the ability to call on technical expertise when it comes to specifying materials and equipment," says Brown. "Following our acquisition of IDB Technologies, and along with Ian coming on board, Inseto can help users commercialize their products by de-risking manufacturing aspects they are perhaps encountering for the first time."

Inseto is a Gold Sponsor of 'MicroTech', the annual conference of IMAPS-UK (the United Kingdom Chapter of the International Microelectronics Assembly & Packaging Society), which on 10 April is celebrating 50 years since the foundation of the society.

www.imaps.org.uk
www.inseto.co.uk

Riber receives order for production MBE system from optoelectronics device maker in China

Riber S.A. of Bezons, France, which makes molecular beam epitaxy (MBE) systems, evaporation sources and effusion cells, has received an order for a production MBE system from a new customer in Wuhan Province's Optical Valley (China's leading provider of optoelectronic device solutions) in order to expand its production capabilities for advanced photonic components.

The photonic components enable the rapid increase in traffic in optical fiber networks set for deploying the fiber to the home (FTTH) for consumer access to very high-speed internet, as well as for the 4G mobile network.

The order will be delivered in second-half 2018.

www.riber.com

Veeco gives update on patent litigation with SGL & AMEC

Epitaxial deposition and process equipment maker Veeco Instruments Inc of Plainview, NY, USA has provided an update on its two ongoing patent infringement lawsuits.

Veeco versus SGL Carbon

On 12 April, Veeco filed a patent infringement complaint in the US District Court for the Eastern District of New York (EDNY) against SGL Carbon LLC and SGL Carbon SE, alleging infringement of patents relating to wafer carrier technology used in metal-organic chemical vapor deposition (MOCVD) equipment. The complaint alleges that SGL infringes Veeco's patents by making and selling certain wafer carriers to Veeco's competitor AMEC (Advanced Micro-Fabrication Equipment Inc) of Shanghai, China.

On 2 November, the EDNY granted Veeco's motion for a preliminary injunction prohibiting SGL from shipping wafer carriers using its patented technology without Veeco's express authorization. On 16 November, the EDNY denied SGL's motion to suspend the preliminary injunction prohibiting SGL's sale of wafer carriers for use in MOCVD systems made by AMEC. SGL had filed a motion requesting that the court suspend (stay) the preliminary injunction pending an appeal by SGL to the US Court of Appeals for the Federal Circuit (CAFC).

The court's order means that the preliminary injunction (prohibiting SGL from shipping wafer carriers using Veeco's patented technology) remains in place during SGL's appeal. The CAFC appeal process usually takes over a year to complete. In its appeal, SGL will bear the burden of convincing the CAFC that the preliminary injunction should be overturned. Appeals of preliminary injunctions are evaluated by the CAFC under the highly deferential 'abuse of discretion' standard of review. As a result, Veeco believes that it is highly unlikely that the CAFC will overturn the preliminary injunction, especially in light of statistics showing that a substantial majority of preliminary injunctions are affirmed by the CAFC on appeal. Moreover, Veeco cross-appealed, seeking to broaden the scope of the preliminary injunction.

Meanwhile, Veeco's patent infringement action in the EDNY is proceeding toward trial, seeking a post-trial permanent injunction, monetary damages and other relief.

AMEC versus Veeco

On 13 July, AMEC filed a patent infringement complaint against Veeco Instruments Shanghai Co Ltd with the Fujian High Court in China, alleging that Veeco's MOCVD systems infringed a Chinese utility model patent relating to the synchronous movement engagement mechanism in a chemical vapor deposition reactor and seeking injunctive relief and monetary damages. Veeco Shanghai filed a petition for invalidation of this patent with the Chinese Patent Reexamination Board (PRB). The Fujian High Court suspended the infringement case against Veeco Shanghai pending the outcome of the invalidation proceeding at the PRB. On 24 November, the PRB issued a ruling in the invalidation proceeding which upheld AMEC's patent. During the proceeding, AMEC surrendered its broadest independent claim, significantly narrowing the scope of this patent.

On 7 December, without providing notice to Veeco and without hearing its position on alleged infringement, the Fujian High Court issued a ruling, applicable in China, that requires Veeco Shanghai to stop importing, making, selling and offering to sell Veeco EPIK 700 model MOCVD systems that contain the accused infringing synchronous movement engagement mechanism covered by AMEC utility model patent ZL 201220056049.5 and wafer carriers used as supplies for the EPIK 700 MOCVD system.

Although Veeco is still evaluating the ruling, the firm notes that:

- the ruling applies only in China;
- the ruling does not apply to EPIK 700 systems previously shipped to customers in China;
- Veeco will continue to service and support its installed base of EPIK 700 MOCVD systems (while complying with the ruling);
- by its specific terms, the ruling does not cover Veeco's EPIK 868 MOCVD system; and
- Veeco is working on potential alternative designs that are not covered by the ruling or the utility model patent asserted by AMEC.

"Veeco continues to believe this lawsuit is without merit," says chairman & CEO John R. Peeler. "We plan to appeal this ruling, to vigorously defend against this matter and to enforce Veeco's IP rights. Veeco remains committed to its customers in China and to supporting its installed base of MOCVD systems."

www.veeco.com

Riber receives order from Japanese university for Compact 21DZ 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 a Japanese university for a Compact C21DZ research MBE system, for use in research on compound semiconductor microstructures.

The Compact 21DZ is one of the newest models in the Compact 21 range, with over 125 systems already installed worldwide.

www.riber.com

China's Focus Lightings orders Veeco EPIK 868 MOCVD systems to boost high-volume LED production

Veeco has received an order for multiple TurboDisc EPIK 868 GaN MOCVD systems, to be shipped to the manufacturing facility in Suzhou, China of Focus Lightings Tech Co Ltd for the production of high-volume LEDs for general lighting and display applications (adding to its existing installed base of Veeco systems).

Following a 2014 restructuring, Focus Lightings' main business is LED epitaxial wafers and chip R&D, production and sales operations, as well as LED lighting applications for energy management services.

"Veeco's new EPIK 868 MOCVD system continues their long-standing reputation of offering significant performance, advantages and exceptional process efficiency," comments Focus Lightings Tech's chairman Pan Huarong. "Adding these systems to our manufacturing facility and utilizing Veeco's unique process know-how will provide us with a major competitive advantage," he reckons.

Since its introduction in September, Veeco has shipped several large orders of the EPIK 868 platform to Chinese customers. The EPIK 868 system offers a four-reactor platform with Veeco's proprietary TurboDisc technology for what is claimed to be the highest productivity and a 35% footprint reduction compared with the competition. Further, the wafer carrier capacity can be increased for greater throughput per batch.

"The EPIK 868 was designed for the China market, enabling greater productivity and even lower cost of ownership on a reliable and leading-edge MOCVD platform," says Peo Hansson Ph.D., senior VP & general manager, Veeco MOCVD Operations. "We have received terrific feedback from customers regarding the new platform, and we look forward to supporting Focus Lightings' growth plans."

www.focuslightings.com

Osram orders multi-reactor Propel HVM and K475i MOCVD systems from Veeco for high-volume photonics and LED applications

Osram Opto Semiconductors GmbH of Regensburg, Germany has ordered a multi-reactor Propel High-Volume Manufacturing (HVM) gallium nitride MOCVD system, as well as K475i MOCVD systems from Veeco.

Introduced recently for high-volume production of power electronics, laser diodes, RF semiconductor devices and advanced LEDs, the Propel HVM platform is based on the Propel Power GaN MOCVD single-wafer system with proprietary IsoFlange and SymmHeat technologies that provide homogeneous laminar flow and uniform temperature profile across the entire wafer.

The K475i system incorporates Veeco's Uniform FlowFlange technology, producing films with very high uniformity and improved within-wafer and wafer-to-wafer repeatability with what is claimed to be the industry's lowest particle generation for demanding applications like photonics and advanced LEDs.

"The new Propel HVM system offers superior film quality, improved dopant control, robust production capabilities and the industry's lowest cost of ownership to enable advanced electronic devices with greater energy efficiency, a smaller form factor and exceptional reliability," says Peo Hansson Ph.D., senior VP & general manager of Veeco MOCVD Operations. "Osram's purchase of multiple K475i systems is also evidence that Veeco's MOCVD solutions meet the most demanding process requirements for automotive, advanced display and sensor applications," he adds.

www.veeco.com

Veeco authorizes $100m share repurchase program

Veeco's board of directors has authorized the repurchase of up to $100m of the firm's outstanding common stock, to be completed over the next two years.

Repurchases are expected to be made from time to time on the open market or in privately negotiated transactions in accordance with applicable federal securities laws. The timing of repurchases and the exact number of shares of common stock to be purchased will depend upon market conditions, SEC regulations, and other factors. The program does not obligate Veeco to acquire any particular amount of common stock and may be modified or suspended at any time at its discretion.

The repurchases will be funded using the firm's available cash balances and cash generated from future operations.

"The repurchase program underscores our confidence in longer-term growth prospects and our commitment to enhance shareholder value," says chairman & CEO John R. Peeler. "We believe our strong balance sheet provides us with the flexibility to execute share repurchases while continuing to invest in R&D and other opportunities to profitably grow our business."

www.veeco.com

Aixtron receives German Energy Agency's Energy Efficiency Award 2017

Deposition equipment maker Aixtron SE has received the Energy Efficiency Award 2017 of the German Energy Agency (DENA) in the category 'Energy efficiency 4.0' for its digital measurement and remote monitoring of energy data as well as for carrying out extensive energy-efficiency measures in heating and cooling systems.

In 2014, Aixtron initiated the project to examine the energy management at its headquarters in Herzogenrath (in the urban region of Aachen), as the generation of the required cooling and heating volumes required a high amount of power despite the modern and highly efficient systems. Together with the energy service provider SPIE Energy Solutions GmbH, different energy efficiency measures were developed (based on a thorough analysis) and then subsequently implemented.

The result is a lasting reduction in power consumption by at least 6.4GWh/year, leading to a reduction in CO_2 of 1884 t/year as well as cost savings of 211,000 €/year, it is reckoned. In its evaluation of the project, the panel of judges at the Energy Efficiency Awards particularly emphasized the continuous and committed planning and execution of the energy-efficiency measures.

"With the help of extensive analysis and the subsequent implementation of energy-efficiency measures in collaboration with SPIE Energy Solutions, we were able to reduce the energy and gas consumption of our heating and cooling systems by at least 74% as well as the corresponding energy costs by more than 40%," notes Karl-Heinz Göbbels, head of facility management at Aixtron and one of the project's initiators. "Our investments in an innovative, digitally controlled energy management system will be amortized in just a few years," he adds.

"By reducing the energy consumption and consequently also decreasing the connected CO_2 emissions, we actively contribute to easing the environmental burden in Aachen's urban region," says Aixtron's president Dr Bernd Schulte.

The German Energy Agency issues the Energy Efficiency Award as part of its EnergieEffizienz initiative. The international competition is under the auspices of Federal Economics Minister Brigitte Zypries, and is fostered by the Federal Ministry for Economic Affairs and Energy (BMWi) as well as by partners Danfoss and KfW.

www.aixtron.com
www.spie.de

Changelight orders further Aixtron AIX 2800G4-TM MOCVD systems to expand ROY LED capacity

Deposition equipment maker Aixtron SE of Herzogenrath, near Aachen, Germany has received an order for multiple AIX 2800G4-TM MOCVD cluster tools from Chinese optoelectronic manufacturer Xiamen Changelight Co Ltd to expand its production capacity for gallium arsenide (GaAs)-based red, orange and yellow (ROY) LEDs.

Each production cluster consists of two multi-wafer AIX 2800G4-TM process modules with susceptor configurations of 15x4-inch and one automation module serving both process modules, to enable high-volume manufacturing. Aixtron says that users benefit from maximized throughput as well as what is claimed to be the industry's highest product yield and chemicals efficiency, setting a benchmark for the lowest cost per wafer.

"As a consequence of the increasing acceptance in numerous lighting and display applications such as smart lighting, city lighting and fine-pitch display technology, market demand for ROY LEDs is getting stronger and therefore requires continuous capacity expansion by manufacturers," says Changelight's vice general manager Niu Xingsheng. "As we have been very pleased with Aixtron's reliable AIX 2800G4-TM platform and excellent service over the years, we decided to add further systems to the tools already in production," he adds.

"Aixtron's AIX 2800G4-TM platform has built itself a reputation as the tool of record for the production of GaAs-based ROY LEDs, VCSEL [vertical-cavity surface-emitting lasers] and thin-film solar cells," claims Aixtron's president Dr Bernd Schulte. "We are looking forward to continue our longstanding, trustful collaboration with Changelight."

www.changelight.com.cn/en
www.aixtron.com

Riber receives order for research MBE system from USA

Riber S.A. of Bezons, France — which makes molecular beam epitaxy systems as well as evaporation sources and effusion cells — has received an order for a research MBE system from the USA.

The customer ("a global leader in instrumentation") has ordered the system (for delivery in second-half 2018) for making infrared imaging sensors for the aerospace industry.

www.riber.com

SEMI GAS®

THE MARK OF

Purity.
Precision.
Performance.

When it comes to ultra high purity gas delivery systems, look for the mark of excellence.

For over 35 years, **SEMI-GAS® has been the semiconductor industry's go-to brand for premier, production-ready, ultra high purity gas delivery systems.** Today, Tier 1 leaders and high-tech innovators all over the world look to SEMI-GAS® for proven solutions that uphold their rigorous application demands.

Learn more at **www.semi-gas.com/mark**

SEMI-GAS® IS POWERED BY

APPLIED ENERGY SYSTEMS

Ushio to distribute Picosun's ALD equipment in Japan

Atomic layer deposition (ALD) thin-film technology firm Picosun Oy of Espoo, Finland has begun collaborating with light source and optical equipment maker Ushio Inc of Tokyo, Japan to boost sales of its ALD technology in the Japan market.

Japan has long been one of Picosun's most important markets, where demand for industrial ALD is rising, leading to the establishment of local subsidiary Picosun Japan Co Ltd for customer service in the area. Now, to extend this sales and service network further, Ushio will work as Picosun's sales representative. Ushio is a supplier of manufacturing equipment to the global semiconductor market, and Picosun's fully automated, SEMI-compliant and production-line-compatible industrial ALD systems will be a key addition to its portfolio.

"Through this collaboration we are able to offer added value to our customers, in the form of integrated manufacturing solutions consisting of Picosun's high-class ALD systems combined with our own products such as lithography tools and curing equipment," says Jikihara, general manager of Ushio's System Solution Division sales department. "With Picosun's equipment design, production-proven processes, and unmatched ALD expertise, our customers can realize a wide range of cutting-edge products in areas such as integrated circuits (especially 3D/TSV components), LEDs, and MEMS," he adds.

"Ushio's established position and high reputation in the semiconductor industry will be valuable assets to Picosun," comments Picosun Japan's CEO John Kenney. "When it comes to our industrial clientele, Japan is one of our strongholds. Several Picosun batch and cluster ALD systems are already running in production at high-profile customers, and demand for more is steadfastly growing. It is vital that our local sales and support network is unwavering and always able to meet the requirements of these important customers, with cost-efficient and comprehensive turn-key solutions."

Picosun's ALD solutions were presented at SEMICON Japan 2017 in Tokyo (13–15 December).

www.ushio.co.jp/en
www.picosunjapan.com

Lasertec launches GALOIS gallium nitride wafer inspection and review system

Metrology and inspection equipment maker Lasertec Corp of Tokyo, Japan has launched the GALOIS defect inspection and review system series, designed specifically for the inspection and analysis of gallium nitride (GaN) wafers. The firm is already accepting orders.

The GALOIS Series uses bright-field confocal optics, enabling high-speed inspection of various kinds of GaN wafer defects and high-resolution observation of defect images.

Lasertec says that its SICA88 system is widely used as the de-facto standard SiC inspection tool, enjoying strong market recognition due to its high throughput and high accuracy of defect classification and its high-resolution defect review. GaN, on the other hand, lags behind in device usage, hindered by the high cost of GaN wafer manufacturing and the presence of numerous crystallographic and process defects in wafers, requiring further efforts in wafer quality improvement. The GALOIS Series, which offers the high-speed, high-sensitivity detection and classification of crystallographic and process defects, combined with high-resolution defect image review, has been launched to assist these efforts.

The new GALOIS system

GALOIS uses a combination of confocal optics and differential interferometry optics — both of which are Lasertec core technologies — with a sophisticated algorithm based on advanced imaging technology. This eliminates the effect of noise from the backside of a transparent substrate, or from surface morphology, enabling the high-sensitivity detection of various kinds of defects in GaN wafers.

GALOIS employs a high-speed processing computer system and a model based on machine learning (including advanced deep learning) for defect classification. It uses the high-resolution review images captured by the firm's core technologies and accurately classifies indeterminately formed defects, in parallel with other inspection processing. All review images captured during inspection of whole wafers are saved to computer storage, and can be used for the analysis of unclassified defects. GALOIS achieves an inspection speed of 6 minutes per 6" wafer, which is fast enough for future application in the production phase.

In addition to inspection for GaN wafers, GALIOS can also act as a process and yield improvement tool. It helps in identifying the root cause of defects, acting as a wafer, epitaxy and device process monitor.

www.lasertec.co.jp/en/products/environment/gan/GALOIS.html

CVD Equipment completes purchase of new facility

CVD Equipment Corp of Central Islip, NY, USA (a designer and maker of chemical vapor deposition, gas control, and other equipment for developing and manufacturing materials and coatings) has completed the purchase of its planned additional facility, located at 555 North Research Place, Central Islip, which will be the primary manufacturing center for its subsidiary CVD Materials Corp.

"With the completion of this purchase we now have the manufacturing space to accelerate our capabilities of providing materials, coatings and surface treatments to meet our customers' needs," says president & CEO Leonard A. Rosenbaum. "We look forward to the expansion of our carbon composites and electronic material, Tantaline, and newly acquired MesoScribe, product lines. We also anticipate future growth, both organically and by possible future acquisitions."

"With the purchase behind us, we are now focusing on bringing the new facility on-line and for additional growth opportunities enabled by this additional 180,000ft^2 facility," Rosenbaum concludes.

www.cvdequipment.com

Niacet commissions ULSI-grade anhydrous HCL plant

After producing and supplying technical-grade AHCl (anhydrous hydrogen chloride) since 2013, Niacet Corp of Niagara Falls, NY, USA (a member of the American Chemistry Council with ISO 9001 and GMP Safe certifications that produces organic salts for the food, pharmaceutical, electronics and technical industries) has announced the completion, commissioning and startup of its ULSI-grade AHCL plant. Over 99.999% pure, the ULSI product is available immediately for high-purity markets including semiconductors.

To ensure high levels of reliability and customer service, Niacet has also acquired the AHCL packaging and distribution assets of Alexander Chemical Co. The firm can now offer a full range of packaging options, from tube trailers to cylinders.

www.niacet.com

Phononic focuses on optoelectronics industry by hiring industry veteran Granucci as VP of sales

Phononic of Durham, NC, USA, which provides solid-state thermoelectric cooling solutions, has strengthened its investment in the optoelectronics market by appointing Kevin Granucci as general manager & VP of sales for its optoelectronics vertical, focused on accelerating penetration into the growing opto market and driving the global adoption of Phononic's application-specific thermoelectric solutions. Granucci will be based in San Jose, CA, and will help to expand Phononic's presence in Silicon Valley, as well as lead its already-established team in the Asia-Pacific region.

"The optoelectronics market holds so much world-changing possibility, with 5G networks guaranteed to transform everything from driverless cars to virtual and augmented reality technologies," says CEO & founder Tony Atti. Granucci "shares our vision for revolutionizing this industry through our differentiated thermoelectric modules, which will be vital to cooling the sophisticated optical components that transmit the data needed to make all these innovative applications a reality," he adds.

Granucci began his semiconductor career with Hitachi, before moving to its opto-device division spin out Opnext Inc, where he drove and managed North American sales of optical modules, components and subsystems. Following Opnext's merger with optical communications and laser provider Oclaro in 2012, Granucci led Oclaro's client-side module strategy and marketing team while stationed in Japan, building critical new relationships with customers in China and Europe while improving gross margins and profitability for the business unit to record levels.

Kevin Granucci, general manager & VP sales.

In his more than two decades in the industry, Granucci has worked closely with many of the major firms defining the optoelectronics roadmap, such as Cisco, Huawei, Nokia and ZTE as well as today's biggest data-center and telecoms players, providing a network and understanding of the global marketplace that Phononic reckons will enable it to continue to increase market share in the cooling sector.

"Technological advancements in optoelectronics are gaining traction, with next-generation solutions like wireless 5G front-haul systems, 10G-PON and remote PHY poised for widespread market adoption in coming years," comments Vladimir Kozlov, founder & CEO of optical communications market research company LightCounting. "But the increase in data communication rates and bandwidth also presents a significant challenge, with effective cooling of optical components becoming increasingly critical," he adds.

"It was a bittersweet decision to pursue a new venture after 20 years with such an established industry leader like Oclaro, but I saw the tremendous growth rate and the potential of Phononic to become a household name in thermoelectric cooling," says Granucci. "Phononic's materials, manufacturing processes, and modules deliver significantly lower power consumption, increased heat pumping density, and consistent quality," he believes. "Phononic's team combines deep expertise and passion, bringing application-specific insight and innovation to every project. These qualities, along with the need for devices that pack more sophisticated cooling capabilities into far smaller form factors, are becoming increasingly critical as the industry continues to evolve."

Phononic will exhibit in booth 5831 at the Optical Networking and Communication Conference & Exhibition (OFC 2018) in San Diego, CA, USA (11–15 March).

www.ofcconference.org
www.phononic.com/optoelectronics

Axus hires industry veteran Cerilli as general manager

Axus Technology of Chandler, AZ, USA (which provides CMP, wafer thinning and wafer polishing surface-processing solutions for semiconductor, MEMS/nanofabrication and substrate applications) says that John J. Cerilli has joined the firm as general manager, providing management, logistics, sales, marketing and business development support to the global customer base and sales team. In the past year, Axus has experienced substantial growth, and Cerilli's more than 40 years of semiconductor industry and management experience will support the firm as it continues to grow.

Cerilli was the former VP & general manager for the Silicon Wafer Group of Speedfam-IPEC. He has also held management positions with AXT Inc, Aixtron SE, Intel, Motorola and National Semiconductor. He has a Masters degree in Organizational Management.

"John is an experienced professional with many years of experience including semiconductor equipment, wafers, raw materials, and consumables," comments Axus' president Dan Trojan. "His extensive experience and industry background will help us take Axus to the next level."

www.axustech.com

Exclusively from Conax...

EtchDefender™
TECHNOLOGY

Coated TCs for the ASM® EPSILON® that last up to 3X longer

Conax introduces EtchDefender™ coating—the patent-pending solution for extending the life of quartz sheath thermocouples.

Lab and production tests prove EtchDefender™

- Increases yield and decreases cost of ownership
- Won't flake from the quartz substrate
- Doesn't decompose, out-gas or sublimate under vacuum at high temperature
- Slows devitrification and erosion
- Increases wafer yield and consistency

FIND OUT MORE

Conax® TECHNOLOGIES

Ideas. Solutions. Success.

+1 800 223 2389 | conaxtechnologies.com

Disco develops KABRA laser saw for 8" SiC wafers

Tokyo-based equipment maker DISCO Corp has developed DAL7440, a laser saw that supports KABRA processing of 8" silicon carbide (SiC) wafers.

In the KABRA (Key Amorphous-Black Repetitive Absorption) slicing process, by continuously irradiating the laser vertically from the upper surface of the ingot, a separating layer that absorbs light is formed into a flat shape at the desired depth, enabling peeling and formation of wafers from this point.

At SEMICON Japan 2016 DISCO exhibited the DAL7420 laser saw (measuring 600mm x 1045mm x 1778mm), which supports KABRA processing of 6" wafers. However, R&D to enlarge wafer diameter has been progressing, involving for example the shipping of 8" sample wafers.

DISCO's new DAL7440 laser saw

In response to this, as well as strong demand from wafer manufacturers, the DAL7440 laser saw (which is 750mm x 1350mm x 1800mm) has been developed, to support KABRA processing of 8" wafers.

With a function for measuring ingot thickness (the maximum is 40mm), the system is alignment-free, thanks to an orientation flat detection function using auto alignment. A wafer printing function tracks the total number of processed wafers. In addition to 8" diameter ingots, the DAL7440 also supports future increases in diameter.

In March, the DAL7440 will be set up in DISCO's North Carolina office (Disco Hi-Tec America Inc) to more flexibly handle requests for processing tests in the USA.

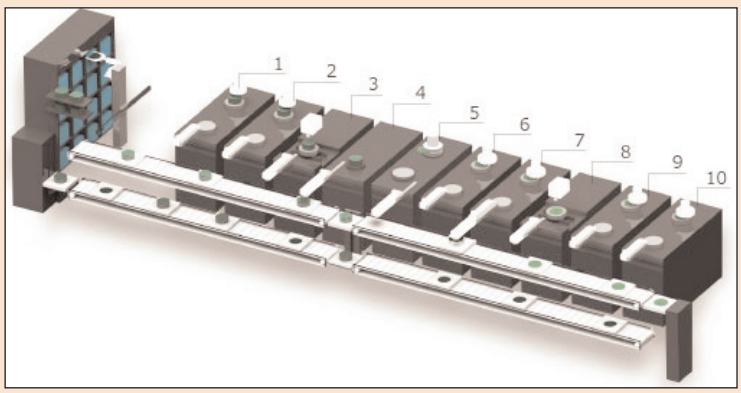
Disco's KABRA!zen fully automates KABRA laser slicing technology

At SEMICON Japan 2017 in Tokyo (13–15 December), Disco Corp exhibited KABRA!zen, which introduces fully automatic transfer between the stages of its KABRA (Key Amorphous-Black Repetitive Absorption) laser-based ingot slicing process for silicon carbide (SiC).

Since there will be an increase in electric power consumption across a wide range of products due to the development of the Internet of Things (IoT) and the use of electronics in vehicles, there is expected to be widespread use of energy-saving power devices that use next-generation materials such as SiC. However, in the conventional diamond wire saw ingot slicing method, low throughput and a large amount of material loss during processing has been causing an increase in manufacturing costs.

In the KABRA slicing process, by continuously irradiating the laser vertically from the upper surface of the ingot, a separating layer that absorbs light is formed into a flat shape at the desired depth, enabling peeling and formation of wafers from this point.

However, because the existing KABRA process requires an operator to remount workpieces before each process (including laser irradiation, wafer separation, fine grinding down to the designated thickness, and grinding of the top surface of the ingot), throughput was affected by the operator's ability.



In contrast, KABRA!zen fully automates transfer between each stage of the KABRA process (all unmanned). Consequently, throughput has been improved by about 50% (for 350μm-thick wafers produced from a 6"-diameter, 40mm-thick SiC ingot). This further accelerates the advances being made in SiC wafer production efficiency, says Disco.

Also, because the system connects each of the laser, separation and grinding processes, the number of machines used for each process can be customized according to the various criteria, such as the number of wafers produced, surface finish condition, etc.

Disco has 53 patents (issued and pending) related to KABRA, including 13 process-related patents, 3 full automation (KABRA!zen) patents, 19 laser irradiation patents, 7 separation patents, 2 grinding patents, plus 9 miscellaneous patents.

The firm says that it has already received inquiries regarding KABRA!zen from major wafer manufacturing companies, and is aiming to ship test equipment in 2018. Full automation is also possible by retrofitting existing equipment, e.g. the preceding, manual DAL7420 KABRA system.

www.disco.co.jp/kabra

EVG completes latest phase of production capacity expansion

Newly opened building provides extra space for final system assembly and technical source inspection by customers

EV Group of St Florian, Austria — a supplier of wafer bonding and lithography equipment for semiconductor, micro-electro-mechanical systems (MEMS), compound semiconductor, power device and nanotechnology applications — has completed construction and opened a new building at its corporate headquarters to expand capacity for producing process equipment.

As part of an investment of more than €20m announced in May, the building allows for a significant expansion of warehouse space and provides more than 50% additional test room space for the final system assembly as well as technical source inspection of the systems by its customers. "EVG operates in highly dynamic markets, where we always strive to provide our customers with the latest technologies to realize their product ideas with the shortest possible time to market," says executive operations & financial director Dr Werner Thallner. "Our headquarters expansion helps ensure that we continue to deliver on this pledge," he adds. "We completed this expansion in record time too, and we already have plans for additional capacity expansion in preparation for future growth."

Completed building at EVG's HQ.

Designed to house larger systems including high-volume manufacturing platforms and solutions for panel-sized substrates, the new test rooms are equipped with the latest air conditioning and cleanroom technology. Ambient conditions created through these measures are similar to those found in customers' semiconductor fabs or bio-medical labs, says EVG. The security concept at the firm's headquarters, which extends to the new building complex, enables customers to have controlled access to individual test rooms where the technical source inspection of their tools can take place together with EVG specialists.

Several EVG systems have been moved to the new facility for final assembly, software installation and initial set-up to make room available for fulfilling additional system orders.

www.EVGroup.com

EVG installs low-temperature plasma activation system at University of Tokyo for III-V on silicon wafer bonding

EV Group of St Florian, Austria — a supplier of wafer bonding and lithography equipment for semiconductor, micro-electro-mechanical systems (MEMS), compound semiconductor, power device and nanotechnology applications — has received an order from the University of Tokyo for its EVG810LT plasma activation system for compound semiconductor research.

Installed at the university's Takagi & Takenaka Laboratory, the EVG810LT augments its research focused on developing novel MOSFET and electronic-photonic integrated circuits (EPICs) using III-V-on-insulator (III-V-OI) and germanium-on-insulator (GeOI) substrates. These are designed to exceed the performance of conventional silicon semiconductors as well as silicon photonics, where III-V materials such as indium phosphide (InP), indium gallium arsenide (InGaAs) and germanium are bonded to silicon wafers. The EVG810LT activates a wafer surface using plasma for low-temperature direct wafer bonding, and has been used by other customers in high-volume manufacturing of silicon-on-insulator (SOI) wafers and backside-illuminated CMOS image sensors.

"The miniaturization of semiconductor devices is reaching its physical limitations, and shrinking transistor (scaling) in line with Moore's Law is not sufficient enough to address future demands for higher performance of LSI devices," notes Dr Mitsuru Takenaka, associate professor at the Takagi & Takenaka Lab. "3D integrated circuits with III-V compound semiconductors or germanium stacked freely on silicon semiconductors are expected to be among the breakthroughs to enhance the performance of the LSIs after the end of Moore's Law. In support of our efforts, we adopted EV Group's plasma activation system, the EVG810LT, to help us achieve lower-temperature and high-quality wafer bonds," he adds.

The EVG810LT low-temp plasma activation system, suitable for direct bonding for manufacturing of SOI strained silicon and GeOI wafers as well as for compound semiconductor applications and MEMS devices.

"The innovative results at The Takagi & Takenaka Laboratory are expected to address the fundamental issues that the semiconductor industry currently faces," says Hiroshi Yamamoto, representative director of EV Group Japan K.K. "EV Group has been working with universities and R&D facilities that are active in advanced fields. We will continue to provide the Takagi & Takenaka Laboratory with the technical support they need to succeed with their leading-edge research."

With the emergence of the Internet of Things (IoT), Big Data and artificial intelligence (AI) fueling a new wave of demand for electronic devices with lower power consumption, higher performance and greater functionality, the semiconductor industry is evaluating the benefits of incorporating new materials with silicon — beyond pure silicon-based wafers. This shift is paving the way for future market growth of compound semiconductors, says EVG, as well as more efficient manufacturing technologies to achieve maximum end-device performance. For example, metal-organic chemical vapor deposition (MOCVD) processes can result in inconsistent wafer formation, compromising the integrity of the wafer surface and ultimately impacting end-device performance. Direct wafer bonding with plasma activation is a promising solution to enable heterogeneous integration of different materials and to realize high-quality engineered substrates, says EVG.

The firm showcased the EVG810LT at the SEMICON Japan 2017 exhibition in Tokyo (13–15 December).

www.EVGroup.com

SACHEM raises TMAH pricing by 5%

Chemical science company SACHEM Inc of Austin, TX, USA (which has commercial operations in the USA, The Netherlands, Japan and China) has announced a price increase for all customers in all segments on tetramethylammonium hydroxide (TMAH) – including the Envure and Devera brands – effective 1 January 2018. Pricing will increase globally by 5%, as contracts allow.

The firm says that the price increase is necessary in order to continue to provide customers with high-quality product and high levels of service in an environment of growth in the electronics industry as well as rising personnel, freight, and raw materials costs.

www.sacheminc.com

Lake Shore launches ultra-low-noise excitation source for material and scientific R&D

Lake Shore Cryotronics Inc of Westerville, near Columbus, OH, USA (which makes scientific sensors, instruments and systems for measurement and control) says that its new MeasureReady 155 Precision I/V Source offers the performance required by researchers for a precise, low-noise source of current or voltage in the lab.

When characterizing materials, the cleaner the excitation signal, the better the end measurements. Lake Shore says that the 155 provides the precise, very low-noise output needed for such measurements, partly because it employs the same proven noise-rejection technology used in the firm's cryogenic thermometry products. The source generates just 200nV RMS

($1\mu V_{p-p}$) of low-frequency noise and 7μV RMS of higher-frequency noise in the 10mV DC range — all without the need to add any external filters. It also provides DC low-noise performance without compromising AC bandwidth.

Because it generates less noise, the source provides a solid foundation for users performing I–V curve, Hall-effect, resistance, resistivity and other fundamental measurements of novel materials and early-stage devices. The source is also suitable for high-accuracy device testing, as well as semiconductor material and device researchers who need a high-quality source to excite samples.

The 155 source is also straightforward to operate, it is claimed. Its uncluttered touch display with a unique TiltView screen presents a natural user interface, with no confusing buttons to navigate. Wi-Fi, USB and LAN connectivity allow easy integration with systems using LabVIEW, .NET and other software. Also included is a unique mobile app, which allows users to operate the instrument remotely, whether in the same room or further away.

www.lakeshore.com/products/MeasureReady/Model-

CRAIC adds Raman microspectroscopy to flagship UV–visible–NIR microspectrophotometer

CRAIC Technologies Inc of San Dimas, CA, USA has added Raman microspectroscopy to its flagship product: the 20/30 Perfect Vision microspectrophotometer.

Users can now acquire Raman spectra by integrating the new Apollo II Raman microspectrometer with the 20/30 PV. Together, the two systems offer multiple laser wavelengths, in addition to ultraviolet (UV)–visible–near infrared (NIR) absorbance, reflectance, fluorescence and emission microspectra. The 20/30 PV can acquire all these types of spectra from micron-scale samples rapidly and easily, says the firm. It can also acquire them from the same area because it features CRAIC's proprietary optical aperturing technology. Additionally, the 20/30 PV features the ability to acquire images of these same microscopic samples in the UV, visible and NIR.

Applications include, for example, development of the latest advanced materials (such as graphene and

carbon nanotubes) as well as the measurement of semiconductor thin-film thickness.

"The 20/30 PV is now able to acquire vibrational spectra in addition to UV–visible–NIR spectra and images," notes president Dr Paul Martin.

"And using CRAIC Technologies proprietary optical technology, the Raman, UV-visible-NIR and luminescence spectra are all from the same area," he adds. "The ability to acquire spectra using multiple techniques and of the same microscopic target area represents a strong advantage."

The 20/30 PV is a self-contained unit that features UV–visible–NIR light sources, solid-state lasers, true UV–visible–NIR microscopy, sensitive Lightblades spectrometers and Lambdafire spectral and imaging software. Raman microspectroscopy is added via the Apollo Raman microspectroscopy packages. The Apollo II is a self-contained package including laser, spectrometer and hardware that is integrated with the 20/30 PV, giving multiple methods for analyzing microscopic samples rapidly and easily, says CRAIC.

www.microspectra.com/products/2030-microspectrophotometer

Monocrystal rated 'Integration Partner' by Osram

Monocrystal Inc of Stavropol, Russia, which makes large-diameter synthetic sapphire substrates and cores for LED, optical product and RFIC applications, has achieved the status 'Integration Partner' with Osram Opto Semiconductors, reaching its highest possible supplier grade.

Osram runs an efficient Supplier Classification Program aimed at evaluating and qualifying business partners that can optimize its value chain and bring cutting-edge solutions, which can further drive both parties' sustainable growth and development. Benefits of being an integration partner of Osram include early involvement in its strategic programs, regular technological roadmap alignment, and extensive communication on all levels.

"This very rarely given status demonstrates the close partnership we have, and even more our intention to strengthen it together with Monocrystal," comments Osram's Commodity Manager Thomas Wirthensohn. "Today only a few suppliers at Osram are rated as Integration Partners, and we expect that Monocrystal will support Osram in developing innovative products for a number of promising applications on its core markets," he adds.

"We value our cooperation and understand our responsibility in supporting Osram in the extremely competitive LED market," says Monocrystal's CEO Oleg Kachalov. "We will continue our efforts in quality improvement and cost reduction, as well as in developing new products according to Osram's current and future needs."

www.monocrystal.com

Crystal IS achieves ISO 9001:2015 certification

Crystal IS Inc of Green Island, NY, USA, an Asahi Kasei firm that makes ultraviolet light-emitting diodes (UVC LEDs) based on proprietary aluminium nitride (AlN) substrate technology, has achieved ISO 9001:2015 certification for its operations and processes implemented for the production of its UVC LEDs.

The latest ISO 9001:2015 standard places more emphasis on the use of risk analysis to anticipate challenges in managing business processes. It also requires organizations to be aware of, and anticipate, the needs of stakeholders including employees, shareholders and customers, in the development of future products.

Previously certified to the ISO 9001:2008 standard, Crystal IS has achieved 2015 certification after the annual external audit of its systems and processes. To uphold this certification, companies must continue to demonstrate the ability to consistently provide products that meet customer expectations, as well as applicable statutory and regulatory requirements.

Crystal IS says that following ISO standards provides a reliable method for delivering consistent, quality products at volume that meet customer requirements, as well as aligning with the its focus on ongoing process and technology improvements to meet the needs of healthcare and point-of-use (PoU) water markets.

www.cisuvc.com

Klaran WD breaks $0.25/mW barrier for PoU water disinfection

Crystal IS has expanded its Klaran platform with the launch of the WD series LEDs.

Developed specifically for the price and performance needs of point-of-use (POU) water disinfection, Crystal IS claims that the Klaran WD series marks the first time that a UVC LED maker has demonstrated the ability to break the $0.25/mW price barrier required for mass production of UVC LED-based water purification products. The firm will initially offer 30mW and 40mW variants, with plans to introduce more powerful devices in the coming months.

"Our aluminum nitride substrates have always held the promise of superior cost for performance at the deep UV wavelengths," says CEO Larry Felton. "Klaran WD series LEDs, developed specifically for point-of-use water, meet OEM requirements at a compelling price per milliwatt to drive innovation in water purification products."

Klaran WD series LEDs aim to enable OEMs to address the rising global demand for water purification products as the surge in industrialization, urban population and rise in water pollution propels consumers to take a more active role in ensuring drinking water quality. This is exemplified in the Asia Pacific region, specifically China and India. In 2015, the water purifier market in China was $4.61bn and is expected to rise at a compound annual growth rate of 19.45% to $11.21bn by 2020.

Klaran UVC LEDs are produced on a unique ultra-wide-bandgap aluminum nitride substrate produced by Crystal IS. The substrate overcomes the material challenges inherent with traditional sapphire-based devices, and the LEDs emit their full germicidal power from the top of the chip, allowing low-cost and simpler packaging design. The resulting UVC LEDs offer high output at peak germicidal wavelengths (260–275nm) and the ability to be operated at high drive currents for more effective disinfection.

www.cisuvc.com/products/klaran

LG Innotek claims first 100mW UV-C LED

Seoul-based LG Innotek has developed what is claimed to be the first 100mW UV-C LED, two years ahead of the industry forecast of 2020. The firm unveiled the first 70mw UV-C LED for sterilization applications only in February 2017.

Emitting UV light with short wavelengths of 200–280nm (deep UV), UV-C LEDs are used in sterilizing and hardening devices due to their ability to destroy bacterial DNA and cause chemical reactions with special materials. LG Innotek's UV-C LED emits in the range of 278nm.

UV-C LEDs can produce more powerful sterilizing effects with higher light output, but it is very difficult to obtain stable quality in products containing them due to heat. Firms that have led the market had planned to launch 100mW UV-C LEDs by 2020.

LG Innotek says it has overcome technical limitations by applying an epitaxial structure and vertical chip technology that maximize light extraction. UV output is raised and heat is discharged effectively, ensuring stable reliability. The new 100mW UV-C LED can emit strong sterilization UV light for more than 10,000 hours, it is reckoned.

LG Innotek says that, by developing the 100mW-output UV-C LED, it can now expand their range of applications. As the product can rapidly sterilize flowing water and even air, it can be used in a wide array of household appliances, from water purifiers and air purifiers to air conditioning systems for buildings and automobiles as well as water treatment devices. Conventional UV-C LEDs (with light output of 1–2mW) are mostly used for portable sterilizers or small household appliances. Due to their weak UV-C power, their scope of application is limited. LG Innotek says that the quality of its UV-C LEDs has already been proven by its launch of products such as LED modules for sterilizing water purifier faucet aerators and UV LED sterilizers for escalator handrails.

As development of products using UV-C LEDs by other global firms proliferates, and as demand for high-output LEDs continues to grow, it is expected that demand for 100mW UV-C LEDs will rise rapidly. According to market researchers, the UV LED market will more than triple from $166m in 2016 to $526m by 2020, with the UV-C segment in particular rising from $28m to $244m, notes LG Innotek.

www.lginnotek.com

New flip-chip LED package allows stable 220lm/W efficiency

LG Innotek has developed a flip-chip LED package that demonstrates high efficiency and high luminous flux without any deterioration in performance, even after completing the 300ºC soldering process.

For the last three years, the firm's flip-chip LED has drawn attention from the back-light unit (BLU) industry as a high-power LED light source because the chip's electrode is directly attached to the top surface of the PCB substrate without using a connection wire, preventing wire disconnection and ensuring excellent heat dissipation.

Packages were commercialized only as high-power LED light sources in chip-scale package (CSP) form, in which reflective white resin is omitted and the process is relatively simple. But they have a critical problem that the bonding between the chip and the substrate melts, dislocating the chip and reducing brightness by about 10% when exposed to high temperature.

With the reflective white resin it was difficult to ensure light quality, as some of the processes for producing lighting modules and finished products exceed 250ºC.

The new high-quality flip-chip LED package produces high efficiency of 220 lumens per watt (lm/W) stably because the bond between the chip and substrate does not melt even at 250–300ºC. Lighting firms can hence use the package to produce premium bulbs, tubes and flat-panel lighting without sacrificing light quality, says LG Innotek.

The new package was developed by improving its internal structure, designing its own production process and enhancing the flip-chip mounting technology. The chip's internal structure is newly designed, with proprietary technology maximizing efficacy and heat dissipation.

LG Innotek also focused on quality and conducted a reliability test of over 6000 hours. The package hence achieved stable performance even when subjected to high-temperature thermal shock at the request of a customer. Due to the strict quality verification process, it took 2 years to develop the product (much longer than required for general LED packages, notes the firm).

LG Innotek applied for 65 new technology patents during development. It says it has taken thorough measures not only to secure its proprietary core technologies but also to help customers focus on manufacture and sales of the modules and finished products without worrying about patent disputes related to the light source.

The firm has established a product lineup of high-quality flip-chip LED packages that can be customized. The main family consists of mid-power, high-efficiency models for mid-power applications at each color temperature, such as 220lm/W class-5630 and 215lm/W class-3030 3V products. LG Innotek has also strengthened its high-power and high-luminous-flux product lineup with 6V, 9V and 12V packages in series two and/or two in parallel in the 3030 product family (previously difficult to make due to the package design and processing limitations.

German-funded UV Power project working on LED replacements for conventional UV light sources

Outputs to exceed 120mW at 290–310nm, 140mW at 270–290nm, and 80mW at 250–270nm

Since February, five research institutes and companies have been working on 'UV Power', a collaborative research project funded by the German Federal Ministry of Education and Research (BMBF) as part of 'Advanced UV for Life', a consortium of research institutes and companies being funded under Germany's federal 'Zwanzig20' program. Prototype LEDs and the technology for producing high-power LEDs for the UVB and UVC spectrums on the basis of the aluminium gallium nitride (AlGaN) material system are scheduled to be presented by 2020.

UV Power is coordinated by Osram Opto Semiconductors GmbH of Regensburg, Germany working with partners Ferdinand-Braun-Institut Leibniz-Institut für Höchstfrequenztechnik (FBH), the Technical University of Berlin, LayTec AG and UVphototonics NT GmbH.

The partners aim to develop new technology for high-power, mass-market UV LEDs spanning a wide variety of applications. The LEDs will eventually replace conventional UV light sources (which often contain toxic mercury) in areas such as production, disinfection, the environment, life sciences and medicine. UV LEDs are also likely to open up new areas of application.

The partners are therefore pooling their scientific expertise and making their highly specialized technical facilities and analysis methods available. Development of the high-power LEDs is taking place along the entire technology chain for LED production. "The various tasks have been distributed among the partners on the basis of their strengths, everything from the production of structured sapphire substrates, epitaxy and chip processing to packaging and analytics," says Dr Hans-Jürgen Lugauer, head of UV development at Osram Opto. "With our presence on the international market and our expertise in industrial manufacturing we are boosting the impact of the consortium considerably," he adds.

To speed up development and make efficient use of resources, the partners are splitting their work into different wavelength ranges. In addition to co-ordinating the entire project, Osram is taking on the wavelength range 270–290nm. In epitaxy, FBH is covering adjacent wavelengths in the 290–310nm UVB range and processing the epitaxial wafers into UV chips. Technical University of Berlin is focusing on the wavelength range 250–270nm, applying its expertise in material analysis for AlGaN materials and AlGaN LEDs. TU Berlin also has extensive specialized equipment for UV analysis. LayTec is developing tailor-made techniques for controlling the epitaxy and plasma etching systems. FBH spin-off UVphotonics is the interface to users, responsible for optimizing the chip design, for achieving high currents, and for efficient cooling. The firm is also handling the statistical collection and analysis of process data from the entire production chain and making this data available to the project partners for optimizing the production process. The important subjects of assembly technology and the effects of ageing will be investigated by FBH, Technical University of Berlin and UVphotonics in further projects as part of the consortium.

The optical outputs of the new LEDs are expected to be greater than 120mW at 300±10nm, 140mW at 280±10nm, and 80mW at 260±10nm. The research group is also working on making significant improvements to the ageing behaviour of the LEDs so they can be operated for longer and more economically.

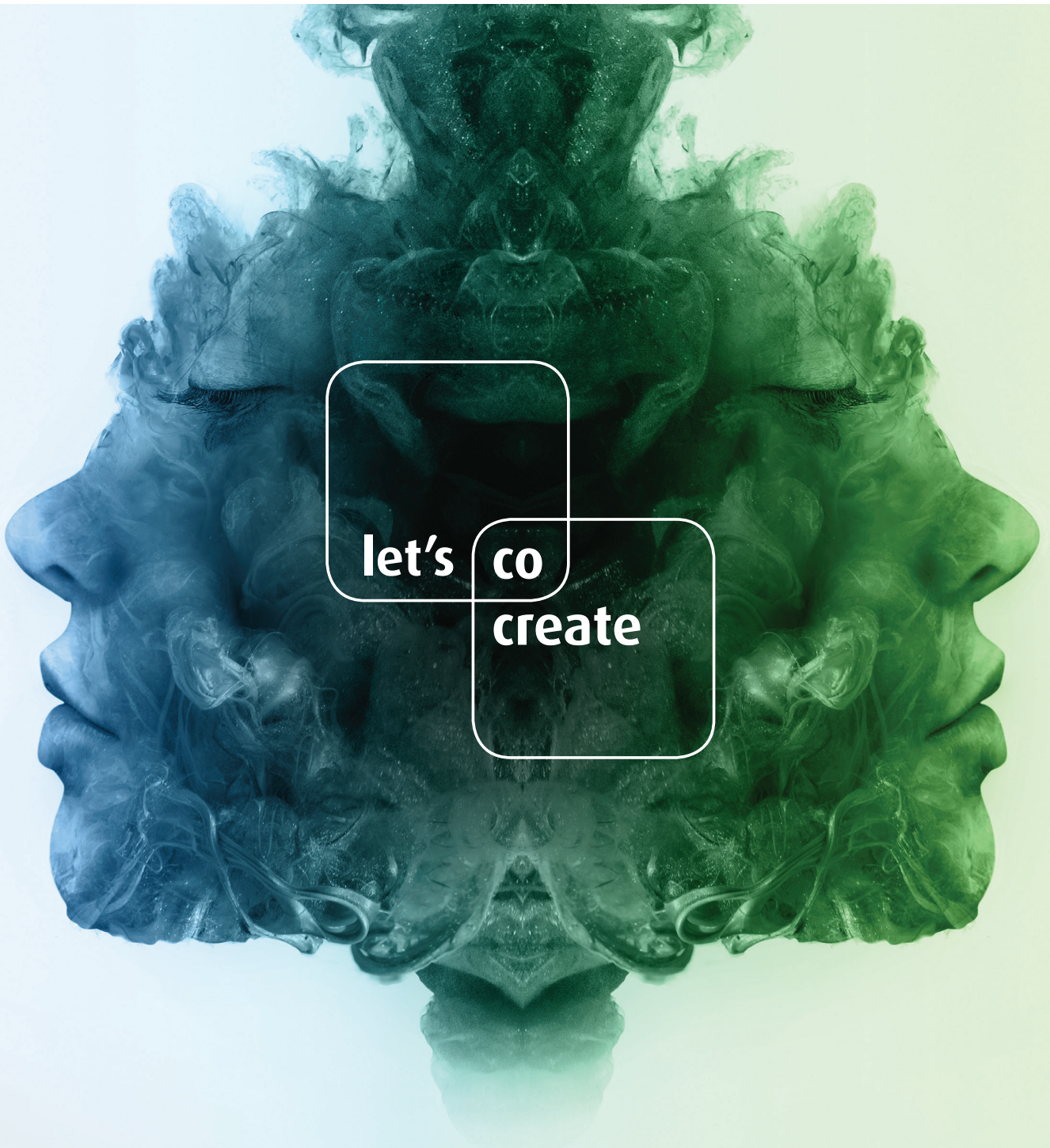
www.advanced-uv.de
www.ur-zwanzig20.de
www.fbh-berlin.com

Everlight launches 228lm/W Series 5630X LEDs

Taiwan-based Everlight Electronics Co Ltd has made available samples of its new 5630 X Series of lighting-class LEDs (in mass production now), which has a luminous efficiency up to 228lm/W (5000K) that meets the high luminance requirements of professional commercial and industrial lighting applications.

To meet increased expectations regarding the brightness and color temperature of lighting (as well as the comfort derived from it), Everlight has developed the new 5630X Series with a high efficiency of 228lm/W (@65mA, with a CCT of 5000K, and CRI>80), in compliance with the DLC 4.0 standard. As per light-on tests at high temperature (105ºC), 5630X LEDs can satisfy L90>36,000 hours and a color tolerance adjustment less than 3 SDCM (standard deviation of color matching). Compared with ordinary LED lamps (2000lm), the 5630X Series can efficiently reduce power consumption by 30–40%, it is reckoned. With its optical efficiency and stability, the 5630X Series is suitable for professional, commercial and industrial lighting applications, says Everlight.

www.everlight.com



Working together to create ground-breaking chemistry

When you need to innovate for sustainable development of next-generation technologies, let's work together to co-create solutions that give you a competitive edge. At Umicore, we offer a collaborative approach to research, development and commercial manufacturing for your complex organometallic chemistry and catalysis needs.

Together with our customers we create and deliver ground-breaking science to pioneer sustainable technologies across many industries, including automotive, electronics, chemistry and pharmaceuticals.

Let's co-create to make a difference | pmc.umicore.com

materials for a better life

umicore
Precious Metals Chemistry

Plessey aims to launch first monolithic microLED displays in first-half 2018

Plessey Semiconductors Ltd of Plymouth, UK has committed to being first to market with a monolithic microLED-based display based on gallium nitride (GaN)-on-silicon. Market analysts Yole Développement forecast that, as demand is accelerating, the microLED display market could hit 330 million units by 2025.

Plessey has also begun an extensive program to license out its GaN-on-Si expertise to microLED makers, in line with its new business strategy of becoming the foremost photonics technology platform provider.

Claiming that GaN-on-Si is the only technology platform capable of addressing all the challenges involved with manufacturing microLED displays both in high volume and cost-effectively, Plessey intends to demonstrate its expertise by being first to manufacture a monolithic display based on microLEDs fabricated using a GaN-on-Si approach.

"We made the decision to become a technology platform provider in order to get our technology out to the widest possible manufacturing base to meet this growing demand," says CEO Michael LeGoff. "By being the first to market with a monolithic microLED display we will be demonstrating our expertise and the ability to access our proven turn-key solution, enabling manufacturers to ramp up the development and production of microLED displays," he adds.

A major challenge in manufacturing microLED displays using a non-monolithic approach is the placement of LED chips onto a CMOS backplane, currently achieved using pick-and-place equipment. This involves the individual placement of every LED on a pitch of less than 50μm, requiring new and expensive equipment that is subject to productivity issues. As the pixel density of displays increases and pitch reduces, pick-and-place becomes less feasible both commercially and technically, says Plessey.

Moving to a monolithic process removes the need for chip placement and will enable smaller and higher-resolution displays for a range of applications, including virtual reality (VR), augmented reality (AR) and head-up displays. Claiming to have the only commercially available monolithic solution, Plessey says that its technology does not require pick-and-place equipment and is not subject to the associated productivity issues.

A fully monolithic approach also supports integration of the standard CMOS circuitry for driving microLED displays, plus the close integration of high-performance graphic processing units (GPUs), all of which can be carried out using standard CMOS manufacturing methods. By solving the major challenges, licensees gain instant access to a technology platform that is ready for volume production, says Plessey.

"GaN-on-silicon is the only technology that makes sense in terms of scalability and performance," reckons chief technology officer Dr Keith Strickland. "It offers better thermal conductivity than sapphire and higher luminosity than OLED [organic light-emitting diodes], which is why this technology is acknowledged to be the only one that can deliver high-resolution, high-luminance displays."

www.plesseysemiconductors.com/microled-displays

Plessey demos microLED-based AR and VR HUD concept at CES

Plessey has demonstrated how its monolithic microLED technology can be used to deliver next-generation head-up displays (HUDs), enabling augmented reality (AR) and virtual reality (VR) applications.

MicroLEDs are emerging as the only technology that can provide high luminance in a small format, says Plessey, with leading makers of wearable technologies currently pursuing providers that can deliver a suitable microLED solution. Plessey reckons the demonstrator confirms its readiness to enable partners to move into production of a monolithic display based on microLEDs using its proprietary GaN-on-silicon approach.

"Monolithic microLED technology is the only viable solution that can enable products that are not only compact enough to be worn without restricting the overall experience for AR and VR applications and in HUDs, but also provide the size, weight, power and luminance needed," said chief technology officer Dr Keith Strickland at the Consumer Electronics Show in Las Vegas.

Produced in collaboration with Artemis Optical, the demonstrator combines Plessey's monolithic display, based on an array of microLEDs integrated alongside an active-matrix backplane, with the patented film technology and a single-lens arrangement from Artemis. The combination of technologies removes ambient light in the wavelength matching the microLED display's output, resulting in an HUD that delivers very high display brightness with low power consumption, in a format that is much smaller than existing HUD designs yet still offers significant cost savings, it is claimed.

During CES, Plessey and Artemis presented the demonstrator to leading companies developing VR and AR electronics. Headsets and eyewear outfitted for AR and VR applications are set for record sales of $1.2bn in the US market alone in 2018, according to the Consumer Technology Association (CTA).

Lumens begins producing micro-LED samples

South Korean mid-sized LED maker Lumens Co Ltd has begun to produce both small- and large-sized micro-LED display prototypes, as showcased at early January's Consumer Electronics Show (CES) in Las Vegas, according to LEDinside.

Lumens claims that it has been granted technologies facilitating the mass production of micro-LEDs, as it publicly announces its entry into the micro-LED market. It now has micro-LED product lines and is currently producing samples. As well as being a long-term partner of Samsung (supplying LED backlight modules for the displays in its TVs), Lumens will target the automotive head-up display (HUD) and digital signage display markets.

President Jung Tae-hong said during an interview with the Korea Herald that Lumens planned is launching the world's first high-definition automotive head-up display using micro-LED technology.

As a transparent display used to present information in front of drivers (so that they can be aware of both road conditions and statuses of their vehicles), a head-up display can be either integrated into a vehicle's windshield or made as a small independent plastic plate (a combiner).

Lumens plans to manufacture two types of micro-LED products — a 0.57" mini display and a large (over 100") digital signage display. They both consist of micro-LEDs, even if they are used differently. The 0.57" mini display adopts chips of 8μm in size, while the large signage display consists of chips that are 300μm long and 100μm wide.

Lumens is first unveiling the combiner type of HUD for the automotive after-market, and expanding into the windshield or built-in type in cars in 2–3 years, says Jung.

He added that Lumens is now in talks with both Korean and overseas automakers to provide the windshield type of HUD and that its products could be seen in some vehicles within three years, which may create a turnaround for the firm.

The 0.57" display uses 921,600 micro-LED chips, and Lumens notes that how to process such a large amount of chips is very crucial. It says that it has developed technologies that can take selected chips from the wafers and transfer them all at a time.

The firm is also partnering with the Korea Institute of Machinery and Materials (KIMM), which invented the roll-to-plate transfer technology for micro-LED production. Lumens was licensed to use the transfer technology to move thick micro-LEDs (100μm in thickness) to target substrates.

LEDinside says that Lumens' micro-LED technology is expected to be used for a major manufacturer's digital signage displays, possibly in 2018, according to a source in the industry.

www.lumensleds.com
www.ledinside.com

Material patent could yield GaN-on-Si micro-LEDs

Solar-Tectic LLC of Briarcliff Manor, NY, USA (which specializes in thin-film solutions for the solar, display, and glass industries) and Blue Wave Semiconductors Inc (which provides thin-film deposition equipment as well as coating services) say that a material for improving the performance of thin-film transistors (TFTs) used in almost all displays on the market, including LCD, LED and OLED, has been patented by the US Patents and Trademarks Office (USPTO).

US Patent no. 9,856,578 is for making crystalline films on glass at low temperature with a high degree of crystal orientation ('texture'). The particular material demonstrated is magnesium oxide (MgO). The insulating material is not only highly transparent but also has very high thermal conductivity, high thermal stability, and a high melting point. Most importantly, the new material has an unusual (111) orientation, which can enhance the preferred orientations of silicon and germanium.

Silicon is used in almost all TFTs made currently using the LTPS (low temperature polysilicon) process, and the new MgO material promises to enhance the LTPS process (as well as the common a-Si TFT process) because of its high (111) crystal orientation which, by inducing texture in the silicon without chemical degradation, can greatly increase electron mobility. This is due to the resulting aligned crystals along the c-axis. The electrical performance and homogeneity of semiconductor layers can also be enhanced by the highly crystalline and oriented MgO film.

The thin film can be grown in a wide range of thicknesses, and deposited on a variety of technical glasses, including soda-lime or alkali-free glass, at temperatures as low as ~450°C or less. When deposited on soda-lime glass, the MgO film serves as a diffusion barrier, preventing impurities such as sodium (Na) from contaminating the silicon layer along with enhancing the crystallography along the (111) plane.

"With this new material, we can now grow oriented silicon films with high mobility on which III-V materials such as GaN can then be grown for micro-LEDs," says CEO Ashok Chadhari. "GaN on highly crystalline silicon thin-film would allow for monolithic micro-LED fabrication."

Last month Solar-Tectic announced an entirely new low-temperature process for making TFTs, which can replace LTPS and IGZO-CAAC (C-axis aligned crystalline indium-gallium-zinc oxide), and the MgO material is an essential part of that technology.

www.solartecticllc.com
www.bluewavesemi.com

Lumileds appoints senior VP of corporate development

LED maker Lumileds of San Jose, CA, USA has appointed Jeff Henderson as senior VP of corporate development.

"As our business continues to scale, Jeff will be critical to our long-term development as he will be responsible for facilitating the process of defining, supporting and executing upon our corporate growth strategy," says CEO Mark Adams.

In over 25 years of experience in executive roles prior to joining Lumileds, Henderson was most recently at Keysight Technologies, responsible for leading corporate development for the $4bn electronic equipment, software and services business (spun out of Agilent Technologies in 2014). Henderson has a BSEE from Auburn University, an MBA from Santa Clara University and an Executive MBA from Boston University, specializing in strategic leadership change.

Jeff Henderson.

"My passion is helping businesses grow and maintain relationships that are vital to our company's success," comments Henderson. "I look forward to working with the Lumileds team to generate ideas and opportunities to help accelerate growth."

www.lumileds.com

Lumileds upgrades LUXEON 5050 LED to 175lm/W

Lumileds has introduced an upgraded LUXEON 5050 LED with what is said to be the best performance of all multi-die emitters on the market, reaching luminous flux of 350 lumens and efficacy of 175lm/W at 2W drive conditions, at a correlated color temperature of 4000K, and a color rendering index (CRI) of 70 at 85°C.

With newly released LM-80 reliability data, the product also meets DLC Premium V4.1 requirements, enabling fixture manufacturers' access to high utility rebates and energy savings.

In addition, the round 4.6mm light-emitting surface (LES) eases optic design. "The majority of commercially available 2W optics can use LUXEON 5050, which leads to the best flux, efficacy and color over angle combination," says Kathleen Hartnett, senior director, product marketing. With what is claimed to be the industry's lowest thermal resistance (2K/W), LUXEON 5050 further enhances performance by removing heat and reducing heat-sink requirements, adds the firm.

LUXEON 5050 LED

The LUXEON 5050 is suitable for high-bay and street lighting applications. Typically for high-lumen fixtures that require high efficacy, a group of standard mid-power LEDs would be used, with the tradeoff of a large fixture size and weight. In contrast, using LUXEON 5050 enables a smaller overall system size, so very compact fixtures are possible.

The LUXEON 5050 is available in color temperatures of 2700–6500K and CRIs of 70, 80 and 90 to meet various high-bay and street lighting as well as indoor spotlighting needs.

www.lumileds.com/LUXEON5050

Philips Lighting delivers billionth LED lamp

Philips Lighting says that it has now delivered 1 billion LED lamps and luminaires as part of its commitment to the 'Global Lighting Challenge', the Clean Energy Ministerial campaign to deploy 10 billion high-efficiency light points to improve energy efficiency worldwide. It has hence passed the halfway mark of its target to deliver 2 billion by 2020.

Philips Lighting says it is the first company to reach this milestone which "marks the latest progress in the global transition to energy-efficient lighting, a vital measure in slowing climate change". In December 2006, when Philips Lighting called for the global phase-out of incandescent light bulbs, lighting accounted for 19% of global electricity consumption. This was down to 15% in 2015 (when the Paris Agreement was signed) and is on track to decline further to 8% by 2030.

"This milestone demonstrates that we can successfully drive the transition from conventional lighting technologies to LED, which can make a significant contribution to global climate change objectives," says Harry Verhaar, Philips Lighting's head of Global Public and Government Affairs. "Energy efficiency is the low hanging fruit – today, energy efficiency improves by about 1.5% every year, but simply doubling this to 3% per year would set us on a sustainable path," he adds. "Compared to the outdated lighting sources these LEDs replaced, the energy savings achieved are equivalent to the energy generated by 30 medium-sized coal-fired power stations and the CO2 reductions achieved are equivalent to the emissions produced by 12 million cars. The impact is real and measurable."

The 1 billionth LED lamp was presented to a group of representatives from international governmental and non-governmental organizations at a special ceremony in Bonn, Germany.

At the event, Philips Lighting called on governments worldwide to join them in its goal to make the world more energy efficient by making the following commitments:

- by 2020 all new buildings should be installed with LED or equivalent energy-efficient lighting;
- by 2025 all street lighting should be LED or equivalent energy-efficient lighting; and
- by 2030 all existing corporate buildings should be fitted with LED or equivalent energy-efficient lighting.

www.lighting.philips.com

High yields and nutritional quality of leafy greens achievable using Lumileds' LUXEON SunPlus LEDs

The results of a controlled horticulture lighting study conducted by the US National Science Foundation (NSF)-funded Center for Lighting Enabled Systems and Applications (LESA) at Rensselaer Polytechnic Institute (RPI) in Troy, NY, USA have been released. Utilizing a variety of commercial LEDs, the study compared the effectiveness of different LEDs on the growth of red lettuce Rouxai. The best combined yield and antioxidant concentrations in the lettuce was observed using LUXEON SunPlus Series LEDs made by LED maker Lumileds of San Jose, CA, USA.

"Comparing the growth results using different combinations of LEDs shows that the spectra that performed best for yield (fresh weight), anthocyanin and chlorophyll concentrations were the LUXEON SunPlus Lime + Purple and Green + Purple LEDs from Lumileds," says LESA's Dr Tessa Pocock, an expert on light and plant physiology. "Green light is necessary for crop growth and the specific wavelengths within the green region matters." This work is also part of the Greenhouse Lighting and Systems Engineering (GLASE) Consortium operated by LESA and Cornell University and funded by the New York State Energy Research and Development Authority (NYSERDA) that is examining the most effective way to add green light to horticultural fixtures.

"Growers today are experimenting with various LEDs to arrive at the best color combinations for their crops," notes LUXEON SunPlus Series product line director Jennifer Holland. "The LESA study indicates that such experimentation is paying off because a common, nutrient-rich crop can be produced with excellent yield," she adds. The study demonstrated that a light spectrum like the combination of LUXEON SunPlus Lime and Purple, which contains a certain ratio of royal blue, green, deep red and far red components, is beneficial to growth optimization.

www.lumileds.com/horticulture

Arkesso's Mike Krames named IEEE Fellow

Dr Mike Krames, president of Arkesso LLC of Palo Alto, CA and Austin, TX, USA (which provides wide-bandgap semiconductor consulting and technology development), has been made a Fellow of the Institute of Electrical and Electronics Engineers (IEEE) for leadership in gallium nitride (GaN)-based light-emitting device physics and its commercialization.

Krames led technology teams at Hewlett-Packard Co, Lumileds, Philips and Soraa before forming Arkesso, in 2015. Over two decades his work has contributed to advances enabling several LED product 'firsts', including automotive headlamps, true replacements for directional halogen lamps, and high-color-gamut flat-panel displays.

Mike Krames.

In addition to many commercial achievements, Krames' work has led to fundamental improvements in the understanding of GaN-based device physics, including identifying Auger recombination as the main cause behind the droop in luminous efficiency seen in LEDs at high drive currents. While at Soraa, Krames pioneered gallium nitride on gallium nitride (GaN-on-GaN) technology as a platform for LEDs, resulting in what is claimed to be the most efficient high-power, visible-spectrum LED.

Krames is recognized for his expertise in LEDs and their applications for lighting and displays. He has served on many roundtables and panels for the US Department of Energy and Basic Energy Sciences and is the chair of the SPIE Photonics West conference on LEDs. Krames has authored more than 80 peer-reviewed publications and more than 100 granted US patents, and has served on several boards of directors/advisors. He earned a Bachelor of Science degree in Electrical Engineering (High Honors) from University of Texas, Austin, and Master of Science and Doctor of Philosophy degrees in Electrical Engineering from University of Illinois at Urbana-Champaign.

www.arkesso.com

Epileds reports flat revenue in second-half 2017 as it completes factory relocation

Capacity to ramp up in first-half 2018, as firm invests in R&D on micro-LEDs and mini-LEDs

LED epiwafer and chip maker Epileds Co Ltd of Tainan Science Park, Taiwan has reported flat revenue in second-half 2017 due to seasonal headwinds and the relocation of its factory, according to LEDinside (a division of TrendForce). Nevertheless, gross margin remains stable. Further, in 2018 Epileds is expected to achieve its best earnings per share (EPS) for the three-year period from 2015.

With relocation scheduled to complete by the end of 2017, the new factory will begin operation in 2018. Epileds is also reported to have started developing its micro-LED products.

In 2018, seasonal headwinds are expected to continue to affect Epiled's performance up to the Chinese New Year holidays in February, after which the market for LED chips should pick up again. The new factory will start to ramp up capacity to meet the returning demand during first-half 2018. The additional equipment that Epiled has purchased for the new factory is mostly second-hand, so further depreciation is limited.

Also, Epileds expects to see noticeable growths in shipments in 2018 as it uses its expanded capacity to churn out new products. Annual shipments of aluminium indium gallium phosphide (AlInGaP) LEDs, for example, are forecasted to rise by at least 30% from 2017. Volume growth in UV-A products should again exceed 10%. UV-C products are still being sampled by prospective customers. Epiled's UV-C strategy focuses on the consumer appliances segment. The goal is to differentiate from Japanese competitors that focus on UV-C components in medical equipment, says LEDinside.

In addition, Epileds has made a series of adjustments in its product mix over recent years. The share for blue LEDs, which was previously significant, has been scaled back to around 20% of the product mix. Conversely, the share for multi-color LEDs (used in various non-consumer applications) has increased. The scope for deployment of multi-color LEDs includes automotive lighting, ornamental lighting, stage lighting, horticultural growth lighting, and surveillance systems. The share for AlInGaP LEDs has surpassed 40%. Green LEDs and UV LEDs also make up 10-20% and about 20% of the product mix, respectively.

In response to emerging trends in the LED industry, Epileds is now investing in R&D on micro-LEDs and mini-LEDs. The firm has also expanded its range of chip-scale packages (CSP), customized in accordance with clients' specifications.

www.epileds.com.tw
www.ledinside.com

KEEPING AN EYE ON THE FUTURE

evatec process systems

Evatec brings you advanced thin film production solutions for Advanced Functionality Materials

From new high piezoelectric coefficient materials like AlScN to highly aligned NiFe soft magnetic layers or complex optical interference coatings, Evatec sputter platforms and processes help you keep an eye on the future. Advanced Process Control (APC) technologies bring precision and throughput to the deposition of new **Advanced Functionality Materials** in **Wireless**, **MEMS** and **LED** technologies. To find out more about Evatec processes and platforms visit **www.evatecnet.com**

RADIANCE SPUTTER CLUSTER

MSP 1232

LLS EVO II LOAD-LOCK SPUTTER

CLUSTERLINE® 300 II SPUTTER

SOLARIS S380 SPUTTER

MORE INFO

ADVANCED PACKAGING • HP OPTICS • MEMS • OPTOELECTRONICS • POWER DEVICES • WIRELESS • THE THIN FILM POWERHOUSE

www.evatecnet.com

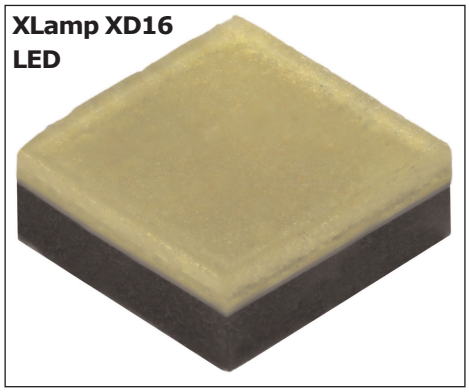
Cree launches first extreme density LED

XLamp XD16 first to surpass 280lm/mm² lumen density

LED chip, lamp and lighting fixture maker Cree Inc of Durham, NC, USA has announced commercial availability of the XLamp XD16 LED (claimed to be the industry's first extreme density LED), which delivers up to 5x times higher lumen density than Cree's previous generation of high-power LEDs.

Built on Cree's NX technology platform, the XD16 LED combines what is claimed to be the highest lumen density achieved by a commercially available lighting-class LED (more than 284lm/mm^2), low optical cross-talk, unsurpassed thermal contact and ease of system manufacturing to enable new designs for a broad spectrum of lighting applications (e.g. color-tuning, street, portable and industrial).

The ceramic-based XD16 LED utilizes the proven XQ footprint and



XLamp XD16 LED

addresses challenges with luminaire manufacturing, thermal design, optical design and reliability faced by competing LEDs, it is reckoned (e.g. reducing system-level optical loss by up to three times versus competing technologies when LEDs are placed close together on a board), translating into fewer wasted lumens and higher efficacy for lighting products.

"Cree's new extreme density LED demonstrates that true LED innovation improves our customers' system performance without forcing compromise," says Dave Emerson, Cree LEDs executive VP & general manager. "The XD16 LED delivers unmatched lumen density without the design and manufacturing challenges associated with inferior LED technology approaches," he adds. "Now, lighting manufacturers can easily achieve previously unattainable levels of light output and efficacy in their existing form factors."

The new LEDs are characterized and binned at 85°C, available in ANSI White, EasyWhite 3- and 5-step color temperatures (2700–6500K) and color rendering index (CRI) options of 70, 80 and 90. Product samples are available now and production quantities are available with standard lead times.

www.cree.com/xlamp/xd16

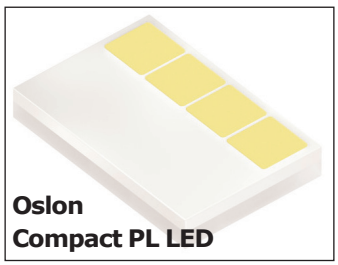
Osram launches Oslon Compact PL LED for headlights on all vehicle classes

Osram Opto Semiconductors GmbH of Regensburg, Germany has added the new Oslon Compact PL to its portfolio of products for the automotive sector.

Particularly suitable for use in vehicle headlights, the LED can be used for adaptive glare-free high-beam, daytime running lights (DRL), low beam and standard high beam. The all-round LED combines improved design with low system costs, making it suitable for different vehicle classes and accessible to a broad spectrum of customers.

The ceramic-based LED's thermal behavior is aided by an electrically insulated thermal pad. In combination with appropriate PCB technology, the Oslon Compact PL can be operated at high currents and achieve high light output.

In addition to the Oslon Compact CL (available as a single-chip version),



Oslon Compact PL LED

the portfolio now includes the Oslon Compact PL as a multichip version with up to five chips. Thermal conductivity is boosted due to the square emission surface of the notchless UX:3 chips, which also makes contacting and the optical design much simpler. The high luminous flux also provides improved brightness values. For applications that previously used halogen, a luminous flux of 1000lm can be achieved with one Oslon Compact PL 3 chip, for example.

"With the Oslon Compact PL we are adding powerful ceramic-based LED types to our portfolio," says Thomas Christl, marketing manager Automotive Exterior at Osram Opto. "Our bandwidth of products with different package technologies for exterior lighting on cars is now even more extensive, with each offering its own benefits depending on the particular application. This means that we can deal much better with the individual wishes of our customers."

With its particularly robust material properties, the new ceramic package improves handling and reliability. Osram's own binning method is being used in the development of the LED, which makes further increases in brightness available to customers in short intervals of time, the firm adds. The design of the components can hence be optimized and adapted to cater for higher minimum brightness values or specific thresholds.

www.osram.com

Pick your size.

The Temescal UEFC-4900—ultimate lift-off metallization performance like the UEFC-5700, but optimized for smaller wafers and smaller production volumes.

Temescal
UEFC–4900

It's the elephant in the room. With our Auratus™ deposition enhancement methodology and the UEFC-5700, we brought you huge metallization process improvements including near perfect uniformity; but UEFC-5700 is a high-volume production tool. Now we've packed this performance into a mid-sized system, the UEFC-4900, because sometimes the elephant is just too big.

Harmonize your process to the vapor cloud and experience the huge performance benefits, even if you run smaller wafers and smaller production volumes.

A Temescal system can bring near perfect uniformity to your lift-off metallization coating process. To find out more, visit **www.temescal.net/auratus-elephant** or call **+1-925-371-4170**.

FerroTec

Automotive market showcasing progress in sensor technology, says Osram Opto

More reliable sensor technology accelerating development of semi-autonomous vehicles

Today's automotive market is a showcase of some of the most important next-generation technologies, as vehicle manufacturers are among the first to adopt the latest technology developments, including the use of visible and invisible light for sensor technology, notes Osram Opto Semiconductors GmbH of Regensburg, Germany, whose portfolio of LED and infrared components for automotive sensor applications is playing a key role in safety, security and comfort.

Much attention has been on LiDAR (light detection and ranging) laser technology. However, it is developments in many fields based on the use of photodetectors and IREDs (infrared-emitting diode) — in particular, as a basis for sensors — that are making headway in bringing a multitude of advances closer to market. The wide range of applications for sensors in car interiors and exteriors span reducing risk (to the lives of drivers, passengers and pedestrians) to enhancing the driving experience in comfort.

"We have seen a huge leap in developments in sensor technology based on photodetectors and IR-LEDs, spurred on by new possibilities to make driving safer and more comfortable," says Osram Opto Semiconductors marketing manager Walter Rothmund. "Perfecting the sensors required for such technology is crucial for the safety of all road users and pedestrians."

Camera-based sensor systems making use of infrared light technology are making headway in interior systems. Driver monitoring is an increasingly critical component for today's safety features as well as for future semi-autonomous cars. IREDs are used to illuminate a driver's face with invisible infrared light. To detect whether the driver is fatigued or distracted, a CMOS camera monitors the face, especially the eyes, to detect the status of attention and the gaze direction of the driver. A warning is activated in case of drowsiness to alert the driver, or recommend taking a break. In semi-autonomous cars (level 3 and higher) the vehicle must be able to hand back the control to the driver in case of a critical situation at any time, making driver monitoring systems mandatory.

Another example of a safety feature is occupancy detection systems, using invisible IR light and a CMOS camera, which monitors the passenger seats. Occupants are recognized and their size and position are determined to ensure appropriate deployment of the airbag in case of an accident.

However, it is not only inside the car where light technologies are improving visibility, vehicle and traffic safety, an overall smoother journey and styling recognition. Cameras used on cars (to detect the environment around the vehicle for night-vision assistance) are benefiting from increasing efficiency of the latest high-power IR-LEDs. This gives headlamp designers, for example, far more flexibility and freedom.

High-power infrared LEDs are also enhancing road camera systems, such as those used to read number plates. Improvements used to sense the plates mean that computers can read them more easily, reducing the risk of error and opening the doorway to additional technologies such as automatic toll booths (ensuring the smooth flow of traffic). Other applications include adaptive cruise control, pre-crash sensing, pedestrian protection and blind-spot detection.

www.osram.com/os/applications/automotive-applications

Excelitas acquired by AEA Investors

Private equity to enable photonics firm to capitalize on growing markets

Excelitas Technologies Corp of Waltham, MA, USA has been acquired by funds sponsored by AEA Investors LP.

Owned by Veritas Capital Fund Management since November 2010, Excelitas provides customized photonic solutions for the lighting, detection and optical technology needs of OEMs. AEA Investors manages funds that have about $10bn of invested and committed capital, and AEA private equity invests across four sectors: value-added industrial products, specialty chemicals, consumer/retail and services.

"AEA Investors is an experienced investor in the industrial technology sector with a strong track record of successful investments," comments Excelitas' CEO David Nislick. "Their focus on facilitating the growth of companies like Excelitas makes AEA the ideal partner to help capitalize on our growing market opportunities as we continue delivering innovative photonics technologies to our customers."

Excelitas will remain headquartered in Waltham, MA and retain its corporate identity and brands as it continues its business growth models.

www.excelitas.com
www.aeainvestors.com

Osram's SFH 4735 Oslon Black Flat receives best overall award in LEDs and Lighting category at 2017 ACE Awards

At the Annual Creativity in Electronics (ACE) Awards in San Jose in December, Osram Opto Semiconductors GmbH of Regensburg, Germany was a finalist in three categories, and received a best overall award in the LEDs & Lighting category for its SFH 4735 Oslon Black Flat.

The awards, in partnership with EE Times and EDN, showcase the best contributions to the electronics industry in 2017 including the most innovative new products, start-up firms, design teams and executives.

"Osram is investing a great deal of time and energy to create innovative technologies that stand-out amongst others in the industry, especially those with life-changing implications," says Ishrat Hakim, president & CEO, North America, at Osram Opto.

Osram was a finalist in the following categories:

- **Company of the Year**: Osram Opto produces and markets LEDs and infrared components for automotive, industrial and end-customer applications as well as for general lighting. Fiscal-year 2016 was a year of growth for the company, including opening a new LED chip factory in Kulim, Malaysia.
- **Automotive**: Osram Opto's prototype four-channel LIDAR laser takes Light Detection and Ranging systems for autonomous or semi-autonomous) has an extremely short pulse length and four parallel output channels. It offers new options for detecting objects and a unique vertical detection zone. This is used in scanning LIDAR sensors based on MEMS, which do not need any mechanisms to redirect the laser beam (making them less susceptible to wear and tear).
- **LEDs and Lighting**: The SFH 4735 Oslon Black Flat is claimed to be the first broadband-emitting infrared LED, suitable as a light source for near-infrared spectroscopy in applications such as assessing the quality of food. Due to its size, robustness and cost position, the new LED enables near-infrared (NIR) spectroscopy technology to move into the consumer market, for example integrated into smartphones.
- **LEDs and Lighting**: The new high-power (3W) Osconiq P 3737 LED provides versatile opportunities for high-quality and cost-efficient outdoor lighting. Until now, costly ceramic-based LEDs have been used for professional exterior lighting applications. With the Osconiq P series, Osram is offering epoxy-based packages that provide superior lumens per dollar, it is claimed.

www.ubm-ace.com
www.osram-os.com

Osram spotlights LED and laser solutions in Rinspeed's Snap concept vehicle at CES

Osram Opto Semiconductors GmbH of Regensburg, Germany is the exclusive lighting partner for Switzerland-based think-tank Rinspeed's Snap autonomous concept vehicle, which features many of Osram's LED, laser and optoelectronic sensing solutions from the ultraviolet (UV) and visible to infrared spectrum, and was launched at the Consumer Electronics Show (CES 2018) in Las Vegas (on display in Harman's exhibit at the Hard Rock Hotel, 9–12 January).

To give Snap a distinctive look and feel, Osram Opto provided human-centric lighting that coordinates the interplay of light, atmosphere and space. Also, using facial recognition technology powered by a new generation of infrared LEDs, Snap can adapt to the individual requirements of each passenger. Everything from personalized lighting options to preferred temperature to seat position can be adjusted to meet a passenger's needs. Entering the vehicle becomes even more customized and secure with iris scanning technology, featuring Osram's infrared LEDs.

Snap autonomous concept vehicle.

"Our cutting-edge infrared LED technologies are making vehicles more individualized for passengers than ever before by bringing the latest biometric identification applications to the automotive industry," says Bodo Ischebeck, VP & general manager of Industry and Mobile Devices at Osram Opto.

Osram Opto's LED technology also demonstrates how dynamic information can be transmitted to both drivers and pedestrians. Projection lighting welcomes passengers and provides safety advice for pedestrians. LEDs and lasers convert front and rear windows into information-rich screens for conveying marketing messages or communicating with the vehicle's surroundings. LED license plates can be customized with the driver's information to accommodate future car-sharing regulations.

"As we enter a new era of autonomous vehicles, lighting will become even more important," believes Wolfgang Lex, VP & general manager of Automotive at Osram. "Suddenly, the car is not just a car. It's an office on wheels, a library, a living room, or an art studio where you can paint a picture during your commute hours. Logically, cars will need lighting that's appropriate for all these activities and more."

Osram Opto says that it is bringing advanced technologies used in other industries to the automotive world. Biomonitoring on smart watches connects to the Rinspeed vehicle to assist passengers experiencing a sudden health issue. Finally, high-power UV LEDs disinfect Snap after each use to prevent the spread of germs.

Osram showcased many of its automotive lighting technologies at CES (including its range of interior and exterior automotive applications).

www.osram.com/ces

Osram lasers featured in LIDAR and ADAS solutions at AutoMobili-D

At the North American International Auto Show's AutoMobili-D 2018 in Detroit, MI, USA (14–21 January), Osram Opto demonstrated how its high-power 905nm-wavelength infrared pulse lasers are helping to speed the adoption of autonomous vehicles and advanced driver assistance systems (ADAS).

Osram Opto's pulse laser diodes have been featured in cars for over 10 years for time-of-flight (TOF) measurements in adaptive cruise control (ACC) systems and automatic braking systems.

At AutoMobili-D, Osram showcased its laser and LEDs in applications for autonomous vehicles and ADAS, including:

- A long-range infrared 4D camera concept from Vergence Automation uses 190 Osram infrared LEDs (4D imaging, when applied to autonomous vehicle use, will be a benefit to computer vision, machine learning, and deep learning).
- The GazeT Driver Monitoring Global Shutter Image Sensor Demo System from ON Semiconductor uses Osram's 940nm IR LEDs.

Osram lasers dedicated to LiDAR applications are based on its high-power 905nm-wavelength infrared pulse laser. The short pulse length allows systems operating at high optical power levels to realize large detection ranges while still being safe for the naked eye, says Osram.

"Osram is pleased to be working with leading companies to enable widespread adoption of autonomous vehicles and ADAS," says regional marketing manager Rajeev Thakur. "Joining forces with companies like Vergence Automation and ON Semiconductor is a testament to Osram's leadership in the development and future of autonomous vehicles."

"Osram is a great technology partner for developing our 4D camera that utilizes a patented 4D pixel to perform 3D image creation," says Vergence's chief product officer Jamie Retterath. "The 4D pixel has the potential to displace TOF for all future 3D imaging applications."

www.naias.com/automobili-d

FBH presents lasers and UV LEDs at Photonics West

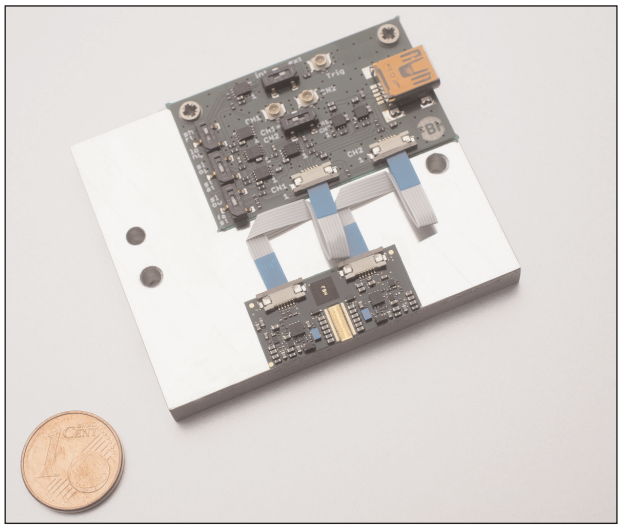
Berlin-based Ferdinand-Braun-Institut, Leibniz-Institut für Höchstfrequenztechnik (FBH) — which researches compound semiconductor-based electronic and optical components, modules and systems — presented developments and advances of its diode lasers and UV light-emitting diodes (LEDs) at SPIE Photonics West 2018 in San Francisco, CA, USA (30 January — 1 February). FBH was also represented at the accompanying conferences (27 January — 1 February) with more than 30 scientific contributions. At the German Pavilion, FBH showcased its full range of capabilities, offering the full value chain in-house: from design through chips to modules. The institute is increasingly advancing these devices up to operational systems.

Exhibits include:

● **High-power pulse laser source for LiDAR systems**

Lasers generating short optical pulses with widths of 200ps to 20ns are key components for a broad range of applications including light detection and ranging (LiDAR), e.g. for autonomous driving, 3D object detection, laser scanning (airborne, satellite and terrestrial) as well as fluorescence spectroscopy and micro-machining systems. FBH has developed a suitable compact laser source. The module uses a tailored design for pulse generation from the FBH's diode laser technology as well as a laser driver with a gallium nitride (GaN) transistor in the final stage, offering pulses up to 250A with controllable pulse amplitude and width. Integrated on these drivers is FBH's latest generation of wavelength-stabilized laser diodes that emit 5ns pulses with 40W (single emitter) or up to 100W (three-emitter array) pulse power near 905nm with good beam quality and up to 85°C. This concept can be transferred to further wavelengths.

● **Compact laser module offering frequency stabilization for interferometry**



FBH has developed a very compact laser module emitting at 633nm. Measuring just 76mm x 54mm x 15mm, the module uses a novel butterfly-type housing and aims to replace bulky helium–neon (HeNe) lasers. Offering a flexible platform for the integration of a wide range of photonic components, it simplifies adaptation for different applications, says FBH.

The particular module presented features an all-semiconductor master-oscillator power amplifier (MOPA) combined with an iodine gas cell to stabilize output power as well as emission wavelength. The MOPA uses newly developed chips, achieving an optical output power of more than 30mW. A miniaturized optical isolator (purpose-built for 633nm wavelength) is interposed between the MO and PA, and features optical isolation of more than 30dB and a transmission loss of less than 3dB. The iodine gas cell is also miniaturized, offering a length of just 30mm and a clear aperture of 2mm. The module's emission frequency can be stabilized by project partner Toptica to be absolute within a 10MHz band over a time period of 1 hour. This corresponds to a frequency stability of $2x10^{-8}$, which translates to an accuracy of about 2µm on a length scale of 100m. Such accuracy could previously only be reached by using large-sized HeNe lasers. The new laser modules should allow significantly greater miniaturization of interferometric measurement systems in the near future, it is reckoned.

Developments include monolithic dual-wavelength distributed Bragg reflector diode lasers with optical output powers up to 200mW, providing two emission lines with a small spectral linewidth for shifted excitation Raman difference spectroscopy

● **Wavelength-stabilized high-brightness light sources**

FBH develops customized wavelength-stabilized high-power diode lasers with laser emission in the 630–1180nm spectral range for spectroscopic applications and as pump sources for non-linear frequency conversion. Developments include monolithic dual-wavelength distributed Bragg reflector (DBR) diode lasers with optical output powers up to 200mW, providing two emission lines with a small spectral linewidth for shifted excitation Raman difference spectroscopy (SERDS). With SERDS, Raman signals can be extracted efficiently and rapidly from disturbing backgrounds such as fluorescence and ambient light, improving Raman spectroscopy in real-world applications. DBR tapered lasers and MOPA systems show diffraction-limited output powers up to 10W and are used for efficient second-harmonic generation of the emission into the visible spectral range and upconversion of mid-infrared radiation via sum frequency generation to the near-infrared range.

www.fbh-berlin.com

China's Fudan University develops optically pumped all-silicon laser

High-pressure low-temperature passivation yields optical gains in silicon nanocrystals comparable to GaAs and InP

Silicon lasers are key to achieving integrated silicon photonics but, due to its indirect bandgap, the optical gains in silicon are lower than those of direct-bandgap III–V compound semiconductors by one or two orders of magnitude. Although the fabrication of matured III–V lasers on silicon substrates has been proposed to circumvent this problem, the development of an all-silicon laser is still highly desired for integrated silicon photonics, due to its better compatibility with state-of-the-art silicon techniques.

Recently, a joint research team led by professor X. Wu, professor M. Lu and associate professor S.-Y. Zhang at Fudan University developed what is claimed to be the first all-silicon laser using silicon nanocrystals with high optical gain (Dong-Chen Wang et al, 'An all-silicon laser based on silicon nanocrystals with high optical gains', Science Bulletin, 5 January 2018).

First, they enhanced the silicon emission intensity greatly by developing a film growth technique for high-density silicon nanocrystals (Physica E, 89, 57–60(2017)). Then they developed a high-pressure low-temperature passivation approach, which contributed to the full saturation of dangling bonds, leading to increased optical gains that were comparable to those achieved by gallium arsenide (GaAs) and indium phosphide (InP).

Lasing characteristics — the threshold effect, the polarization dependence, the significant spectral narrowing and small spread of divergence angle of stimulated emission — were fulfilled

On this basis, they designed and fabricated distributed feedback (DFB) resonance cavities and successfully achieved optically pumped all-silicon DFB lasers. The optically pumped all-silicon laser also paves the way towards the realization of electrically pumped all-silicon laser, it is reckoned.

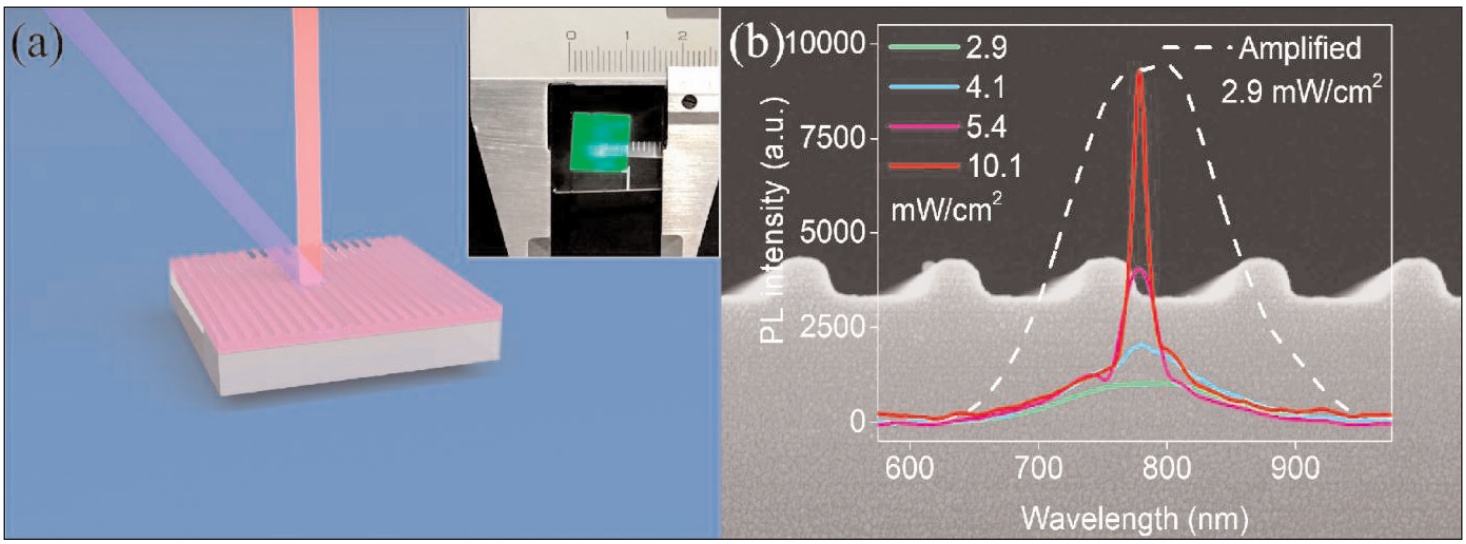
It was found that the optical gain of silicon nanocrystals was constantly enhanced as the passivation proceeded and eventually reached the value comparable to those of GaAs and InP. Lasing characteristics — the threshold effect, the polarization dependence, the significant spectral narrowing and small spread of divergence angle of stimulated emission — were fulfilled, suggesting the realization of an optically pumped all-silicon laser.

The full-width-at-half-maximum (FWHM) of the emission peak was narrowed from ~120nm to 7nm when the laser was pumped above threshold.

The lasers also showed reliable repeatability. The lasing peaks of the four additional samples made under similar fabrication conditions were within the spectral range 760–770nm. The variation in the lasing peak was due to the slight difference in effective refractive indices.

The program is supported by the National Natural Science Foundation of China (51472051, 61275178, 61378080, 61705042) and Shanghai Sailing Program (16YF1400700).

www.sciencedirect.com/science/article/pii/S2095927318300069
www.fudan.edu.cn/en



(a) Schematic image of DFB silicon laser; inset: photograph of fabricated DFB device. (b) Emission spectra of the silicon laser as a function of pump power; background: cross-sectional SEM image of DFB structure.

Leti integrates hybrid III–V silicon lasers on 200mm wafers using standard CMOS process

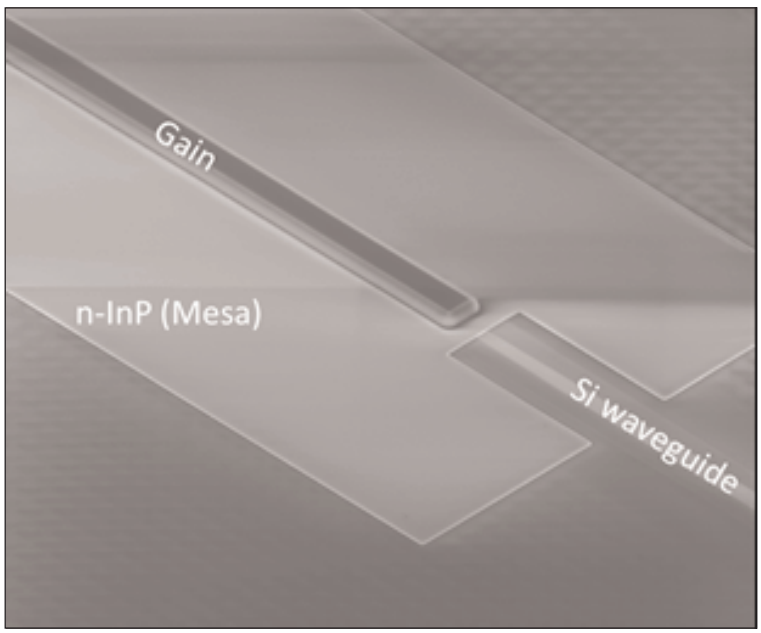
Fabrication flow fully planar and compatible with large-scale integration on silicon photonic circuits

At the 63rd IEEE International Electron Devices Meeting (IEDM 2017) in San Francisco (4–6 December), micro/nanotechnology R&D center CEA-Leti of Grenoble, France has reported the integration of hybrid III–V silicon lasers on 200mm wafers using a standard CMOS process flow. This shows the way to transitioning away from 100mm wafers and a process based on bulk III–V technology that requires contacts with noble metals and lift-off based patterning, Leti says.

Carried out in the framework of the IRT Nanoelec program (which is headed by Leti), the project demonstrated that the hybrid device's performance is comparable to the reference device fabricated with the existing process on 100mm wafers. The fabrication flow is fully planar and compatible with large-scale integration on silicon photonic circuits.

CMOS compatibility with silicon photonics lowers fabrication costs and provides access to mature and large-scale facilities, which enables packaging compatibility with CMOS driving circuits, notes Leti.

"Silicon photonic technologies are becoming more mature, but the main limitation of these platforms is the lack of an integrated light source," says Bertrand Szelag, a co-author of the paper 'Hybrid III–V/Si DFB Laser Integration on a 200mm Fully CMOS-compatible Silicon Photonics Platform'. "This project showed that a laser can be integrated on a mature silicon photonic platform with a modular approach that does not compromise baseline process performances," he adds. "We demonstrated that the entire process can be done in a standard CMOS fabrication line with conventional process and materials, and that it is possible to integrate all the photonic building blocks at large scale."

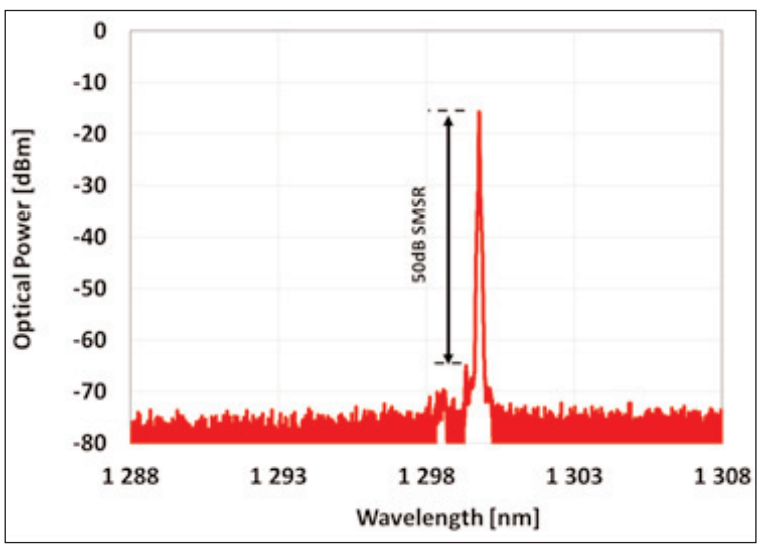


Tilted scanning electron microscopy view of the III–V/Si DFB laser after the III–V patterning steps.

The integration required managing a thick silicon film, typically 500nm thick, for the hybrid laser, and a thinner one, typically 300nm, for the baseline silicon photonic platform. This required locally thickening the silicon by adding 200nm of amorphous silicon via a damascene process, which presents the advantage of leaving a flat surface favorable for bonding III–V silicon. The laser can be integrated on a mature silicon photonic platform with a modular approach that does not compromise the baseline process performance.

The novelty of the approach also included using innovative laser electrical contacts that do not contain any noble metals, such as gold. The contacts also prohibit integration lift-off-based processes. Nickel-based metallization was used with an integration technique similar to a CMOS transistor technique, in which tungsten plugs connect the device to the routing metal lines.

The next steps include integrating the laser with active silicon photonic devices, e.g. a modulator and photodiode with several interconnect metal levels in a planarized backend. Finally, III–V die bonding will replace III–V wafer bonding in order to process lasers on the entire silicon wafer.



Laser spectrum at 160mA injection currents.

www.leti.fr

UNIST and University of Maryland integrate InAs/InP quantum dot single-photon emitters onto silicon photonic chip

Photonic devices targeted at quantum information processing

A team led by professor Je-Hyung Kim in the School of Natural Science of South Korea's Ulsan National Institute of Science and Technology (UNIST) in collaboration with professor Edo Waks and a group of researchers at the University of Maryland in the USA has presented a core technology for quantum photonic devices used in quantum information processing by combining quantum dots for generating light and silicon photonic technologies for manipulating light on a single device (Je-Hyung Kim et al, 'Hybrid Integration of Solid-State Quantum Emitters on a Silicon Photonic Chip', Nano Letters, 2017, 17 (12), p7394).

"To build photon-based integrated quantum optical devices, it is necessary to produce as many quantum light sources as possible in a single chip," says Kim. "We have proposed the basic form of quantum optical devices by producing highly effective quantum light source with quantum dots and creating the pathway to manipulate light with the use of silicon substrates."

However, as the size of quantum dots decreases, they begin to exhibit discontinuous energy structure, which results in having similar properties to the light emitted by atoms. Although quantum dots have been used successfully as highly efficient single-photon sources, they had difficulty controlling light.

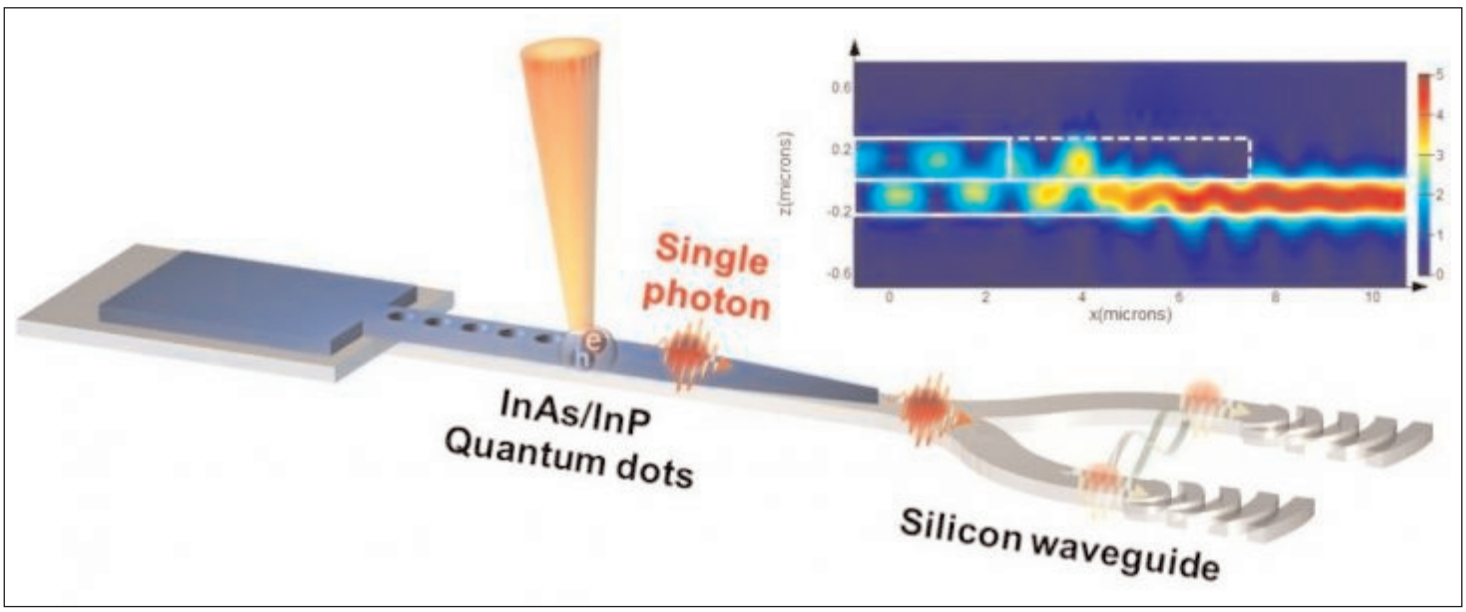
The team has demonstrated the integration of silicon photonic devices with a solid-state single-photon emitter. They used a hybrid approach that combines silicon photonic waveguides with InAs/InP quantum dots that act as efficient sources of single photons at telecom wavelengths spanning the O-band and C-band. Then they removed the quantum dots via a pick-and-place procedure with a microprobe tip combined with a focused ion beam and scanning electron microscope. This technique allowed transferring of tapered InP nanobeams containing InAs quantum dots onto a silicon waveguide with nanometer-scale precision.

"This integration opens up the possibility to leverage the highly advanced photonics capabilities developed in silicon to control and route non-classical light from on-demand single-photon sources," the team notes. "In addition, the fabricated devices operate at telecom wavelengths and can be electrically driven, which are useful for fiber-based quantum communication."

The quantum optical device developed by the team has successfully transferred the emission from the quantum dots along the silicon photonic circuits with high efficiency. Using this, they have also incorporated an on-chip silicon-photonic beam-splitter to perform a Hanbury–Brown and Twiss measurement.

"Our approach could enable integration of pre-characterized III–V quantum photonic devices into large-scale photonic structures to enable complex devices composed of many emitters and photons," believes Kim.

http://pubs.acs.org/doi/abs/10.1021/acs.nanolett.7b03220
www.unist.ac.kr



Schematic of integrated InP nanobeam and silicon waveguide.

PHIX and Tyndall strengthen collaboration

PHIX engineers to be trained on Tyndall's packaging equipment

PHIX Photonics Assembly (PHIX) of Enschede, The Netherlands and PIXAPP Photonic Integrated Circuits Assembly and Packaging Pilot Line coordinator Tyndall National Institute (based at University College Cork in Ireland) have strengthened their collaboration in developing the photonic packaging ecosystem by arranging dedicated training of PHIX engineers on Tyndall's advanced packaging equipment. This sharing of knowledge is targeted at strengthening the photonic ecosystem in Europe and assuring open access to high-volume photonic integrated circuit (PIC) packaging through the PIXAPP pilot line.

PHIX supplies photonic assembly & packaging services targeting high-volume PIC applications. The initiator and shareholder of PHIX (LioniX International) is also a partner in the PIXAPP Pilot Line and will provide PIXAPP with access to a new high-volume assembly line as the next stage for customers after accessing the pilot line. Both PHIX and Tyndall will actively supply engineering resources to support the further development of the packaging and assembly processes.

PHIX will provide state-of-the-art infrastructure, supporting the European and global industrial development of photonic integrated circuits (PICs). PHIX focuses on a hybrid platform, consisting of two or more different chips that are assembled in a planar configuration and coupled to optical fibers. The PICs are fabricated on indium phosphide (InP) or silicon substrates. The hybrid platform supports a wide range of applications, and PHIX will standardize key processes and assembly steps with the support of Tyndall.

PHIX Photonics Assembly engineers visiting Tyndall's packaging laboratories for training on advanced packaging technologies and to learn about packaging design rules.

"Offering packaging services requires both processing and state-of-the-art equipment knowledge," says PHIX CEO Albert Hasper. "With Tyndall we have found a partner that has a broad range of processing knowledge for PIC assemblies complementary to our expertise," he comments.

"We are delighted to support PHIX develop volume packaging processes and to provide comprehensive training to its staff," says Peter O'Brien, head of group and director of the PIXAPP pilot line at Tyndall. "A key objective of PIXAPP is to build the integrated photonics ecosystem, establishing a volume manufacturing capability in Europe. Our focus on packaging design rules helps achieve this objective, ensuring efficient and scalable assembly processes," he adds. "We plan to train PHIX engineers on the principles of these design rules, and how to implement them to build complex integrated photonic assemblies."

http://phix-photonics-assembly.com
www.tyndall.ie

ProPhotonix's Ireland subsidiary achieves ISO9001:2015

ProPhotonix Ltd of Salem, NH, USA, a designer and manufacturer of LED illumination systems and laser diode modules for OEMs and medical equipment companies (as well as a distributor of laser diodes for Ushio, Osram, QSI, Panasonic and Sony), says that its Ireland subsidiary has transitioned from ISO9001:2008 to ISO9001:2015 certification. ProPhotonix (Irl) Ltd has been continuously certified to the ISO9001 standard since 1999.

International Organization for Standardization (ISO) 9001:2015 is the most recent version of the ISO9001 standard that measures the effectiveness of a company's quality management system and performance, with a focus on organization-wide risk-based thinking. The ISO process assists companies in developing a management system that aligns their quality strategy with its business strategy.

The new certification "demonstrates additional assurance to our customers that we are focused on continuous improvement and achieving excellence in our customer service and delivery," says president & CEO Tim Losik. "The ISO 9001:2015 standard demands a higher degree of leadership commitment than the previous standards," he adds. "We are dedicated to constant improvement and development and maintaining our ISO 9001 accreditation, ensuring we have the processes and systems in place for this. Our UK subsidiary continues to be certified to ISO9001:2008, with transition to ISO9001:2015 expected to take place during the first half of 2018."

www.prophotonix.com

CST Global receives £83,774 funding to continue GaN laser technology development for quantum sensing

Year-long CoolBlue2 project to investigate feasibility of fully monolithic, narrow-linewidth gallium nitride DFB laser

III-V optoelectronic foundry Compound Semiconductor Technologies Global Ltd (CST Global) of Hamilton International Technology Park, Blantyre, near Glasgow, Scotland, UK (a subsidiary of Sweden's Sivers IMA Holdings AB) is to lead the UK government-funded project 'Quantum Cooling using Mode Controlled Blue Lasers' (CoolBlue2).

The project will be led by research engineer Dr Thomas Slight, with support from commercial partner Helia Photonics Ltd, research partner National Physical Laboratory Ltd and academic partners the University of Glasgow and Aston University.

Running from April to March 2019, the CoolBlue2 project cost will total £499,076, including government funding of £410,209, of which CST Global will receive £83,774.

"CoolBlue2 is a continuation of our work in developing next-generation GaN [gallium nitride] laser technology, for implementation in quantum sensors based on ultracold atoms," says Slight. "The direct blue laser diode source we developed in the original CoolBlue project [which started in April 2017] offered increased power, lower complexity and smaller size over conventional laser sources. This showed it was possible to transform quantum sensors from 'laboratory instruments' into miniaturized, robust systems," he adds.

"CoolBlue2 investigates the feasibility of developing a fully monolithic, narrow-linewidth GaN DFB [distributed feedback] laser," Slight continues. "They will operate in the 4XXnm region and will be used as a source in laser-cooled quantum sensing systems, such as quantum clocks, gravimeters and magnetometers. Other applications include atomic spectroscopy, subsea communications and medical instrumentation."

"The funding allows for two iterations of chip design and manufacture, with the aim of producing a laser suitable for evaluation in a real-world, low-cost, integrated system," Slight concludes.

Paper at Photonics West

At SPIE Photonics West 2018 in San Francisco (27 January — 1 February), Slight presented a paper 'Distributed feedback InGaN/GaN laser diodes' giving an interim summary of the government-funded project CoolBlue which, led by Slight during 2017, developed next-generation GaN laser diodes for quantum sensing systems (such as atomic clocks) based on ultracold atoms.

"The single-wavelength blue laser diode source offered increased power, lower complexity and smaller size over conventional laser sources," says Slight. "This showed it was possible to transform quantum sensors from 'laboratory instruments' into miniaturized, robust systems for a far wider range of commercial applications."

CoolBlue involved two cycles of laser design, fabrication and testing at CST Global. The knowledge and expertise generated allows the firm to develop new products for the emerging GaN laser and quantum technology markets.

CST Global appoints principal device development engineer

CST Global has appointed Dr Susannah Heck as principal device development engineer.

"Susannah brings a wealth of technical experience in monolithic and hybrid optoelectronic integration; active and passive device design and verification on III-V compound semiconductors; and epitaxy, lithographic-mask and process design for wafer production," notes technical director Dr Andrew McKee. "She also brings invaluable project planning, budgeting, resource allocation and management expertise, with exceptional communication skills."

Heck was previously principal

engineer at Kaiam Corp in Livingston, West Lothian, Scotland, and senior R&D engineer at Oclaro Inc in Northamptonshire, England. She has been both program manager and technical lead on projects including next-generation, 100G data-center optoelectronic hardware design, development and verification.

Heck began her working career as a research intern at the Tyndall National Institute at University College Cork, Ireland, before becoming a research associate in the Experimental Solid-State Physics department at Imperial College London.

Heck has a B.Sc. Hons and Ph.D. in Physics from University College Cork, specializing in characterization of quantum dot and dash devices; material properties related to quantum dot anisotropy; and threshold current and efficiency of III-V semiconductor lasers. Also, she is the author and co-author of a number of journal articles and conference papers in photonics.

www.CSTGlobal.uk

CST Global receives £108,000 from UK government to lead 60GHz radio-over-fiber project

£285,000 total funding for Wi Phi project, including Optocap and University of Glasgow

III-V optoelectronic foundry Compound Semiconductor Technologies Global Ltd (CST Global) of Hamilton International Technology Park, Blantyre, near Glasgow, Scotland, UK (a subsidiary of Sweden's Sivers IMA Holdings AB) has received £108,000 (about SEK1.2m) from the UK government to lead the project 'High performance wireless to photonic interfaces for 60 GHz Radio-Over-Fiber applications'.

The 'Wi Phi' project will be managed by CST research engineer Dr Horacio Canto alongside commercial partner Optocap Ltd and academic partner the University of Glasgow.

Running throughout 2018, the Wi Phi project has received over £285,000 of government funding in total UK government agency through Innovate UK, of which CST has received £108,000.

"This is yet another project to establish the combination of optical device and millimeter-wave-based technology to offer multi-gigabit, wireless transmission for fiber networks," says Canto. "The wireless-optoelectronic technology that we are developing targets V-band frequencies in the millimetre-wave spectrum at 60GHz, one of the designated 5G network bands for telecommunication infrastructures," he adds.

The data rates possible with this technology exceed 7Gb/s, which is several times larger than those of currently available technologies. It benefits from low latency, increased transmission speed, immunity from interference, enhanced security, and a reduction in component count and antenna size. Ultimately, this enables a cost reduction for communication links with point-to-point configuration.

"We are pleased that CST once again is trusted by the British government to manage an important technology development project, and especially since this 'Wi Phi' project relates to our joint long-term strategic goal to offer the best wireless and fiber-based broadband solutions to the market," comments Sivers IMA Holding's CEO Anders Storm. "This confirms the strong position of CST and Sivers IMA in the development of next-generation broadband networks," he believes.

CST Global appoints senior process integration engineer

CST Global has appointed Antonio Samarelli as senior process integration engineer, actively involved in the development of new integrated photonics and compound semiconductor devices.

"Antonio is a pioneer of integrated silicon photonics," comments technical director Andrew McKee. "We have already worked with Antonio when he was a researcher at the University of Glasgow." The appointment "increases our research and design capacity whilst also adding extensive fabrication and process integration capability," he adds.

Samarelli has a BA in Electronics and Telecommunications and a Master's Degree in Engineering Optoelectronic Systems, both from the Politecnico di Bari, Italy. He then moved to the University of Glasgow for his PhD, working on the EU-funded SPLASH project,

Antonio Samarelli.

which developed silicon-on-insulator devices for optical communication systems. During this period Samarelli developed and optmized basic building blocks and their integration to create more complex photonic telecommunication networks. Some of these results still represent the state-of-the-art in the current photonic technology, says CST.

Samarelli remained at the University of Glasgow as a research associate, working on further EU-funded projects: first GREENSi (developing integrated thermoelectric materials and devices for energy harvesting systems) then GEMINI (focusing on the development of germanium plasmonic antennas for mid-infrared sensing). The latter is used in low-cost sensing devices for environmental, healthcare and security monitoring applications.

Samarelli was also a research fellow at the University of Glasgow, working on Quantum Technology systems.

Before joining CST Global, Samarelli worked for Kelvin Nanotechnology as project manager, producing devices and systems for both industrial and academic partners.

www.CSTGlobal.uk

Oxide two-dimensional electron gases integrated with GaAs, paving way for new opto devices

Work opens path to integrate oxide 2DEGs with other III–Vs too

Insulating oxides are oxygen-containing compounds that do not conduct electricity but can sometimes form conductive interfaces when they are layered together precisely. The conducting electrons at the interface form a two-dimensional electron gas (2DEG), which boasts quantum properties that make the system potentially useful in electronics and photonics applications.

Yale University has now grown a 2DEG system on gallium arsenide, promising new electronic devices that interact with light, such as new kinds of transistors, superconducting switches and gas sensors (Lior Kornblum et al, 'Oxide Heterostrutures for High Density 2D Electron Gases on GaAs', J. Appl. Phys., 123, 025302 (2018)). "I see this as a building block for oxide electronics," says Lior Kornblum, now of the Technion — Israel Institute of Technology.

Oxide 2DEGs were discovered in 2004. Researchers were surprised to find that sandwiching together two layers of some insulating oxides can generate conducting electrons that behave like a gas or liquid near the interface between the oxides and can transport information.

Oxide 2DEGs have much higher electron densities than semiconductor 2DEGs, making them promising candidates for some electronic applications. They have interesting quantum properties, drawing interest in their fundamental properties as well. For example, the systems seem to exhibit a combination of magnetic behaviors and superconductivity.

Generally, it is difficult to mass produce oxide 2DEGs because only small pieces of the necessary oxide crystals are obtainable, Kornblum notes. However, if researchers can grow the oxides on large, commercially available semiconductor wafers, they can then scale up oxide 2DEGs for real-world applications. Growing oxide 2DEGs on semiconductors also allows researchers to better integrate the structures with conventional electronics. According to Kornblum, enabling the oxide electrons to interact with the electrons in the semiconductor could lead to new functionality and more types of devices.

The Yale team previously grew oxide 2DEGs on silicon wafers. In the new work, they grew oxide 2DEGs on gallium arsenide, which proved to be more challenging.

Most semiconductors react with oxygen in the air and form a disordered surface layer, which must be removed before growing these oxides on the semiconductor. For silicon, removal is relatively easy — researchers heat the semiconductor in vacuum. However, this approach does not work well with GaAs.

Instead, the team coated a clean surface of a GaAs wafer with a layer of arsenic. This protects the surface from air while the wafer is transferred into a molecular beam epitaxy (MBE) system that grows oxides. This allows one material to grow on another while maintaining an ordered crystal structure across the interface.

Next, the researchers gently heated the wafer to evaporate the thin arsenic layer, exposing the pristine semiconductor surface beneath. They then grew an oxide layer of $SrTiO_3$ on the GaAs and, immediately after, another oxide layer of $GdTiO_3$, forming a 2DEG between the oxides.

It is reckoned that this work opens a path to integrate oxide 2DEGs with not just GaAs but also other III-V semiconductor materials too.

"The ability to couple or to integrate these interesting oxide two-dimensional electron gases with gallium arsenide opens the way to devices that could benefit from the electrical and optical properties of the semiconductor," Kornblum says. "This is a gateway material for other members of this family of semiconductors," he believes.

http://aip.scitation.org/doi/full/10.1063/1.5004576

https://ahnlab.yale.edu

US Army and Stony Brook grow InAsSb on GaAs substrates using gallium antimonide intermediate defect-trapping layer and graded buffer

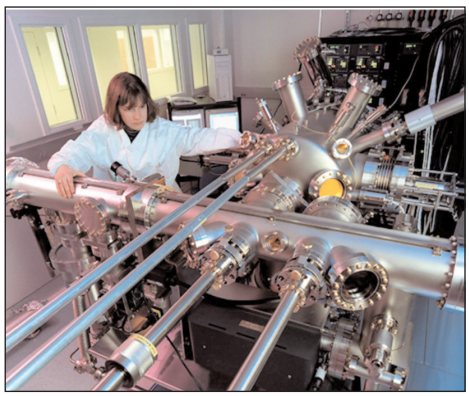
Practical, lower-cost solution for night-vision systems based on III–V long-wavelength IR materials

The US Army Research Laboratory (ARL) and Stony Brook University (funded by the Army Research Office) have developed a new synthesis process for the low-cost fabrication of a material previously discounted for high-sensitivity infrared cameras, opening new possibilities for future Army night-time operations ('Bulk InAsSb with 0.1 eV bandgap on GaAs', J. Appl. Phys. 122, 025705 (2017)).

ARL's Drs Wendy Sarney and Stefan Svensson led a novel approach to using the III–V compound semiconductor material indium arsenide antimonide (InAsSb), which is used in opto-electronics in many commercial products (such as DVD players and cell phones) but has not been used before in high-performance IR cameras for the longest wavelengths (10μm). The best materials for the IR camera light-sensors are currently based on the II–VI compound semiconductor material mercury cadmium telluride (HgCdTe). "Unfortunately, they are very expensive, mostly because there are only military customers for this material," says Svensson.

"The human eye is optimized by nature to observe reflected light from the sun in a very narrow band of colors… the visible spectrum; however, all objects in nature glow with a faint light even at low temperatures, which produces colors in the infrared range which are invisible to the naked eye. These wavelengths are about ten times longer than those of visible light," he adds.

"By using cameras that can see the faint IR light, soldiers can operate during night times," Sarney says. "The more sensitive such a camera is, or in other words, the smaller the color or temperature differences are that it can see, the more details that can be discerned on a battlefield and enemies can be detected at longer ranges. High-performance IR cameras are therefore extremely important for the Army."



Dr Wendy Sarney using the MBE reactor at ARL to produce IR detector materials using a new synthesis process. Credit: US Army.

Key to the development was realizing that the material needed to be undistorted by strain in order to see at 10μm. This was a major difficulty that had to be overcome before InAsSb could be used as a sensor material. The performance of devices based on semiconductor materials also depends on the material's crystalline perfection. Since InAsSb is deposited onto a substrate that has a smaller spacing between the atoms, this crystal lattice mismatch must be managed carefully for the light-sensitive material to work properly.

The research shows a path to a practical, lower-cost solution for the eventual fielding of night-vision systems based on III–V long-wavelength infrared materials

Among possible substrates, larger and cheaper ones typically have progressively smaller atomic spacing. Over several years ARL and Stony Brook found a way to manage the lattice mismatch, culminating in the current work which uses gallium arsenide as a substrate.

ARL and Stony Brook combined strain-mediating techniques to effectively manage the ~10% atomic spacing mismatch between the InAsSb sensing material and GaAs substrate. To do this, they deposited an intermediate layer of GaSb onto GaAs in a way that trapped most of the defects caused by the size mismatch. They then further increased the atomic spacing with a graded layer that also kept defects away from the InAsSb sensor material.

The material was examined with high-resolution transmission electron microscopy (HR-TEM) to make sure it had sufficient structural quality. They also found that the optical quality related to detection properties was remarkably high.

As the most common substrate used in the III–V industry for numerous consumer products, GaAs is inexpensive and available in large sizes. Large-area substrates allow manufacturing of multiple camera sensors simultaneously, which can be done in commercial foundries. This also opens up opportunities to produce high-quality IR cameras at a much reduced cost.

The research hence shows a path to a practical, lower-cost solution for the eventual fielding of night-vision systems based on III–V long-wavelength infrared materials.

http://aip.scitation.org/doi/abs/10.1063/1.4993454
www.stonybrook.edu/commcms/electrical/research

O-Net uses Semtech's ClearEdge CDRs to develop first 400m-reach SFP28 active optical cables

O-Net Technologies (Group) Ltd of Shenzhen, China (which provides optical networking products for telecoms and datacoms applications) says that its SFP28 active optical cable (AOC), which is integrated with the 25Gbps Dual ClearEdge CDR (clock & data recovery chip) of Semtech Corp of Camarillo, CA, USA (which supplies analog and mixed-signal semiconductors for high-end consumer, enterprise computing, communications and industrial equipment), has reached a transmission distance of 400m of OM4 fiber with RS-FEC and 300m without RS-FEC by passing multiple tests.

The SFP28 AOC (part number 1AT-LS6MxxXX-01A, which entered mass production in August) is a 25G/28G transceiver that can accelerate data-center and high-performance computing interconnections.

To offer next-generation computing connectivity, global web-scale data centers have a growing need for high-speed connectivity solutions that deliver increased bandwidth and reach. Existing AOCs typically have a maximum transmission distance of 100m per cable.

O-Net says that, leveraging its transceiver design and durable low-cost packaging technology as well as Semtech's GN2147 25G ClearEdge CDR technology with integrated vertical-cavity surface-emitting laser (VCSEL) compensation, O-Net has made significant strides by developing the new SFP28 AOC with reach of up to 400m. The firm's AOC transmits 25Gbps data over parallel multi-mode fiber cable and enables the acceleration of storage, data and high-performance computing connectivity. Compared with conventional AOCs, the technology can be more easily adopted in the new 100G AOC/SR 100G SWDM4 and 400GBASE-SR16 product series with a conventional VCSEL, it is claimed. Its extended reach plus superior low-power consumption means that a cost-effective and powerful cabling solution is accessible to data-center operators and high-performance computers, the firm adds.

"Our dedication to developing innovative products has translated into synergies for our business," says O-Net's chairman & CEO Austin Na. "We will seek to cooperate with more world-leading technology solution providers in the foreseeable future," he adds.

The GN2147 is a solution for SFP28 SR modules and AOCs that includes dual ClearEdge CDRs, integrated transimpedance amplifier (TIA) and a VCSEL driver. Offered in a compact 1.7mm x 3.0mm bare die format, the transceiver consumes less than 400mW total power to enable highly differentiated module solutions. It uses proprietary VCSEL compensation technology to enable low-bandwidth VCSELs and extended reach beyond 150m OM3 fiber, and supports data rates from 24.0Gbps to 28.1Gbps to enable a wide range of applications.

"Semtech's comprehensive ClearEdge CDR platform provides highly differentiated and innovative solutions to customers, which is an essential part of our long-term commitment as an IC supplier to our customers in the optical market," says Dr Timothy Vang, senior director of datacom marketing for Semtech's Signal Integrity Products Group. "The SFP 25G AOC segment will become a critical building block for medium-size data centers," he believes.

www.o-netcom.com
www.semtech.com

Lumentum receives 2017 Joint Innovation Partner award from Huawei

Optical and photonic optical component and subsystem maker Lumentum Holdings Inc of Milpitas, CA, USA has received the 2017 Joint Innovation Partner award from communications and data network solutions provider Huawei Technologies. The award recognizes the "strong partnership between the companies", who are working together on product planning and joint technology and product development initiatives.

Lumentum's president & CEO Alan Lowe accepted the award during the 2017 Core Partner Convention hosted by Huawei in Shenzhen, China. "It highlights that our relationship has evolved over the years to become an important strategic partnership," says Lowe. "We look forward to continuing to work together on next-generation products and their deployment within global networks."

Lumentum and Huawei are jointly developing innovative solutions to more efficiently switch high-speed optical signals in fiber-optic networks.

At Huawei's annual supplier event, over 500 people are invited to attend a day-long meeting with guest speakers, panel discussions, and an award ceremony. Lumentum's chief technology officer Brandon Collings participated on the 'High-speed Interconnects' panel, providing Lumentum's perspective on trends in future advanced network technologies.

www.huawei.com

semiconductorTODAY

COMPOUNDS & ADVANCED SILICON

www.semiconductor-today.com

Join our LinkedIn group: Semiconductor Today

Follow us on Twitter: Semiconductor_T

Choose *Semiconductor Today* for . . .

MAGAZINE

Accurate and timely coverage of the compound semiconductor and advanced silicon industries

Targeted 82,000+ international circulation

Published 10 times a year and delivered by e-mail and RSS feeds

WEB SITE

Average of over 26,000 unique visitors to the site each month

Daily news updates and regular feature articles

Google-listed news source

E-BRIEF

Weekly round-up of key business and technical news

E-mail delivery to entire circulation

Banner and text marketing opportunities available

100G Lambda MSA releases preliminary specifications for 100GbE and 400GbE interfaces based on 100Gbps-per-wavelength technology

Consortium to complete full specifications by early 2018

The 100G Lambda Multi-Source Agreement (MSA) Group has announced the release of preliminary specifications based on 100Gbps-per-wavelength PAM4 (4-level pulse amplitude modulation) optical technology.

Under the MSA, member companies addressed the technical challenges to achieving optical interfaces using 100Gbps-per-wavelength PAM4 technology, enabling multi-vendor interoperability for optical transceivers produced by different manufacturers and in various form factors. The new optical interface specifications target the next generation of networking equipment required to address the industry's growing demand for increased bandwidth and bandwidth density.

The new interfaces defined by the 100G Lambda MSA increase the distances supported for 100GbE and 400GbE applications compared with the 100Gbps (100GBASE-DR) and 400Gbps (400GBASE-DR4) 500m-reach interfaces currently being defined by IEEE 802.3 Ethernet. The 100G Lambda MSA has developed optical specifications for 100GbE with reaches of 2km and 10km and for 400GbE with a reach of 2km over duplex single-mode fiber. By focusing on 100Gbps per wavelength, the 100G Lambda MSA says that it is enabling a technology ecosystem for next-generation networking equipment.

The new interfaces defined by the 100G Lambda MSA increase the distances supported for 100GbE and 400GbE applications compared with the 100Gbps and 400Gbps 500m-reach interfaces currently being defined by IEEE 802.3 Ethernet

The 100G Lambda MSA preliminary specifications are available for download at www.100GLambda.com. The MSA Group expects to complete the full specifications by early 2018.

The 100G Lambda MSA Group's Promoter members include: Alibaba, Applied OptoElectronics, Arista Networks, Broadcom, Ciena, Cisco, Finisar, Foxconn Interconnect Technology, Inphi, Intel, Juniper Networks, Lumentum, Luxtera, MACOM, MaxLinear, Microsoft, Molex, NeoPhotonics, Nokia, Oclaro, Semtech, Source Photonics, and Sumitomo Electric. Companies are invited to join the consortium as Contributor members.

www.100GLambda.com

CWDM8 MSA Group releases 400G 10km optical interface specification for data-center optical links

The CWDM8 MSA (8-wavelength Coarse Wavelength Division Multiplexing Multi-Source Agreement) Group has released a new technical specification for 400Gb/s optical links up to 10km over duplex single-mode fiber (SMF), available for download at www.cwdm8-msa.org.

The new specification represents the industry's first 400G 10km interface specifically targeted for implementation in next-generation optical module form factors such as QSFP-DD or OSFP for high-density data-center networking equipment. The new 10km-reach specification joins the 2km-reach 400G specification that the MSA Group released in November. These 400G CWDM8 optical interfaces were developed to support a wide range of high-bandwidth networking applications in data-center, campus, enterprise, and metropolitan area networks.

The CWDM8 MSA Group is now open to accepting new contributor member companies.

The CWDM8 MSA was formed to meet the bandwidth and expansion needs of modern data centers and to support deployment of 12.8T Ethernet switches and other advanced networking equipment with 50G SerDes. MSA participants are developing optical link specifications that will enable cost-effective, low-power-consumption 400G duplex single-mode optics using 50G per wavelength optical NRZ modulation, while maintaining full compatibility with standard 50G PAM4 electrical interfaces. These optical interfaces can be implemented in next-generation module form factors such as QSFP-DD, OSFP and COBO, and are believed to have significant time-to-market and performance advantages compared with other approaches. MSA participants expect to address industry needs by advancing unique technologies to create a diverse and competitive supply chain, while providing products that are optically compatible and interoperable.

Current members of the CWDM8 MSA are Accton, Applied Optoelectronics, Barefoot Networks, Credo Semiconductor, Hisense, Innovium, Intel, MACOM, Mellanox, Neophotonics, New H3C Technologies, and Rockley Photonics.

www.cwdm8-msa.org

POET appoints ex-Cisco veteran Don Listwin to board

POET Technologies Inc of Toronto, Canada and San Jose, CA, USA —a designer and manufacturer of opto-electronic devices, including light sources, passive waveguides and photonic integrated circuits (PIC) for the sensing and datacom markets — has appointed Don Listwin to its board of directors, including roles on both the Compensation and Audit committees. Concurrently, Todd DeBonis, who served as a director since April 2015, resigned from the board and has transitioned to a non-fee based strategic advisory role.

Listwin has over 30 years of technology investing and management experience, highlighted by a decade at Cisco Systems, where he served as executive vice president. During his tenure at Cisco, he built several multi-billion-dollar lines of business, including its Service Provider line of business that underpins much of today's global Internet infrastructure. More recently, Listwin served as CEO of both Sana Security and Openwave Systems.

"It is a pleasure to add a senior technology industry veteran of Don's caliber to POET's board as the company continues the development and commercialization of its next-generation photonic solutions," comments POET's executive chairman David Lazovsky. "Don's broad experience in networking and telecommunications is extremely relevant and applicable to both our technology and product roadmaps… I'm confident that his deep network of relationships will prove valuable as the company seeks to achieve increased commercial visibility and adoption of its technology," he adds.

"Integration is the clear path to delivering meaningfully differentiated solutions and economic value in next-generation data communications applications," believes Listwin. "POET's unique optical dielectric technology has the potential to revolutionize the photonics market," he adds.

"We greatly appreciate the valuable perspective and insight that Todd has provided to the company over the last few years, and I personally look forward to working with both Don and Todd in their respective roles going forward," comments CEO Dr Suresh Venkatesan.

In addition to Listwin founding and holding the role of CEO of the Canary Foundation (a non-profit research organization focused on the early detection of cancer), Listwin currently serves as a director on the boards of AwareX, Calix, D-wave, ischemaView, Robin Systems and Teradici. Previously, he has also served on the boards or been an advisor to companies including JDS Uniphase, PLUMgrid, Redback Networks, E-TEK Dynamics, the Cellular Telecommunications & Internet Association (CTIA) and the Business Development Bank of Canada (BDC).

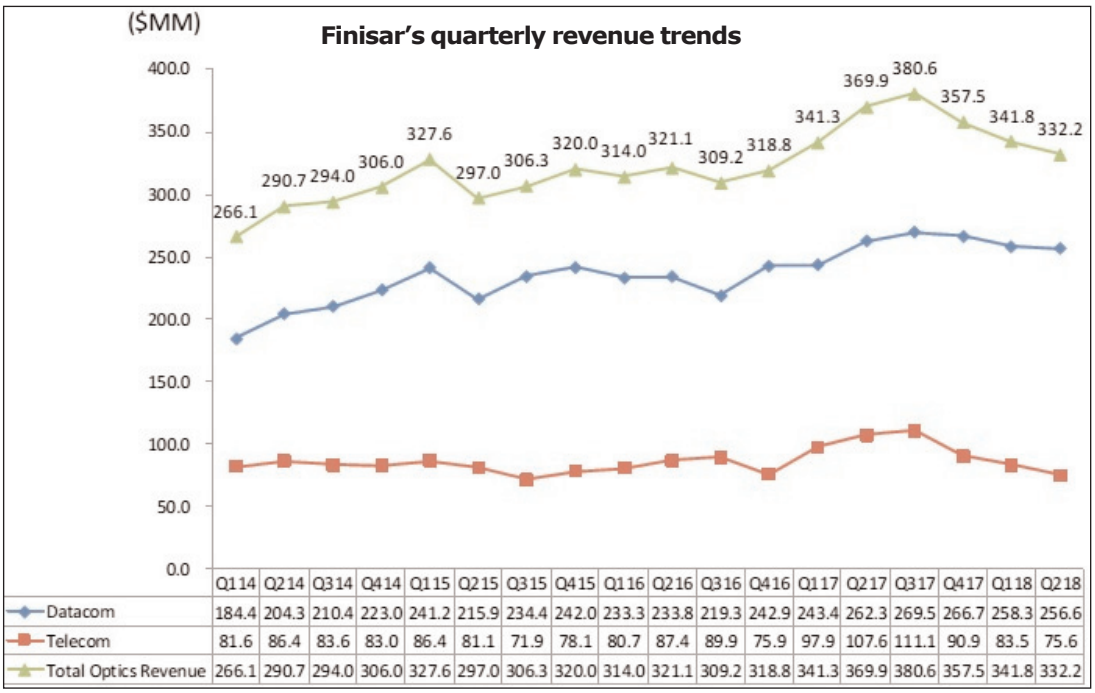
Listwin received a BSEE from the University of Saskatchewan, where he remains active with student engineering entrepreneurial programs. He is also a consulting professor in the School of Medicine at Stanford University.

The board has approved a grant of 468,750 stock options to Listwin, exercisable for 10 years at a price of CAD$0.22 (US$0.18) — the closing price of the shares on 18 January — and vesting quarterly in arrears over the next four quarters.

www.poet-technologies.com

Finisar sees lower quarterly telecom revenues from Chinese OEMs

New fab in Texas to expand VCSEL array capacity



	Q114	Q214	Q314	Q414	Q115	Q215	Q315	Q415	Q116	Q216	Q316	Q416	Q117	Q217	Q317	Q417	Q118	Q218
Datacom	184.4	204.3	210.4	223.0	241.2	215.9	234.4	242.0	233.3	233.8	219.3	242.9	243.4	262.3	269.5	266.7	258.3	256.6
Telecom	81.6	86.4	83.6	83.0	86.4	81.1	71.9	78.1	80.7	87.4	89.9	75.9	97.9	107.6	111.1	90.9	83.5	75.6
Total Optics Revenue	266.1	290.7	294.0	306.0	327.6	297.0	306.3	320.0	314.0	321.1	309.2	318.8	341.3	369.9	380.6	357.5	341.8	332.2

For fiscal second-quarter 2018 (ended 29 October 2017), fiber-optic communications component and subsystem maker Finisar Corp of Sunnyvale, CA, USA has reported revenue of $332.2m, down 2.8% on $341.8m last quarter and down 10.2% on $369.9m a year ago.

This is due mainly to Telecom product sales falling to $75.6m, down 9.5% on $83.5m last quarter (driven primarily by lower revenue from Chinese OEM customers) and down 29.7% on $107.6m a year ago.

Datacom product sales were $256.6m, down only slightly by 0.7% on $258.3m last quarter, due mainly to lower demand for 10G-and-below transceivers, 40G QSFP transceivers and 100G CFP Ethernet transceivers, partially offset by strong demand for 100G QSFP28 transceivers for data centers (about $100m) as well as new revenues from vertical-cavity surface-emitting laser (VCSEL) arrays for 3D sensing (which began shipping in production quantities).

Like last quarter, Finisar had two 10%-or-greater customers, but the top 10 customers represented 60.2% of revenue, down from 62.5%.

On a non-GAAP basis, gross margin has fallen further, from 37.2% a year ago and 34.9% last quarter to 30.3% (below the 33–34% guidance). As well as the lower revenue, this was due to an unfavorable product mix and under-absorption of fixed manufacturing costs at the firm's 4"-wafer VCSEL fab in Allen, TX (primarily a result of shipments of production quantities of VCSEL arrays starting only late in the quarter).

Operating expenses have risen further, from $69.4m a year ago and $73.2m last quarter to $74.6m (due mainly to the impact of the annual merit increase that took effect on 1 August), although this is below the expected $75–76m.

Operating margin has fallen from 18.5% a year ago and 13.5% last quarter to 7.8% (below the 10–11% guidance). Likewise, net income was $26.1m ($0.23 per fully diluted share, below the $0.27–0.33 guidance), down from $45.8m ($0.40 per fully diluted share) last quarter and $65.2m ($0.58 per fully diluted share) a year ago.

Capital expenditure (CapEx) has fallen back from $51.9m last quarter to $45.2m (below the targeted $50–55m), despite construction continuing on the third building of Finisar's manufacturing site in Wuxi, China (for which construction is on schedule for completion in calendar second-half 2018).

Cash, cash equivalents and short-term investments remained about $1.233bn.

For fiscal third-quarter 2018, Finisar expects revenue of $325–345m. Datacom product sales should grow, driven by 100G QSFP28 transceivers (for which the firm believes it is the world's largest supplier) as well as VCSEL arrays for 3D sensing. This will be partially offset by declines in both 100G CFP and CFP2 Ethernet transceivers as well as 40G-and-below transceivers. Telecom product revenue is expected to fall, due mainly to the impact of one month of the annual telecom price decreases (which typically take effect on 1 January). However, Finisar did achieve full qualification of its CFP2-ACO coherent transceiver at a key OEM customer and still expects to finish qualification of the ROADM line-card of that customer in late fiscal Q3 or early Q4/2018. "In addition, we believe we are well positioned in the China market for ROADMs, as we are the largest supplier there for wavelength-selective switches (WSS)," says chairman & CEO Jerry Rawls.

Finisar expects gross margin of 30-31%, as the benefit from the sales of additional VCSEL arrays is offset by the impact of the annual telecom price decreases.

Operating expenses should be relatively flat at about $75m. Operating margin is expected to be 7.5–8.5%. Earnings per diluted share should be $0.21–0.27 per share.

This is after CapEx of an estimated

$50m. However, this does not include the cost of acquiring (after the end of fiscal Q2/2018) a 700,000ft^2 semiconductor fab in Sherman, TX for $20m, as well as at least another $20m to upgrade it (starting during fiscal Q3). At least $100m more will be spent over the coming year equipping the fab for 6" wafer processing. This will expand Finisar's volume production of VCSEL arrays, starting in calendar second-half 2018. "We have people in the company that have processed 6" wafers at prior employment, but it will be a new experience for Finisar. So, it will be challenging," notes Rawls.

"While the near-term environment is a bit uncertain, we remain very optimistic about our long-term growth prospects," says Rawls. "We expect Finisar's VCSEL technology will be used in a variety of applications including several high-volume uses in consumer and automotive."

www.finisar.com

Apple allocates $390m to boost production of VCSELs

Funds to create 500 jobs at new fab in Sherman, Texas

In the latest award from its $1bn Advanced Manufacturing Fund, Apple is allocating $390m to fiber-optic communications component and subsystem maker Finisar Corp of Sunnyvale, CA, USA as part of its commitment to support innovation and job creation by American manufacturers.

The award will enable Finisar to increase its R&D spending and high-volume production of vertical-cavity surface-emitting lasers (VCSELs). VCSELs power some of Apple's new features, including Face ID facial recognition, Animoji and Portrait-mode selfies enabled by the iPhone X TrueDepth camera as well as the proximity-sensing capabilities of AirPods.

VCSEL technology is a better performing, more compact and cost-efficient solution compared with traditional edge-emitting lasers for many emerging applications. Apple has rapidly adopted depth-sensing technology in recent years, driving the development and production of more advanced VCSELs for consumer electronics. In fourth-quarter 2017, Apple will purchase 10 times more VCSEL wafers than were previously manufactured worldwide in previous quarters.

As a consequence of Apple's commitment, Finisar will transform a 700,000ft^2 manufacturing plant in Sherman, Texas (which has been shuttered since 2012) into a fabrication plant for VCSEL manufacturing. Apple's funding will create over 500 jobs at the Sherman facility, including engineers, technicians and maintenance teams. Combined with Finisar's nearby fab in Allen, Texas, Finisar's payroll in Northern Texas is expected to be $65m. Hiring, capital equipment planning and infrastructure upgrades are already underway at the Sherman facility, which is expected to begin shipping VCSELs in second-half 2018.

All of the VCSELs that Apple buys from Finisar will be made in Texas. Consistent with Apple's commitment to the environment, Finisar intends to procure enough renewable energy to cover all of its Apple manufacturing in the USA.

"VCSELs power some of the most sophisticated technology we've ever developed and we're thrilled to partner with Finisar over the next several years to push the boundaries of VCSEL technology and the applications they enable," says Apple's chief operating officer Jeff Williams. "Our involvement will help transform another American community into a manufacturing powerhouse," he adds.

"When you combine our proven ability to consistently manufacture exceptional products with our new state-of-the-art Sherman facility, we're confident we can achieve our shared goal of providing consumers with incredibly exciting features," says Finisar's Jerry S. Rawls.

Finisar co-founder Jerry Rawls retires

Finisar has announced the retirement of chairman & CEO Jerry Rawls and the appointment of Michael Hurlston as CEO and director, who will work together to ensure a smooth transition. Rawls will continue to serve as a director. Lead director Robert Stephens has been appointed chairman of the board.

"Michael has broad experience as a highly successful technology industry executive," comments Stephens. "I want to thank Jerry for his tireless and inspired leadership of Finisar over the past nearly 30 years. Finisar has grown from its founding in Quonset hut in Menlo Park, California to a world-leading optics company with cutting-edge products and approximately $1.4bn in revenues in its most recently completed fiscal year... He has positioned the company solidly for the great opportunities in our industry today," he adds.

Hurlston was most recently senior VP & general manager of the Mobile Connectivity Products/Wireless Communications and Connectivity Division at Broadcom Ltd. Previously, he held senior leadership positions in sales, marketing and general management. Prior to joining Broadcom in 2001, Hurlston held senior marketing and engineering positions at Oren Semiconductor Inc, Avasem, Integrated Circuit Systems, Micro Power Systems, Exar and IC Works. He is also a director of Ubiquiti Networks Inc and a member of the board of advisors of Vilynx Inc.

www.finisar.com

Emcore's quarterly revenue suppressed by vendor-managed-inventory deferral

R&D spending targets 30% non-CATV revenue and 15% operating margin by end fiscal 2018

For fiscal fourth-quarter 2017 (to 30 September), Emcore Corp of Alhambra, CA, USA — which provides indium phosphide (InP)-based optical chips, components, subsystems and systems for the broadband and specialty fiber-optics markets — has reported revenue of $29.2m (at the low end of the $29–31m guidance range). This is up 14% on $25.6m a year ago but down 5.7% on $30.9m last quarter, affected by discontinuation of the video product line and a slight downtick in chip revenue, while cable TV held steady and navigation revenue grew. However, late in fiscal Q4 Emcore shipped about $800,000 of products to a cable TV customer's vendor-managed inventory partner, for which revenue recognition was consequently recorded after the end of the quarter.

Of total revenue (compared with last quarter), satcom video and chips each fell from 7.5–12.5% to 5–10%, while navigation rose from 2.5% of total revenue to 2.5–7.5% and cable TV rose from 75–80% to 77.5–82.5%.

Full-year revenue has risen by 33.6%, from $92m for fiscal 2016 to $122.9m for fiscal 2017.

"2017 was a strong year for Emcore," says president & CEO Jeff Rittichier. "Compounded annual growth rate (CAGR) is nearly 31% over the last three years," he adds. "Once again in 2017, our core cable TV products were a significant growth driver, as all three leading MSOs [multi-service operators] deployed DOCSIS 3.1 architecture."

Revenue growth was driven by cable TV, which includes $17–19m of RF-over-glass (RFoG) products in full-year fiscal 2017. Cable TV in Q4 saw continued strong market demand for transmission products as cable operators continued the deployment of DOCSIS 3.1 transmitters, modules and receivers. Beyond the firm's traditional strength in laser modules and transmitters, its RF micro-node products (launched in late 2016) provided almost a $13m revenue boost year-over-year. However, during Q4, Emcore saw a slowdown in sales of these micro-nodes as portions of the market began to favor low-cost, low-performance modules from competitors.

Also, full-year growth was offset by year-over-year declines in satcom video and navigation. However, in the second half of fiscal 2017, Emcore saw chip and navigation product lines recover from the weakness seen in the first half of the year, when the chip product line saw a sharp decline in the 2.5G GPON market.

On a non-GAAP basis, full-year gross margin has risen from 34.1% for 2016 to 35.1% for 2017, driven by variances in cable TV revenue mix. Most recently, Q4 gross margin was 36.9%, up from 35.4% last quarter, aided by the new high-power DOCSIS 3.1-based cable TV transmitter introduced during the quarter.

While full-year sales, general & administrative (SG&A) expenses grew by only $0.3m (1.8%) year-on-year, R&D expenses rose by $2.5m (26%). "We continue to invest in R&D [especially during fiscal Q3–Q4] to accelerate delivery of new products across all three of our major product families," notes chief financial officer Jikun Kim. "In the [fourth] quarter, we invested aggressively in new navigation chips [working on multiple products with larger ASPs] and cable TV products," he adds.

Operating income was $3.3m (operating margin of 11.4% of revenue), up from $2.5m (9.8% margin) a year ago but down from $3.6m (11.5% margin) last quarter (and below the 12.5% margin guidance). However, results include final expenses of about $100,000 from Emcore's relocation of its Beijing manufacturing facility. Without this, as well as the $800,000 of revenue shifted from fiscal Q4 to Q1 by the cable TV customer's logistics partners, operating income would have been close to $3.7m (operating margin of 12.7%, slightly above the 12.5% guidance). Full-year operating income has risen from $5m in 2016 to $7.7m in 2017 (with operating margin more than doubling from 5.4% to 11.5%).

Q4 pre-tax income was $3.4m ($0.12 per diluted share), down slightly from $3.6m ($0.13 per diluted share) last quarter but up from $2.6m ($0.10 per diluted share) a year ago. Full-year pre-tax income has risen from $9.2m ($0.19 per diluted share) in 2016 to $14.3m ($0.52 per diluted share) in 2017.

Capital expenditure (CapEx) was $2.4m (falling back from $2.7m last quarter). Depreciation was $1.1m. Despite the increased CapEx, driven by the strong profits and effective management of working capital, cash and cash equivalents rose by $4.4m during the year and by $2.2m during the quarter to $68.3m.

"Operating performance and earnings growth delivered 182% year-over-year non-GAAP pre-tax net income and a 174% year-over-year non-GAAP EPS growth as we demonstrated the operating leverage that we have built into our business," says Rittichier. "We have grown while reducing headcount by over a third [by 38%, from a peak of nearly 430 in December 2016 to about 270] and reducing facilities expense and footprint all while keeping inventories roughly

constant… Emcore is a far more efficient operation than it was when we started rebuilding it nearly 3 years ago," he adds. Over the past 3 years, revenue has grown 121% from about $55m to $123m, with profits growing from a loss of $0.46 a share to a profit of $0.52 a share (a nearly $1 improvement in non-GAAP EPS). Emcore also generated cash despite massive capital reinvestment, all via organic growth and improved execution.

"We have not only brought our operational fixed costs down and created a much more flexible manufacturing operation, but we have also increased our leverage of Chinese engineering resources for future operational improvement and product development initiatives," says Rittichier. "We expect to add fully automated material management systems to our Beijing assembly test & tune process in fiscal Q1 and Q2/2018," he adds. Also in fiscal 2018, Emcore's facility in Alhambra, CA will have important automation upgrades in its fab along with the FOG/IMU (fiber-optic gyroscope/inertial measurement unit) assembly process. "We would expect that operations hiring will be very limited going forward, enabling us to take advantage of the operating leverage that we are creating."

"The company is now at an inflection point that it has been preparing to take advantage of for nearly three years," continues Rittichier. "Emcore is finally poised to become much more than a cable TV business. The operational and technical foundation that we have built in the chip and navigation market is ready to support rapid growth and we have got the team necessary to build those two businesses," he adds. "My most important set of objectives for this year revolve around building revenue diversity. We are going to do that by taking advantage of our cross-product synergies in broadband by accelerating the growth in our chip and navigation businesses… Emcore now has the foundation to increase our non-CATV revenue to 30% for the next year as well as improve non-GAAP operating margins to 15% as we exit fiscal year 2018."

For fiscal first-quarter 2018, Emcore expects revenue to fall to $24-26m, given the RFoG market dynamics combined with the vendor-managed inventory. The latter is "a relatively new phenomenon", says Jikun Kim. "We are anticipating a greater impact in our fiscal Q1/2018 financial results due to the extended holidays," he notes. "This will effectively result in shipment cutoff three weeks prior to actual fiscal quarter-end for this particular customer."

Emcore's third-generation L-EML (linear externally modulated laser) micro-nodes (launched at June's ANGACOM 2017 Exhibition & Congress for Broadband, Cable and Satellite in Cologne, Germany) will not complete qualification until early calendar 2018, enabling delivery only in fiscal Q3 and Q4/2018 (leading Emcore to remove RFoG revenue from its fiscal Q1 guidance). "This is the primary reason why projections for our first fiscal quarter are soft, as the rest of our cable TV and other product families are actually showing growth in the quarter," notes Rittichier. "Outside of RF micro-nodes, we have a number of exciting developments within the cable TV market, notably, the traction that we are seeing with our L-EML transmitter product line," he adds. In fiscal Q4, Emcore began shipping LEML head-in transmitters for RFoG applications and received design wins for additional L-EML transmitters that will start shipping as early as fiscal Q1.

"We expect to recover the RFoG revenue and grow the base cable TV business over fiscal 2018 through new L-EML transmitters that are just starting to ship and a streamlined RF micro-node distribution model," says Rittichier. "As our revenue diversity initiatives take hold, we will see greater than 30% of the company's revenue coming from non-cable TV products over the whole year, exiting at an even higher rate in Q4, setting the stage for larger absolute growth in fiscal 2019. We expect to do this while keeping our goal of 15% non-GAAP operating margin on a run-rate basis as we exit Q4," he adds.

Over the next 3-5-years, Emcore believes that it can grow its chip and navigation businesses to each be the same size as its current cable TV business, concludes Rittichier.

www.emcore.com

First Solar forecasts full-year 2018 sales of $2.3–2.5bn

Cash balance to fall due to higher capital expenditure for Series 6 CdTe PV module production ramp

During its 2017 Analyst Day at its Series 6 factory in Perrysburg, OH, First Solar Inc of Tempe, AZ, USA — which makes cadmium telluride (CdTe)-based thin-film photovoltaic modules as well as providing engineering, procurement & construction (EPC) services — said that, for full-year 2018, it is forecasting net sales of $2.3–2.5bn (down from 2017's expected $3–3.1bn), with solar power systems comprising 75-80% of the total and third-party module sales the remainder. Shipments should amount to capacity of 2.7–2.8GW (up slightly from 2017's expected 2.6–2.7GW).

First Solar expects gross margin of 22–23% (up from 2017's forecasted 17–18%) and operating expenses of $400–410m (up from 2017's forecasted $370–385m), including respectively about $60m of production ramp costs and $110m of production start-up expenses associated with the deployment of Series 6 module capacity in 2018.

Operating income should be $110–170m (down from 2017's expected $165–190m). Also including projected restructuring-related charges of about $10m, earnings per share (EPS) are hence forecasted to be $1.25–1.75 (down from 2017's expected $2.05–2.30).

After CapEx of $650–750m, the 2018 ending net cash balance is projected to be $1.6–1.8bn, with the expected decrease from end-2017 resulting from the higher projected capital expenditure in 2018 (up from 2017's expected $400–500m) to support the Series 6 production ramp

Operating cash flow is forecasted to be $100–200m (down from 2017's expected $850–950m). After capital expenditure of $650–750m, the 2018 ending net cash balance (cash and marketable securities minus expected debt) is projected to be $1.6–1.8bn, with the expected decrease from end-2017 resulting from the higher projected capital expenditure in 2018 (up from 2017's expected $400–500m) to support the Series 6 production ramp. As a result of ongoing improvements, CapEx for a brownfield Series 6 factory is now expected to be approximately $0.25 per watt.

www.firstsolar.com

First Solar to power first utility-scale project in Pakistan

First Solar is supplying over 860,000 cadmium telluride (CdTe) photovoltaic modules to power a 100MW$_{AC}$ utility-scale solar power plant developed by Zorlu Enerji in Pakistan. The Independent Power Producer (IPP) facility, part of the Quaid-e-Azam Solar Park in the country's Punjab province, is expected to be completed and connected to the electricity grid by first-half 2018.

When completed, the plant will increase Zorlu Enerji's installed capacity in the country to 156.4MW (a portfolio that includes a 56.4MW wind farm completed in 2013). The facility will generate an estimated 180 million kilowatt-hours of electricity per year (sufficient to power about 140,000 average homes) for Pakistan's Central Power Purchasing Agency, under a 25-year power purchase agreement (PPA).

"First Solar's advanced PV modules will thrive in Bahawalpur's desert conditions, delivering over 8% more energy than conventional crystalline-silicon panels, and enabling our successful bid for a PPA," believes Zorlu Enerji's CEO Sinan Ak. "We will set a new benchmark for solar energy in Pakistan. This project will be a new milestone for the development of utility-scale solar in the country," he adds.

"This project is part of a pivotal move by Pakistan to secure its energy independence by harnessing its solar resource," comments Stefan Degener, First Solar's head of business development for Europe and Africa.

In February, First Solar and Zorlu Holding signed a collaborative sales agreement under which Zorlu Solar became a major distributor of First Solar's modules in Turkey, Afghanistan, Albania, Bosnia, Bulgaria, Cyprus, Georgia, Kosovo, Macedonia, Pakistan, Romania, Serbia, Turkmenistan, the Ukraine, and the Commonwealth of Independent States. In addition to selling PV modules in these markets, Zorlu Solar is undertaking its own project development activity, powering its projects with First Solar technology.

"This deal demonstrates Zorlu Group's ability to enable our sales strategy by expanding First Solar's installed capacity well beyond our existing markets," says Degener. "It also proves that our high-performance technology and Zorlu Group's commercial expertise makes for a winning combination in any of the 26 markets covered by our agreement," he adds.

www.firstsolar.com

First Solar unveils first functional Series 6 CdTe PV module after Perrysburg factory retooling

Expansion of Vietnam production facility also announced

First Solar Inc of Tempe, AZ, USA has unveiled the first functional Series 6 thin-film photovoltaic module off its new production line in Perrysburg, OH.

Presented during a meeting with investment analysts at the Perrysburg facility, the large-area cadmium telluride glass-on-glass module was part of the first batch of material run completely through the recently activated line, marking a milestone in a factory retooling that began just under a year ago and included about $177m in capital investment.

In late November 2016, as a response to the highly competitive and dynamic PV market environment and customer demand for higher-efficiency modules, First Solar made a strategic decision to accelerate development and production of Series 6. The new product, still based on First Solar's thin-film CdTe PV technology, increases physical dimensions and performance characteristics while adding an undermount frame that allows simple, high-velocity installation of the product in the field. With superior temperature coefficient, spectral response and shading behavior, Series 6 modules can generate significantly more energy than conventional crystalline silicon modules, the firm says.

The new line is expected to begin producing commercial product in early second-quarter 2018, and will have annualized output of 600MW$_{dc}$ when operating at full capacity.

Series 6 is expected to enter the commercial market with a power rating of 420–445W and conversion efficiency of more than 17%. Measuring about 2m by 1.2m, the modules will provide more watts per lift than comparable crystalline silicon solar panels, and can be installed on virtually any ground-based PV mounting system, says First Solar.

"Last November, we were in full Series 4 production mode," says CEO Mark Widmar. "Since our decision at the end of 2016 to rapidly transition to Series 6, we've hit every incremental target with precision," he adds.

First Solar will continue to maintain some Series 4 production at its plant in Kulim, Malaysia, as long as economic global demand calls for the product.

Also during the analysts' meeting, First Solar said that it is expanding its production facility in Vietnam, doubling capacity of the initial site (which is still under construction). Annualized production capacity in Vietnam, when fully operational, will be 2.4GW$_{dc}$. In combination with Perrysburg and facilities in Kulim, this will give First Solar a total Series 6 manufacturing capacity of 5.4GW$_{dc}$ by 2020, and represents about $1.4bn in capital investment.

www.firstsolar.com

First Solar to supply 200MW of Series 6 modules to DESRI

First Solar has completed a module sale deal with an affiliate of D. E. Shaw Renewable Investments LLC (DESRI) totaling 200MW$_{dc}$ and with delivery dates in 2019.

First Solar will provide its new large-area Series 6 modules for DESRI's near-term pipeline of projects going into construction in the next two years in the USA. Also, First Solar signed operations & maintenance (O&M) contracts for two projects DESRI is developing.

"We are proud to build on our strong relationship with this trusted partner," says First Solar's chief commercial officer Georges Antoun. In addition, DESRI has acquired three solar projects from First Solar since 2016 — the 40MW$_{ac}$ Cuyama Solar Project in Santa Barbara County, CA, the 31MW$_{ac}$ Portal Ridge Solar Project in Los Angeles County, CA, and the 11MW$_{ac}$ Rancho Seco Solar Project in Sacramento County, CA.

www.deshaw.com

First Solar to supply 595MW of Series 4 and Series 6 CdTe PV modules to Origis over three years

First Solar and Origis Energy USA of Miami, FL, have completed a module sale deal totaling 595MW$_{dc}$, for delivery over three years.

The deal includes delivery of Series 4 modules in 2017 and 2018 as well as Series 6 modules in 2019 and 2020, for use in projects throughout the USA in which Origis Energy is constructing solar sites.

"The bankability of solar and energy storage components is a key consideration for us to deliver high-performing clean energy assets to our clients," says Origis' chief investment officer Samir Verstyn. "This alliance with First Solar fulfills the site and schedule commitments we have made to the market in the foreseeable future," he adds.

"First Solar is pleased to be selected by Origis Energy as a long-term partner," says First Solar's chief commercial officer Georges Antoun. "Our technology advantage will help enable the projects Origis has in construction and development to be reliable, high-performance assets."

www.origisenergy.com

CNBM begins production at China's largest CIGS solar module factory, using technology from Avancis

Three more gigawatt-scale CIGS solar factories in China planned

China National Building Materials Group Corp (CNBM) has celebrated the 'First Module Out' production launch of what is said to be China's largest copper indium gallium diselenide (CIGS) thin-film photovoltaic solar module factory.

The 55,000m^2 factory is starting up with an initial annual output of 300MW, with a planned annual output of 1.5GW through future expansion to 270,000m^2.

The technology was supplied by CIGS PV firm Avancis GmbH of Torgau, Germany, which has been a subsidiary of CNBM since 2014.

"China has ambitious solar energy programs. By the end of March 2017, the generated solar energy in the People's Republic of China increased to 21.4 million kilowatt hours. Nevertheless, solar energy accounts for only 1% of the Chinese energy mix," says Avancis' CEO Oliver Just. 'The demand for solar energy in the country is huge; especially the demand for premium-quality solar modules is enormous," he adds. "With the start of production, we will have the opportunity to manufacture and market our high-quality thin-film technology on site for the largest photovoltaic market."

The expansion of solar energy through gigawatt production facilities is being pursued in line with China's high sustainability goals. CNBM hence has plans for three more gigawatt-scale CIGS solar factories in China, with groundbreaking ceremonies having taken place over the last two years.

www.avancis.de/en
www.cnbm.com.cn/EN

CNBM acquires minority stake in Singulus

Singulus Technologies AG of Kahl am Main, Germany (which makes production equipment for the optical disc and solar sectors) says that Beijing-based China National Building Materials (CNBM), has acquired a minority interest of about 1.5 million shares (16.8%) of its existing 8.9 million issued shares from external shareholders.

Just last November Singulus signed a contract with the "subsidiary of a major listed energy company and solar module manufacturer in China" to supply several TENUIS II systems for wet-chemical coating processing in copper indium gallium diselenide (CIGS) solar module production.

The corresponding legally binding purchase agreements have been signed, and a transfer of ownership of the shares to CNBM will take place soon, after certain conditions have been fulfilled. For example, the acquisition of the shares remains to be approved by Chinese government agencies and the relevant competition authorities. It is expected that the approvals will be granted over the coming months.

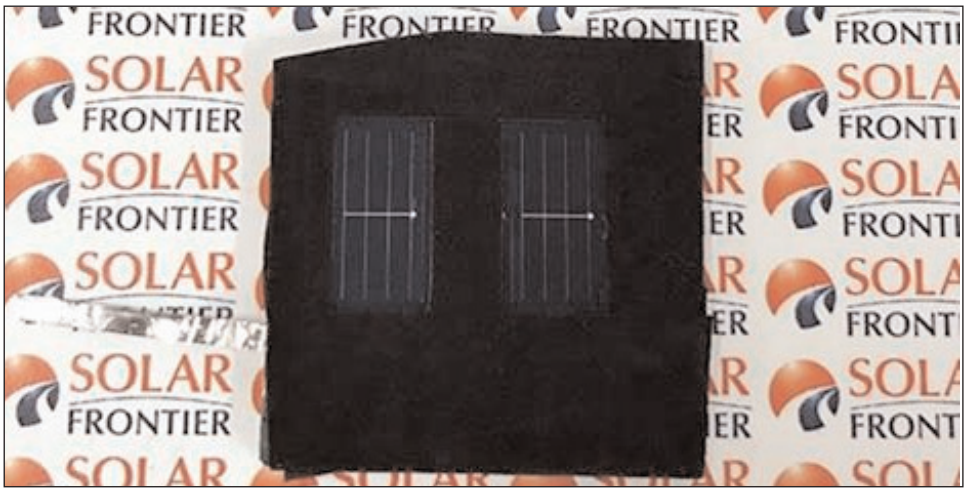
www.singulus.com

Solar Frontier raises thin-film solar cell efficiency record from 22.6% to 22.9%

Progress made via absorber engineering and enhanced surface treatment of the absorber layer

Tokyo-based Solar Frontier — the largest manufacturer of CIS (copper indium selenium) thin-film photovoltaic (PV) solar modules — says that, in joint research with the National Research and Development Agency's New Energy and Industrial Technology Development Organization (NEDO) in Japan on a 1cm^2 cell, it has set a new record for thin-film solar cell energy conversion efficiency of 22.9%, as verified independently by the National Institute of Advanced Industrial Science and Technology (AIST) in November.

The new record is a 0.3 percentage point increase over the existing record of 22.6% that was set in February 2016 by ZSW (Zentrum für Sonnenenergie- und Wasserstoff-Forschung — or Center for Solar Energy and Hydrogen Research — Baden-Württemberg) in Stuttgart, Germany.



Record-setting CIS thin-film solar cell (about 1cm^2) with 22.9% conversion efficiency.

The latest achievement was enabled through technologies such as CIS absorber engineering and enhanced surface treatment of the absorber layer, which Solar Frontier says demonstrates the steady progression made by thin-film photovoltaic technology.

The new record is a 0.3 percentage point increase over the existing record of 22.6% set by ZSW

www.solar-frontier.com

Solar Frontier Americas Development sells 66MW project to X-ELIO

San Francisco-based Solar Frontier Americas Development, a US subsidiary of Tokyo-based Solar Frontier — the largest manufacturer of CIS (copper indium selenium) thin-film photovoltaic (PV) solar modules — has completed the sale of its solar power project Midway I to X-ELIO, a global developer and operator of solar plants headquartered in Spain that became the solar development vehicle of multi-national investment firm KKR in 2015. The 66MW$_{DC}$ solar power plant is located in Imperial County, a few miles northwest of Calipatria, California.

The project has been financed by Santander Global Corporate Banking, a division of Santander Bank and Prudential Capital Group under a hybrid debt and fixed-rate notes structure that covers the entire contracted period. Tax equity is being provided by US Bancorp Community Development Corporation (a division of US Bank). Still under construction, the project will commence operations in the next few months and will supply renewable energy under two power purchase agreements (PPAs) during a total period of 23 years.

"Solar Frontier Americas has developed and sold six utility-scale projects totaling 173MW$_{DC}$ and we are continuing to grow our pipeline, which currently exceeds 550MW of solar projects," notes Solar Frontier Americas Development's CEO Charles Pimentel. "The addition of such a highly esteemed international investor to our customer base is proof that our development capabilities continue to expand and gain recognition. X-ELIO's world-class team worked collaboratively with us to complete this transaction," he adds.

"We have partnered with Solar Frontier's expert team since May, and worked hard in creating an extremely competitive capital structure," says X-ELIO's CEO Jorge Barredo. "We are now ready to deploy capital at any stage of the project lifecycle, from development to operation, and we rely on a growing team of highly experienced people to develop our pipeline, forge partnerships with other development companies, and become a major player also in the United States."

www.solar-frontier.com/eng
www.x-elio.com

Removing sapphire substrate from light-emitting diodes without cracking

Titanium/gold leveling layer provides support for fragile epitaxial film during thermal shock of laser lift-off.

Ferdinand-Braun-Institut and Technische Universität Berlin in Germany have developed a fabrication process for deep ultraviolet (DUV) light-emitting diodes (LEDs) that allows laser lift-off (LLO) separation of the sapphire growth substrate without chipping or cracking damage of the device [H K Cho et al, Semicond. Sci. Technol., vol32, p12LT01, 2017]. The LLO was performed at the chip level. The researchers developed a titanium/gold leveling layer that provided support for the fragile epitaxial film during the thermal shock of the LLO and subsequent processes.

The researchers see DUV LEDs as having potential for sterilization, water purification, medical diagnostics, phototherapy and UV curing. Removal of the sapphire substrate, and subsequent surface texturing, is seen as a route to increasing light extraction efficiency, boosting overall external quantum efficiency from the single-digit percentages presently achieved in the DUV region.

The process also allows the use of thin films of planar solder instead of gold stud bumps for mounting, which should improve thermal management in applications. "To the best of our knowledge, LLO of the sapphire substrate from DUV LEDs flip-chip mounted via solder has not yet been reported," the team writes.

Metal-organic chemical vapor deposition (MOCVD) on (0001) sapphire resulted in a DUV LED structure (Figure 1) with a 900nm AlN buffer, a 200nm 80x(AlN/GaN) short-period superlattice (SPSL) with 0.65 Al mole fraction average, 600nm of $Al_{0.5}Ga_{0.5}N$, a 4.2μm silicon-doped n-$Al_{0.5}Ga_{0.5}N$ contact,

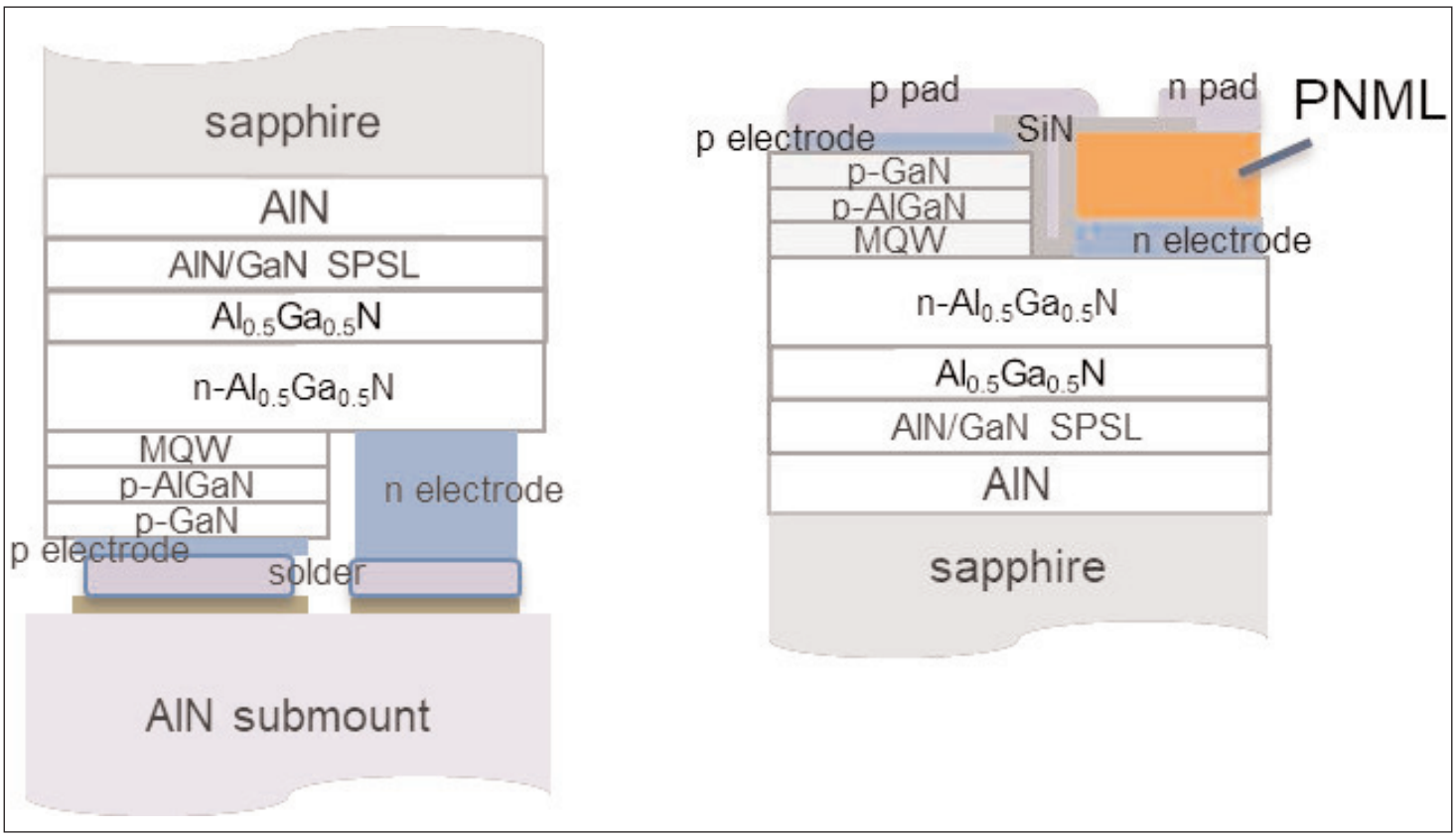


Figure 1. Schematic of AlGaN-based heterostructure and DUV LED chip on AlN submount (left) and chip structure with PNML (right).

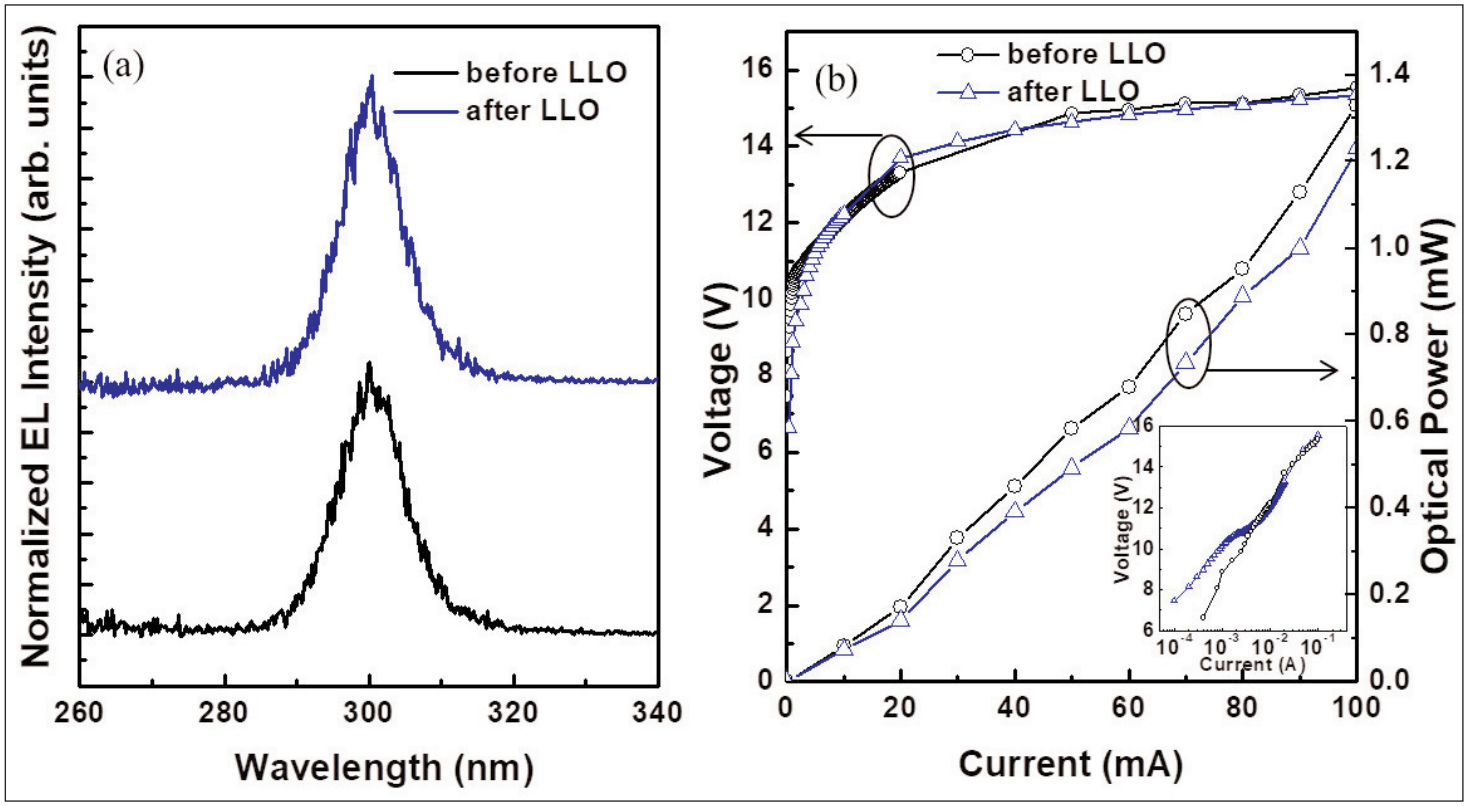


Figure 2. Performance of flip-chip-mounted DUV LEDs before and after LLO: Normalized emission spectra at a current of 20mA (a) and light output-current-voltage (L–I–V) characteristics (b).

a 3x(AlGaN/AlGaN) multiple quantum well (MQW) active region, a p-AlGaN electron-blocking layer, a p-AlGaN/AlGaN superlattice, and a p-GaN contact.

Fabrication began with exposure of the n-contact layer with reactive ion etch (RIE) and formation of an ohmic vanadium/aluminium/nickel/gold contact with electron-beam evaporation and 725ºC annealing. The p-contact was palladium annealed at 530ºC. Silicon nitride passivation was applied by plasma-enhanced chemical vapor deposition (PECVD). The chips were completed with soldering pads and dicing into 1mmx0.6mm dies. The active area was 0.07mm^2. The chips were bonded to AlN submounts with gold-tin solder.

Before mounting, some of the chips had an added p and n metal leveling layer (PNML) deposited on the n-electrode, consisting of 30nm of titanium and 70nm of gold. The researchers believe that the PNML in particular fills the region between the p- and n-electrodes, giving a flat surface topography.

A 248nm-wavelength krypton-fluoride excimer laser was used to remove the sapphire substrate. The beam spot was larger than the chip, at 2mmx2mm. "The sapphire substrate lifted off spontaneously by itself after LLO without the need of activation by subsequent steps," the team reports. Residue from the process was removed with hydrochloric acid solution.

Without the p and n metal leveling layer, cracking was observed to be generated by the thermal shock of the LLO and propagated by the hydrochloric acid clean

Without the PNML, the LLO process tended to result in chipping and cracking, mostly in the region between the p- and n-electrodes. The researchers explain: "This area can be easily damaged by the physical shock during LLO because it is free-standing without bonding to the submount. The thin metal layer of the n-electrode and the SiNx passivation layer on top are not sufficient to stabilize the epi layer in this area. The PNML fills the region between the p-pad and the n-pad, where it is thought to stabilize the fragile epitaxial structure."

With the PNML, the team reports, "the device had no mechanical damage after LLO, i.e. the sapphire substrate was successfully removed without crack formation in the epitaxial layers or material chipping."

Scanning electron microscope analysis of the LED surfaces showed that the LLO caused separation in the undoped $Al_{0.5}Ga_{0.5}N$ layer, so that the AlN buffer and AlN/GaN SPSL layers were also removed with the sapphire.

Without the PNML, cracking was observed to be generated by the thermal shock of the LLO and propagated by the hydrochloric acid clean.

The performance of the LEDs with PNML was not substantially affected by the LLO process (Figure 2), although there was a slight increase in leakage at low voltages. ■

https://doi.org/10.1088/1361-6641/aa9402

Author: Mike Cooke

Ex-situ AlN-on-Si templates

Pulsed laser deposition used to create substrates for 0.5mmx0.5mm devices with 70.2mW light output power at 300mA current injection.

South China University of Technology has been studying the use of ex-situ low-temperature pulsed laser deposition (LT-PLD) to create aluminium nitride on silicon (AlN/Si) templates for indium gallium nitride (InGaN) light-emitting diodes (LEDs) [Haiyan Wang et al, IEEE Transactions on Electron Devices, vol64, p4540, 2017]. The researchers began their work with ultra-high-vacuum PLD of aluminium nitride on cleaned silicon (111) substrates at 650°C. The template growth was carried out in nitrogen plasma generated by radio-frequency excitation. The aluminium came from sintered AlN, which was ablated by 200mJ krypton fluoride excimer laser pulses repeated at 30Hz.

The hope is that such work will reduce manufacturing costs by using much less expensive substrates, compared with gallium nitride, silicon carbide, or sapphire. The team produced 0.5mmx0.5mm LEDs with light output power of 70.2mW at 300mA current injection.

The LED material was grown on the low-temperature AlN/Si templates by metal-organic chemical vapor deposition (Figure 1). The structure includes a number of layers to bridge the mismatches between GaN and Si in terms of lattice parameters (16.9%) and thermal expansion (54%) that can reduce crystal quality and induce cracking of the material on cooling. The templates had a varying thickness of low-temperature AlN, ranging from 10nm to 130nm. The materials were fabricated into standard lateral 500μmx500μm LEDs.

Contact	p-GaN	150nm
Electron blocking	p-$Al_{0.15}Ga_{0.85}N$	20nm
MQW	5x($In_{0.13}Ga_{0.87}N$/nGaN)	5x(3nm/15nm)
Superlattice	12x(n-$In_{0.13}Ga_{0.87}N$/n-GaN)	12x(2nm/4nm)
Contact	n-GaN	1500nm
Undoped layer	GaN	500nm
Interlayer	Ultrathin SiN	
Nucleation	GaN	200nm
Buffer	$Al_{0.25}Ga_{0.75}N$	200nm
Buffer	$Al_{0.45}Ga_{0.55}N$	200nm
Buffer	$Al_{0.7}Ga_{0.3}N$	150nm
Buffer	AlN	100nm
Low-temperature PLD template	AlN	10nm-130nm
Substrate	Si	

Figure 1. LED epitaxial structure.

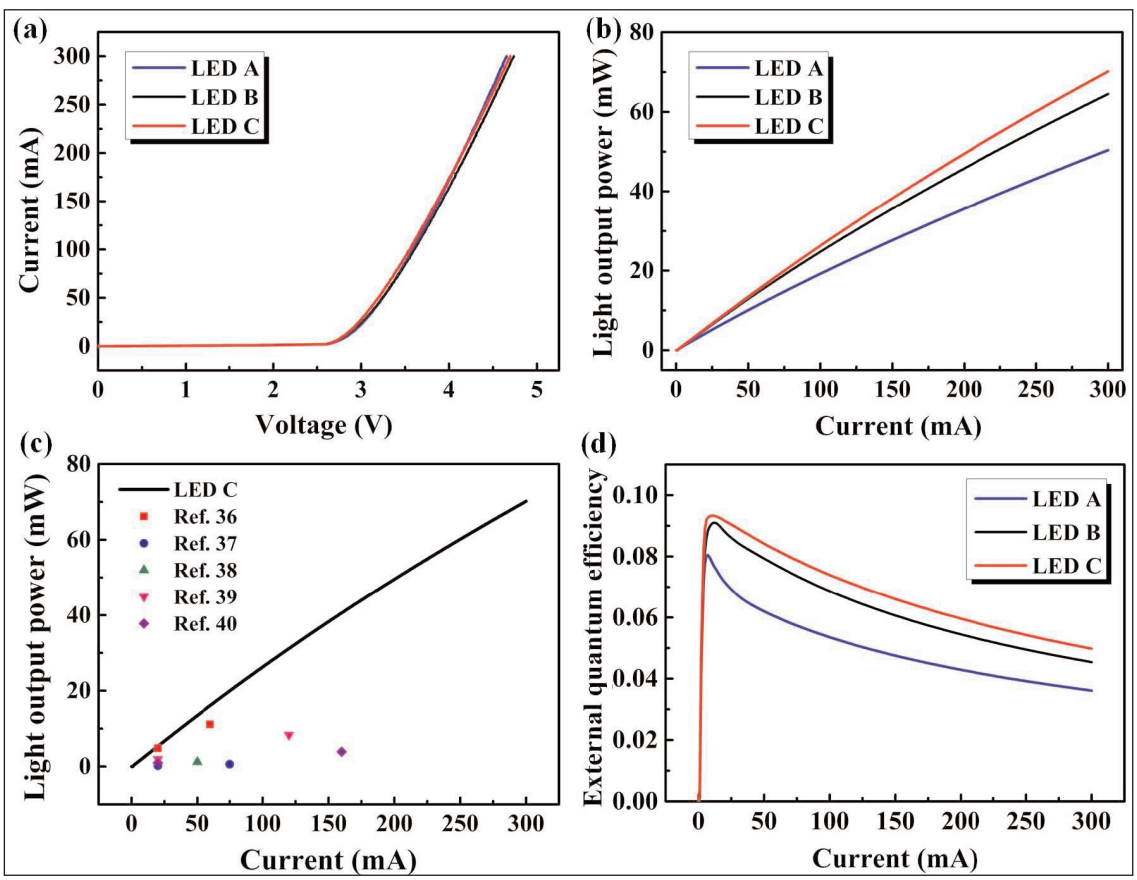


Figure 2. (a) Current versus voltage, (b) light output power versus current for LEDs A, B and C, (c) comparison of light output power of LED C with previously reported values, and (d) EQE versus current for LEDs A, B and C.

X-ray analysis suggested that a 40nm AlN/Si template gives the best crystal quality in subsequent metal-organic chemical vapor deposition (MOCVD). The team explained the quality trend as being due to the smoother surface morphology of the 40nm sample, which also has a large number of small AlN grains that can act as nucleation sites for subsequent lateral growth. By contrast, thicker AlN templates have large islands of AlN that coalesce and present a rough surface, potentially reducing surface mobility of precursors and retarding AlN buffer coalescence. Also, the 40nm (and 70nm) AlN/Si template resulted in crack-free material. Larger AlN thickness templates tended to result in cracked heterostructures.

In terms of light output power, LEDs based on 70nm AlN/Si templates (LED-C) gave the highest value of 70.2mW at 300mA injection current (Figure 2). This compares with 50.4mW for LED-A on a 10nm AlN/Si template. The power from LED-C was also 9% greater than that from LED-B on 40nm AlN/Si. Power output was also greater than previous reports, corrected for device size, as shown in Figure 2(c). The peak external quantum efficiency (EQE) of LED-C was 9.3%. At 300mA, the EQE fell to around 5%. The efficiency droops between the peak and 300mA for LEDs A–C were 55.1%, 50.1% and 46.2%, respectively.

Since the light was strongly absorbed by the underlying silicon, higher output would result from substrate removal and the use of thin-film flip-chip LED chip manufacturing processes. Simulations of the structures suggested that LED-C benefited from higher and more uniform carrier concentrations across the quantum wells, boosting output power (Figure 3). ■

https://doi.org/10.1109/TED.2017.2753844

Author: Mike Cooke

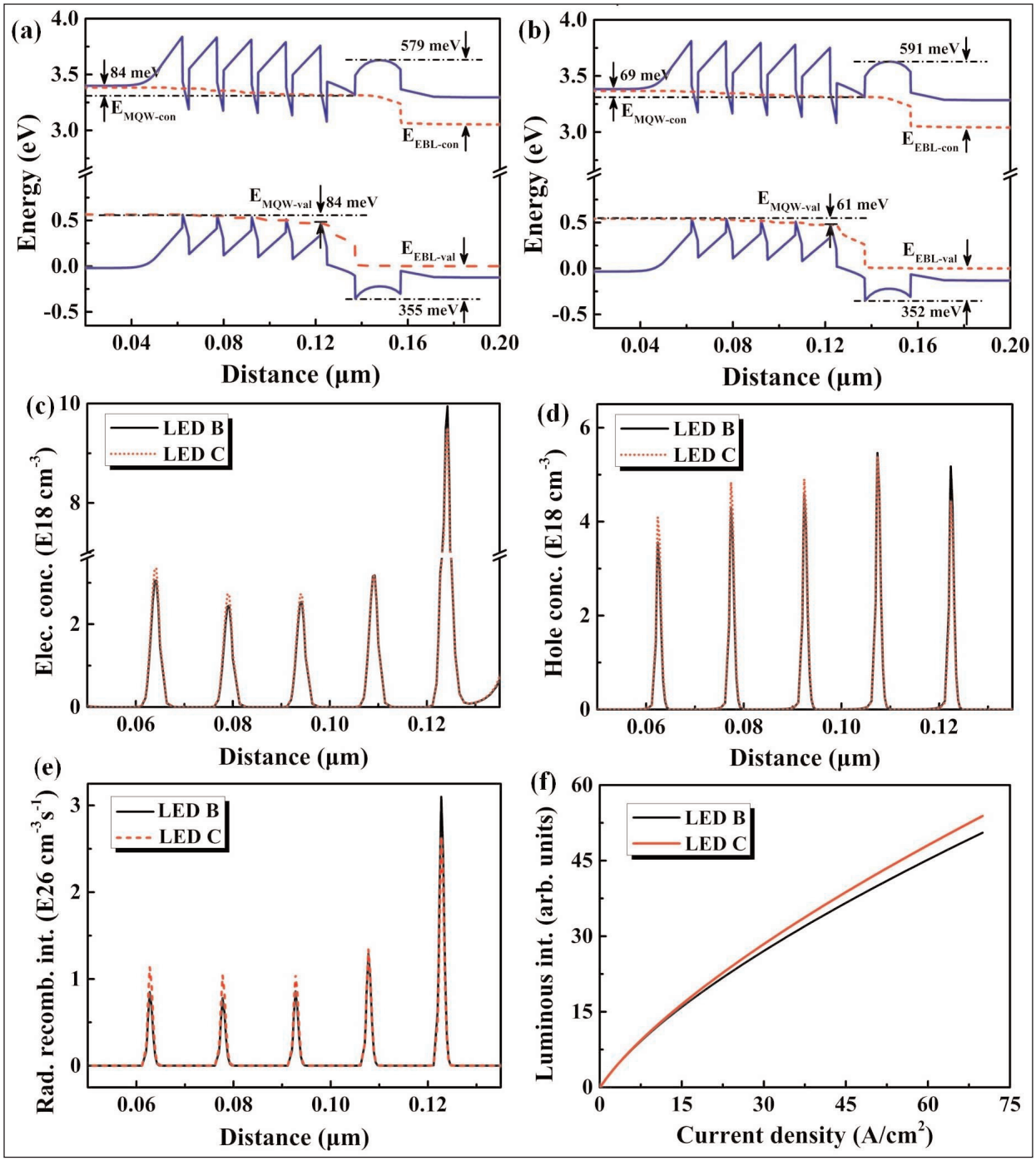


Figure 3. Band diagrams of (a) LED B and (b) LED C at a current density of 35A/cm^2. The blue solid line and red dashed line represent the energy band and Fermi energy, respectively. (c) Electron concentration, (d) hole concentration, (e) radiative recombination intensity, and (f) simulated luminous intensity of LEDs B and C, respectively.

Monolithic indium arsenide quantum dots on silicon optoelectronics

Researchers develop photodetectors with low dark current and comparable performance to germanium devices.

Researchers based in USA, Taiwan and China have monolithically integrated photodetectors (PDs) and lasers using indium arsenide (InAs) quantum dot (QD) in indium gallium arsenide/aluminium gallium arsenide (InGaAs/AlGaAs) well/barrier active structures on silicon [Yating Wan et al, Optics Express, vol25, p27715, 2017]. The devices operated in the 1260-1360nm O-band of wavelengths.

The researchers hope that their work will help to combine the economies of scale of silicon with the high optoelectronic efficiency of III-V materials for photonic integrated circuits . In particular, the InAs QD photodetector showed much reduced dark current compared with germanium-based photodetectors on silicon.

The team from University of California Santa Barbara (UCSB), Taiwan's National Central University, Hong Kong University of Science and Technology (HKUST) and Hewlett Packard Labs in the USA report, "to the best of our knowledge, the first characterization of high-speed performance and the first demonstration of the on-chip photodetection for this QD-on-silicon system."

The researchers see the monolithic integration of photodetectors and lasers on silicon as a means to create power monitors or amplifiers for pre-amplified receivers.

The GaAs-on-silicon template was prepared using metal-organic chemical vapor deposition (MOCVD). The silicon substrate was V-grooved to allow aspect ratio trapping of dislocations. Further cyclic annealing and strain-balancing layers further reduced the dislocation density to $7x10^7/cm^2$.

The template was used in molecular beam epitaxy (MBE) to create photodiodes with an active region consisting of seven stacks of InAs dots-in-wells (DWELLs), sandwiched between 1.4μm layers of n- and p-AlGaAs. The epitaxial structure also included 500nm n-GaAs bottom contact layers, and a 300nm GaAs cap. Plan-view transmission electron microscopy of one layer of QDs gave an estimate of $6x10^{10}$ dots/cm^2.

Device fabrication (Figure 1) consisted of inductively coupled etching of 20μmx50μm mesas; deposition of palladium/titanium/palladium/gold and palladium/germanium/gold p- and n-contacts, respectively; atomic layer deposition (ALD) of aluminium oxide and sputtering of silicon dioxide passivation; via the opening and deposition of 1.5μm titanium/gold

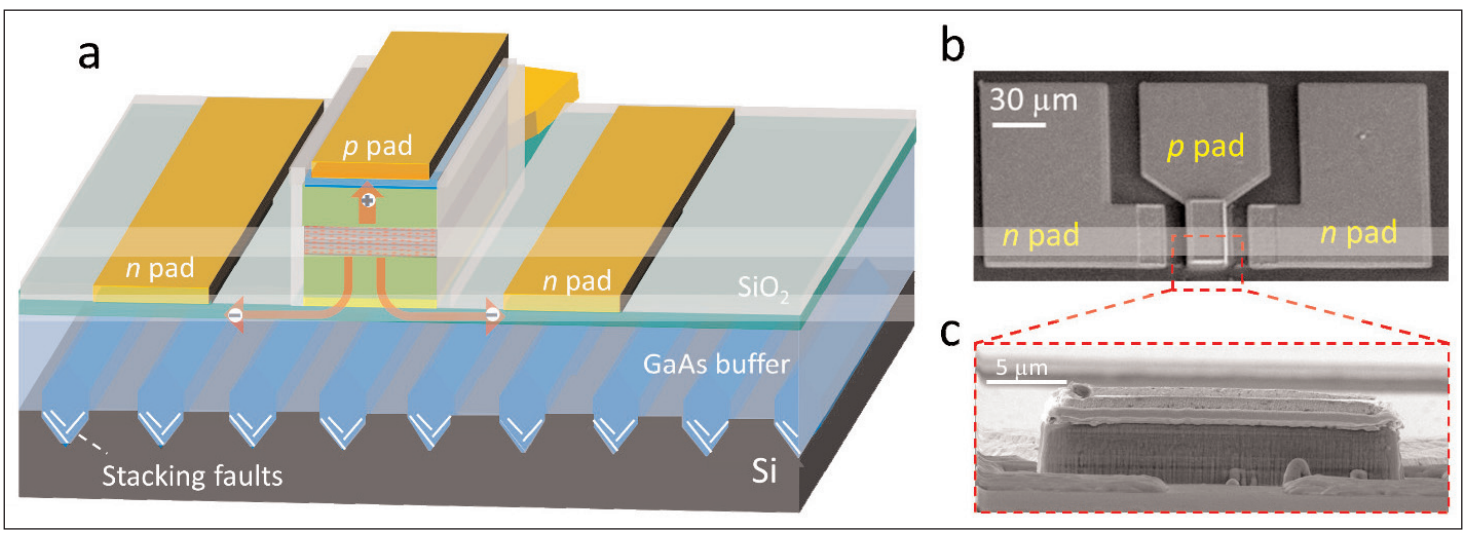


Figure 1. (a) Schematic of fabricated photodetector on V-grooved substrate; (b) top-view and (c) cross-sectional view scanning electron microscope images.

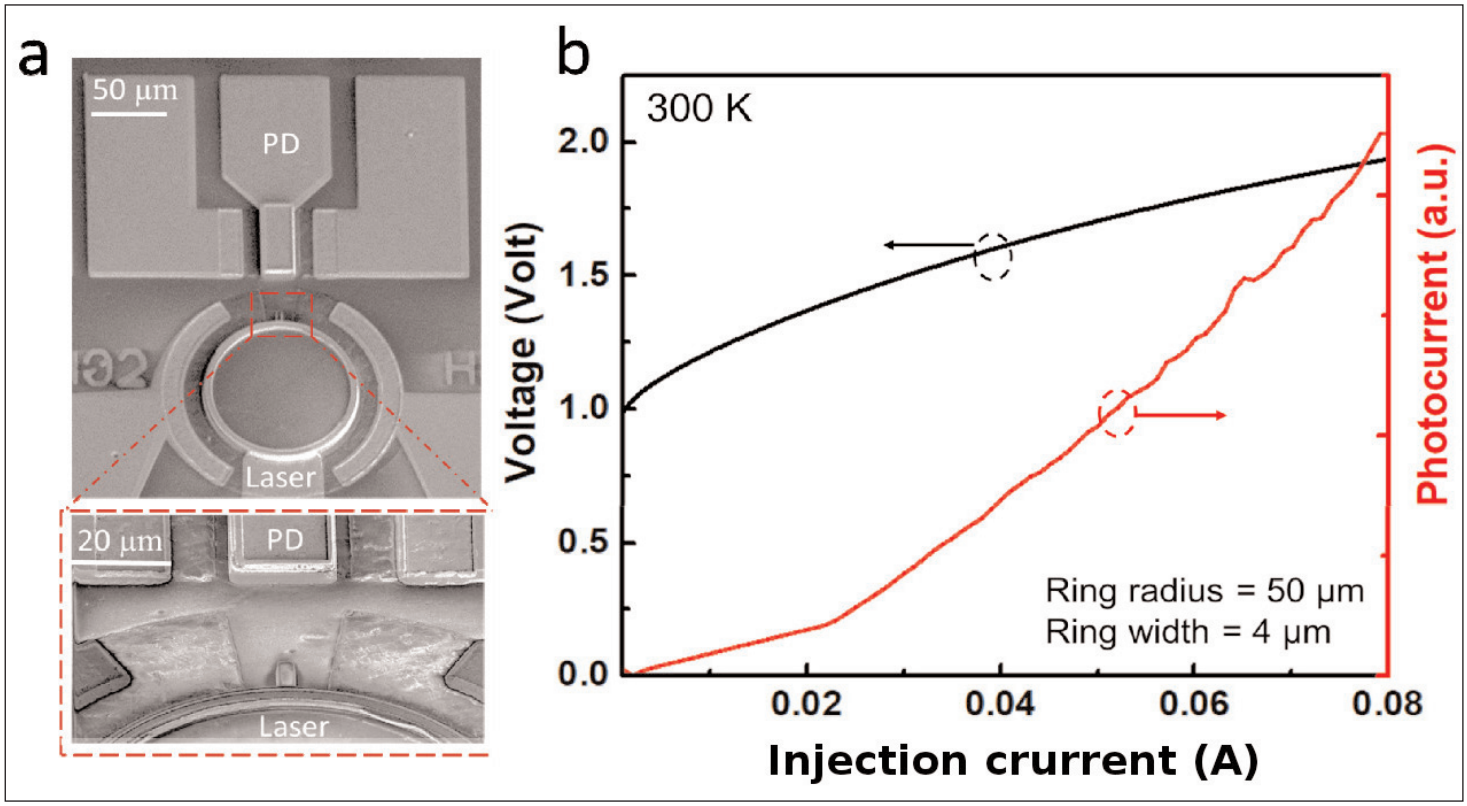


Figure 2. (a) Top-view of fabricated free-space coupled laser-photodetector system; (b) measured laser voltage and detector photocurrent as a function of injection current.

ground–signal–ground measurement pads; and, dicing and polishing of photodiode facets without an anti-reflective coating.

The dark current ranged from 0.8nA to 18nA under reverse biases of –1V and –5V, respectively. Given the 10^{-5}cm^2 device area, 1nA corresponds to a current density of 0.1mA/cm^2. The researchers point out that 0.08mA/cm^2 dark-current density is "two orders of magnitude lower than the competing Ge-on-Si PDs with thin Ge or SiGe buffer layers (typically in the order of 10mA/cm^2)." They attribute the improvement to high crystalline quality, low dislocation density, shorter diffusion lengths, and good sidewall passivation.

Coupling a 1.3μm laser source into a photodetector facet with a lensed fiber gave a responsivity of more the 0.3A/W over the 1240–1340nm spectral range. At 1250nm wavelength, the responsivity was 0.33A/W with bias conditions ranging from –1V to –6V. The researchers estimate the facet reflection at around 30% and the coupling loss at 3dB, corresponding to a corrected photodetector responsivity of 0.94A/W. High-quality Ge-on-SOI waveguide photodetectors have been reported with ~1A/W responsivity. "The extracted internal responsivity (0.9A/W) corresponds to 90% internal efficiency," the team adds.

The researchers hope that their work will help to combine the economies of scale of silicon with the high optoelectronic efficiency of III-V materials for photonic integrated circuits .

The team reports "the first characterization of high-speed performance and the first demonstration of the on-chip photodetection for this QD-on-silicon system."

The frequency performance was measured and model parameters extracted that suggest a (resistance)x(capacitance)-limited 3dB bandwidth of ~2.9GHz. The measured 3dB device bandwidth was slightly lower at 2.3GHz. The researchers attribute the lower value to carrier trapping effects of the QDs.

The researchers also integrated the photodetector with a neighboring micro-ring laser (Figure 2). UCSB has been developing lasers on a similar InAs QD platform (www.semiconductor-today.com/news_items/2017/oct/ucsb_131017.shtml). The ring had a 1μmx9μm waveguide to scatter light through free space to the neighboring photodetector. The ring measured 50μm outer radius with 4μm mesa width. The laser threshold was around 21mA, according to the photodetector measurement. A more integrated arrangement (with the laser and photodetector connected by a waveguide) is presently being developed. ■

https://doi.org/10.1364/OE.25.027715

Author: Mike Cooke

Reducing bow of InGaP on silicon wafers

Researchers use strain engineering without impacting dislocation density.

Researchers based in Singapore and the USA have been working to control the wafer bow of indium gallium phosphide (InGaP) epitaxial layers on 200mm silicon (Si) wafers [Bing Wang et al, Semicond. Sci. Technol., vol32, p125013, 2017].

Wafer bow is caused by stress arising mainly from mismatches of coefficients of thermal expansion between InGaP, or other III-V compound semiconductors, and silicon. The bow (more than 200μm in one recent report of gallium arsenide on 300mm silicon wafer) is introduced when the material cools after high-temperature epitaxial deposition. Bowing adversely affects wafer-scale processing, particularly for large-diameter substrates. Wafer-scale equipment typically restricts the permitted bow to less than 50μm.

The team from the Singapore–MIT Alliance for Research and Technology, Nanyang Technological University in Singapore, and Massachusetts Institute of Technology in the USA used strain engineering to reduce bow in InGaP templates grown on high-quality germanium (Ge) buffers on silicon.

The 200mm (8") silicon substrate was offcut 6º toward the nearest {111} plane. Epitaxy was by metal-organic chemical vapor deposition (MOCVD). The germanium on silicon template layer was prepared separately in a two-step low/high-temperature process, using germane (GeH_4) precursor. Plan-view transmission electron microscopy (PV-TEM) and etch pit density (EPD) analysis gave an estimate of dislocation density of the order $3x10^7/cm^2$.

"Based on these observations, we can conclude that the threading dislocation densities of the InGaP wafers are not affected by the lattice mismatch. Our Ge buffers have similar threading dislocation density of $3x10^7/cm^2$. The hetero-epitaxy of GaAs buffers and InGaP films did not increase the threading dislocation density, which indicates very good epitaxy quality." The team believes that the technique can be applied to other III-V systems on silicon

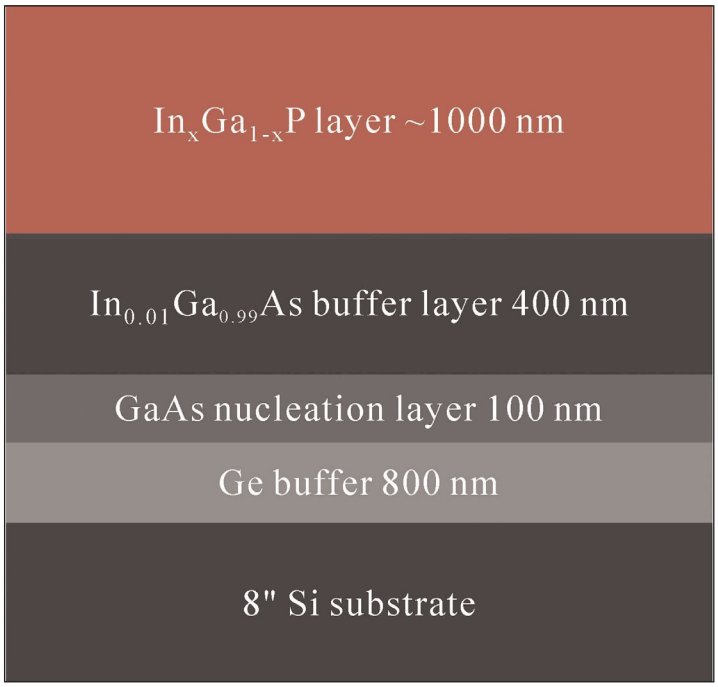


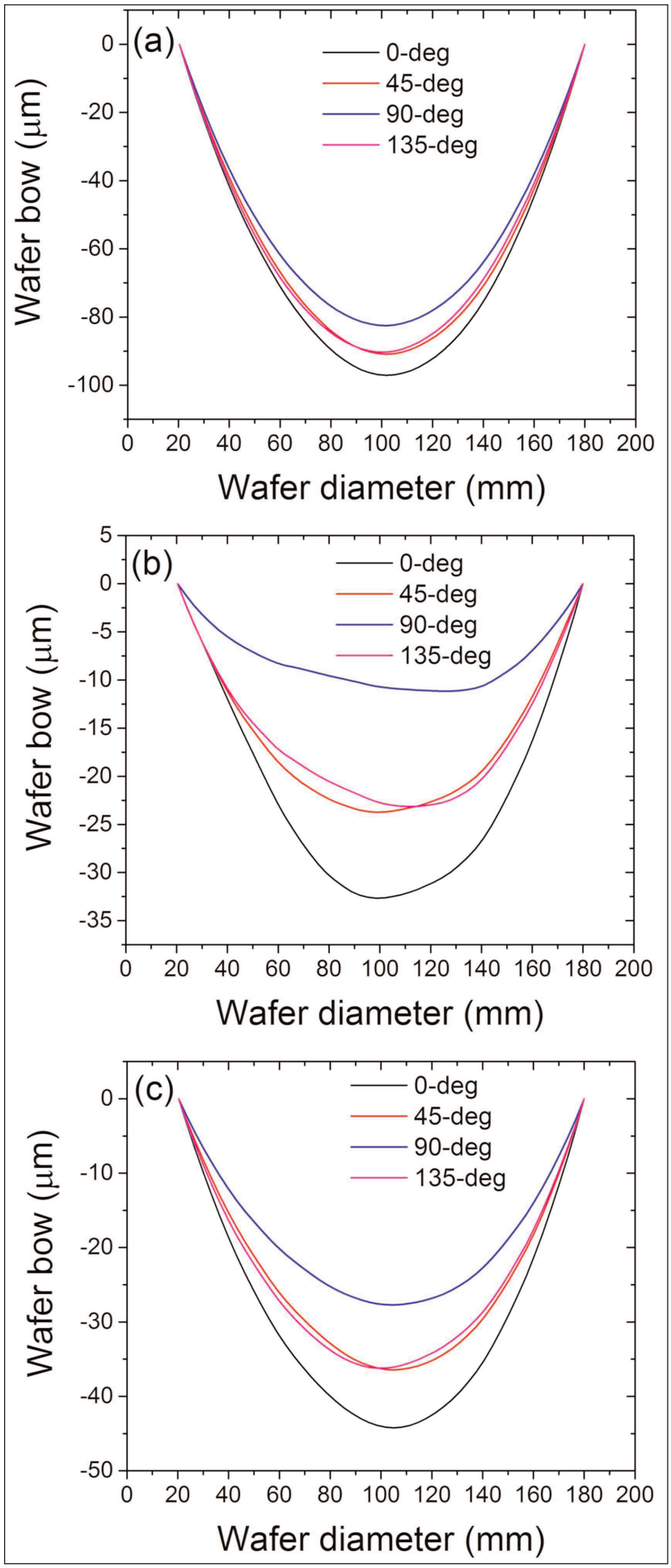
Figure 1. Epitaxial layer structure of three InGaP/Si wafers.

The MOCVD reactor was thoroughly cleaned to remove Ge residues before III-V epitaxy (Figure 1), avoiding uncontrollable n-type doping. The group-III metal-organic precursors were trimethyl-gallium and

Table 1. Summary of InGaP sample compositions, wafer bow, strain, relaxation, and threading dislocation densities (EPD and PV-TEM).

Sample $In_xGa_{1-x}P$	Wafer bow	Strain	Relaxation	EPD ($x10^7/cm^2$)	PVTEM ($x10^7/cm^2$)
x = 0.49	–82.5μm (110)	0.251%	–37%	1.5	3.1
	–97μm (1–10)	0.222%	29%		
x = 0.54	–11μm (110)	–0.054%	17.5%	1.6	2.8
	–32.7μm (1–10)	–0.041%	25.5%		
x = 0.52	–27.7μm (110)	0.012%	–0.9%	1.7	1.9
	–44.2μm (1–10)	–0.003%	1.5%		

Figure 2. Wafer bow of InGaP wafers: x = 0.49 (a), x = 0.54 (b), and x = 0.52 (c). Wafer notch orientation (1–10) is 0º, and (110) direction is 90º.



trimethyl-indium. The group-V arsenic (As) and phosphorus (P) components were delivered by arsine (AsH_3) and phosphine (PH_3), respectively. Hydrogen was the carrier gas.

The 1%-indium-content InGaAs formed the main part of the buffer since its lattice mismatch with Ge was smaller than that of pure GaAs. Three InGaP compositions were produced: lattice-matched with 49% indium content, along with non-matched 52% and 54% samples. The MOCVD temperature was 630ºC, with less than 10ºC variation across the wafer.

Atomic force microscopy showed increasing roughness as the InGaP became more mismatched — 1.68nm root-mean-square for $In_{0.49}Ga_{0.51}P$, 2.08nm for $In_{0.52}Ga_{0.48}P$ and 2.34nm for $In_{0.54}Ga_{0.46}P$. The roughness of the GaAs buffer was 0.8nm. The wafers exhibited anisotropic concave bows of up to 97μm (Figure 2). The bow was greatest for the $In_{0.49}Ga_{0.51}P$, decreasing with increase in indium content.

X-ray reciprocal space map analysis was used to assess strain in the resulting wafers (Table 1). The lattice-matched $In_{0.49}Ga_{0.51}P$ wafer was observed to have a tensile strain and the $In_{0.49}Ga_{0.51}P$ sample was under compression. The middle $In_{0.52}Ga_{0.48}P$ material was slightly tensile strained (0.01%) along the (110) direction and compressed (–0.003%) along the $(1\bar{1}0)$ direction.

The researchers point out that dislocation mobility is anisotropic, commenting "anisotropic strain and relaxation correlate with the anisotropic wafer bow very clearly." They add: "compensation of the thermal stress by the lattice-mismatch strain decreases the wafer bow."

The threading dislocation density (TDD) of the InGaP layers was about the same at $1.6x10^7/cm^2$, according to EPD analysis. PV-TEM gave an estimate of $3.1x10^7/cm^2$ for the $In_{0.49}Ga_{0.51}P$ wafer.

The researchers comment: "Based on these observations, we can conclude that the TDDs of the InGaP wafers are not affected by the lattice mismatch. Our Ge buffers have similar TDD of $3x10^7/cm^2$. The hetero-epitaxy of GaAs buffers and InGaP films did not increase the TDD, which indicates very good epitaxy quality." The team believes that the technique can be applied to other III-V systems on silicon. ■

https://doi.org/10.1088/1361-6641/aa952e

Author: Mike Cooke

Gallium nitride transistor on silicon with 250GHz cut-off frequency

Lower costs could benefit the next generation of communication systems for 5G telecoms, vehicles and Internet of Things.

Researchers based in Singapore and the USA claim the highest cut-off frequency so far for gallium nitride (GaN) high-electron-mobility transistors (HEMTs) produced on silicon (Si) substrates [Weichuan Xing et al, IEEE Electron Device Letters, published online 13 November 2017]. The devices with indium aluminium nitride (InAlN) barrier layer and gate length of 40nm achieved a cut-off of 250GHz.

The performance compares well with GaN HEMTs produced on silicon carbide (SiC) substrates, which have smaller diameter and are much more expensive. silicon-based production methods could open up many commercial opportunities. The III-nitride material system with its wide bandgaps enables higher breakdown fields and high electron saturation velocity with potential applications for high-frequency and high-power performance. The researchers estimate that their devices achieved $1.1x10^7$cm/s electron saturation velocity.

"The next generation of communication systems, including 5G, vehicles and Internet of Things, needs devices operating at mm-wave bands with low cost and high-efficiency", comment the researchers from Singapore's Nanyang Technological University, Singapore–MIT Alliance of Research and Technology, Temasek Laboratories Singapore, and Massachusetts Institute of Technology in the USA. The 1cm to 1mm range of wavelengths covers frequencies from 30GHz to 300GHz.

The epitaxial structure (Figure 1) was grown by metal-organic chemical vapor deposition (MOCVD) on (111)silicon with high-resistivity greater than 6000Ω-cm. High-resistance substrates are preferred in high-frequency applications to avoid energy losses from induced current flows. The InAlN barrier layers was lattice matched with 17% indium content. Hall measurement gave a carrier concentration of $2.04x10^{13}$/cm^2 in the two-dimensional electron gas that forms in the GaN channel near the GaN/AlN/InAlN interface. The electron mobility was 1190cm^2/V-s. The AlN spacer was designed to screen channel-electron scat-

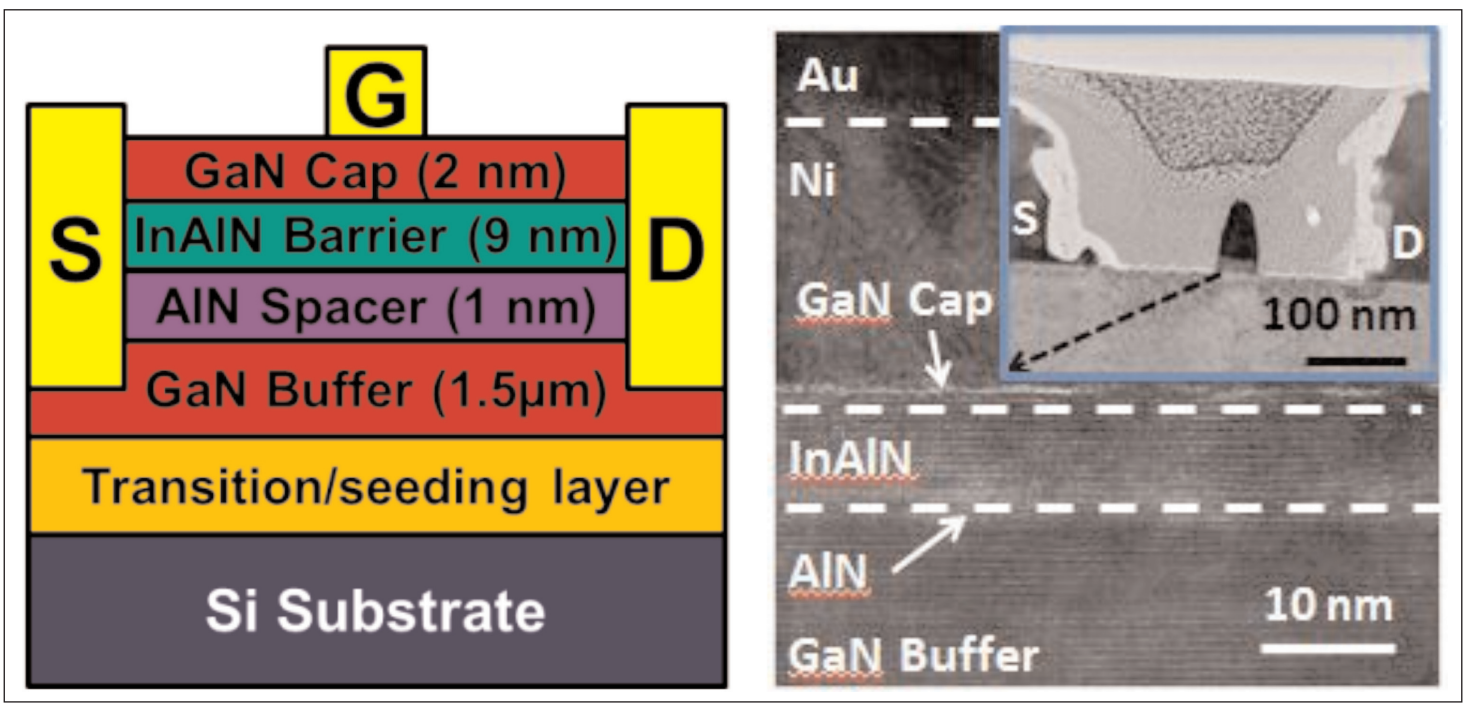


Figure 1. Schematic and transmission electron microscope (TEM) image (gate region) of 40nm-gate InAlN/GaN on Si.

tering from the barrier, improving electron mobility.

Mesa isolation for transistor fabrication was achieved with 120nm-deep plasma etching. The ohmic source and drain contacts consisted of annealed titanium/aluminium/nickel/gold. The rectangular gate was nickel/gold. Further metalization for inter-connects and probe pads consisted of titanium/gold. Initially, there was no surface passivation.

The source–drain distance was 300nm for the shortest 40nm gate-length transistor. Longer gates were accommodated in a 700nm gap. The gate width was 2x50μm (100μm total).

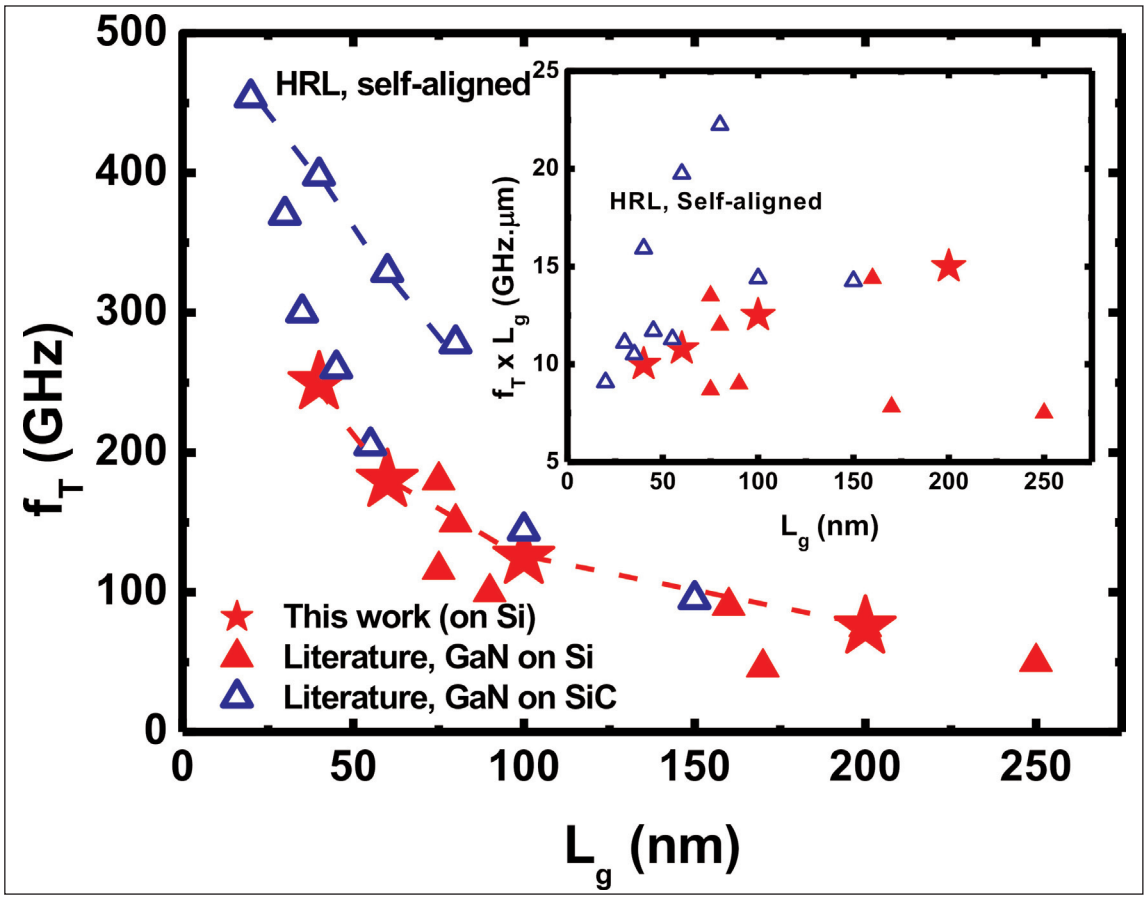


Figure 2. Comparison of f_T of GaN HEMTs on Si in Xing et al's work with other reported GaN HEMTs on Si and on SiC. Inset: gate-length (L_g) dependence of f_T x L_g product.

The maximum drain current of the 40nm-gate device was 2.66A/mm with 2V gate and 6V drain bias. The peak transconductance was 438mS/mm at –2.8V gate and 6V drain voltage points. Reported III–nitride devices on SIC substrates have achieved similar drain currents, but slightly higher transconductance (520mS/mm). The researchers point to two factors that give the SiC-based device the edge: a higher mobility of 1581cm^2/V-s, and a thinner total barrier thickness of 9.4nm. The barrier for the silicon-based contender consisted of 2nm GaN cap, 9nm InAlN, and 1nm AlN spacer, giving a 12nm total.

The gate leakage (I_g) was high, exceeding 1mA/mm with –10V gate. "The high I_g is due to the thin InAlN barrier and the high peak electrical field in the deeply scaled gate HEMT," the team comments.

Frequency measurements gave a cut-off (f_T) of 250GHz and maximum oscillation (f_{max}) of 60GHz. The researchers comment: "To the best of our knowledge, this f_T value is the highest among the reported GaN-based transistors on Si substrates. A relatively low fmax is due to the high resistance of the short rectangular-shape gate, which can be improved by using T-shape gate structure." They also suggest that "fin-like or planar nano-channels under the gate" could improve linearity.

To reduce current collapse, the researchers applied surface passivation consisting of 10nm aluminium oxide from an atomic layer deposition (ALD) process. The collapse under pulsed operation was reduced from 90% to 15% with a –8V gate and 6V drain quiescent state. At 0V drain and –8V gate quiescent, the collapse decreased from 85% to 5% by adding passivation. The penalty of passivation was that f_T fell to 235GHz. The researchers suggest a low-k passivation could restore the frequency performance.

Longer-gate devices had lower f_T values: 75GHz, 125GHz and 180GHz for respective gate lengths of 200nm, 100nm and 60nm. In 2013 HRL reported a 454GHz f_T for an AlN/GaN HEMT on SiC. Other reports of GaN on SiC have similar frequency performance to Xing et al's HEMT on Si (Figure 2). "These excellent results show the great potential of InAlN/GaN HEMTs on Si for future mm-wave and sub-THz applications", the team writes.

The researchers also suggest that reducing the gate length further to 20nm and adopting a self-aligned process as in HRL's device could lead to performance improvement. The team's analysis suggests an f_T of 440GHz could be accessed with 20nm gate, 150nm source–drain distance, and regrown n^{++}-GaN ohmic contacts. ■

https://doi.org/10.1109/LED.2017.2773054

Author: Mike Cooke

Vertical power & high-speed III–V devices show their promise

Mike Cooke reports on presentations at International Electron Devices Meeting (IEDM 2017) in San Francisco (2–6 December).

Compound semiconductor materials for power and high-speed applications continue to have fair representation among the contributions at the year-end IEDM. Combining group-III metals — gallium (Ga), indium (In) and aluminium (Al) — with group-V elements — nitrogen (N), arsenic (As), phosphorus (P), antimony (Sb) — offers a huge palette of electronic and thermal behaviors that can be harnessed in modern and future technology.

At the most recent IEDM, one theme from the power and high-speed sections was the use of vertical devices, which can offer advantages in terms of smaller footprints and hence more compact electronics. At the same time, lateral devices continue to be developed and improved. Finally, researchers are seeking to combine light emitting devices with low-cost silicon photonics.

Here, we report on some of these developments. Next issue, we plan to look beyond the near future to IEDM presentations on the prospects for the two-dimensional (2D) electronics of thin layers provided by materials such as graphene, dichalcogenides, black phosphorus, etc.

Vertical power

At IEDM, Fuji Electric Co Ltd and Japan's National Institute of Advanced Industrial Science and Technology (AIST) proposed a vertical gallium nitride (GaN) Schottky barrier diode (SBD)-wall-integrated trench metal-oxide-semiconductor field effect transistor (SWITCH-MOS, Figure 1) structure to solve issues from PiN body diodes such as forward degradation and reverse recovery loss [session 9.1].

The design enabled a small 5μm cell pitch and 1.2kV operation while successfully inactivating the PiN-diode without degradation of on- and off-state characteristics. The freewheeling PiN diode is aimed at protecting the transistor from voltage spikes. The small cell size is helpful from the perspective of not adding unduly to on-resistance by the inclusion of an extra SBD. The on-resistance and blocking performances were similar to those of conventional power MOSFETs with U-shape trench (UMOS) without an integrated Schottky barrier diode, according to the team.

Massachusetts Institute of Technology in the USA, the Singapore–MIT Alliance for Research and Technology, and RF LLC and Columbia University in the USA have claimed record performance from a normally-off GaN vertical transistor (Figure 2) with +1V threshold [session 9.2]. The device features submicron fin-shaped channels and uses only n-GaN layers without resistive p-GaN or costly, complex epitaxial regrowth processes.

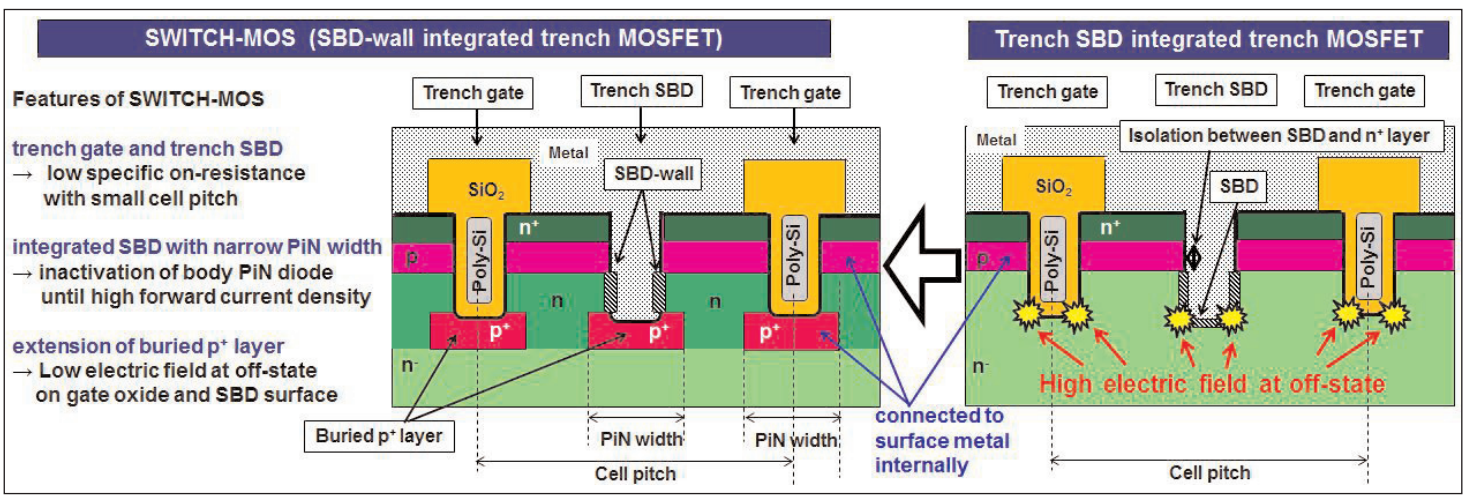


Figure 1. Schematic cross-sectional illustration and features of SWITCH-MOS.

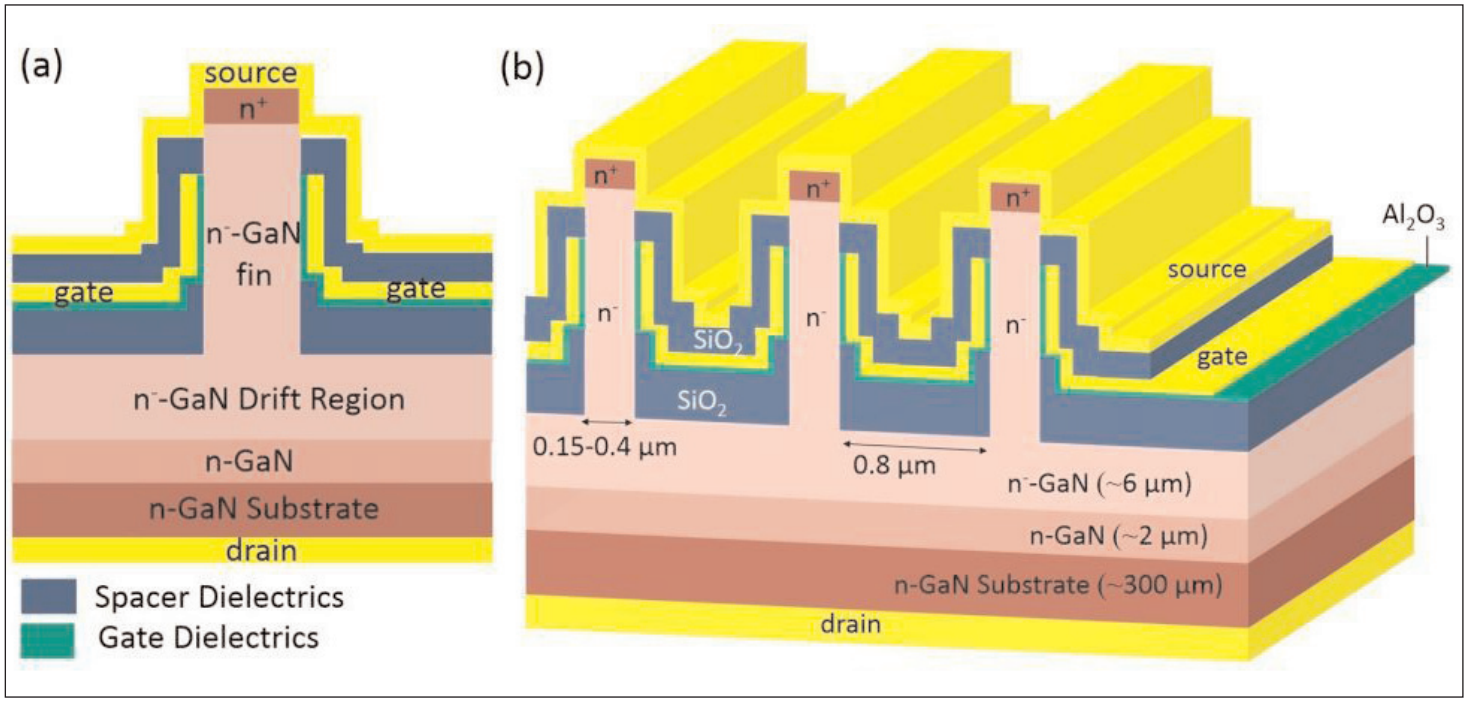


Figure 2. (a) Cross-sectional schematic of device fin unit-cell and (b) side-view three-dimensional schematic of proposed vertical GaN fin power FETs with multiple fins. Fin length ~1µm in vertical direction.

The specific on-resistance (R_{on}) was 0.2mΩ-cm^2 fin area and 1mΩ-cm^2 device area. The on/off current ratio was around ten orders of magnitude. The breakdown voltage (BV) for 10^{-4}A/cm^2 current leakage was more than 1200V. In the on-state, currents reached 10A for a large 0.8mmx0.55mm device or 25kA/cm^2 density in smaller devices. The Baliga figure of merit (BV^2/R_{on}) reached 7.2GW/cm^2 for fin area normalization and 1.44GW/cm^2 for device area. These figures are claimed to be the "best in all reported normally-off GaN transistors".

The researchers comment: "The R_{on} of our vertical fin power FETs normalized to total device area can be further reduced by reducing the lateral distance between fins and increasing the fin aspect ratio, while the BV can be further improved by incorporating multiple gate and source field plates to smoothen the peak E-field at the gate edge."

The transistors work by depleting the n-GaN material due to its work function difference with the molybdenum gate metal on the two free surfaces of the fins, blocking current flow at 0V gate potential. As the gate potential increases, electrons accumulate at the n-GaN/aluminium oxide dielectric interfaces, opening up two channels for current flow. The epitaxial structure was grown by metal-organic chemical vapor deposition (MOCVD) on freestanding GaN.

University of California Davis (UCD) and University of California Santa Barbara (UCSB) in the USA have used a double-field plate design to create a vertical GaN open-gate FET (OG-FET) with up to 1435kV blocking 50mA/cm^2 current density, low specific on-state resistance of 2.2mΩ-cm^2, and normally-off +4.7V threshold [session 9.4].

The device (Figure 3) used a 10nm MOCVD regrown GaN channel layer to reduce resistance. The rest of the structure was grown by commercial epitaxy foundry IQE by MOCVD on freestanding GaN. The regrown layer had 2x reduced contact and sheet resistance, compared with an in-situ-grown layer. The improvement was attributed to an acid treatment before the regrowth, aimed at inhibiting the diffusion of the magnesium doping of the p-GaN layer.

A large-area 0.4mmx0.5mm transistor using the technology featured a 900V breakdown voltage and 4.1Ω on-state resistance. The average channel electron mobility was 185cm^2/V-s.

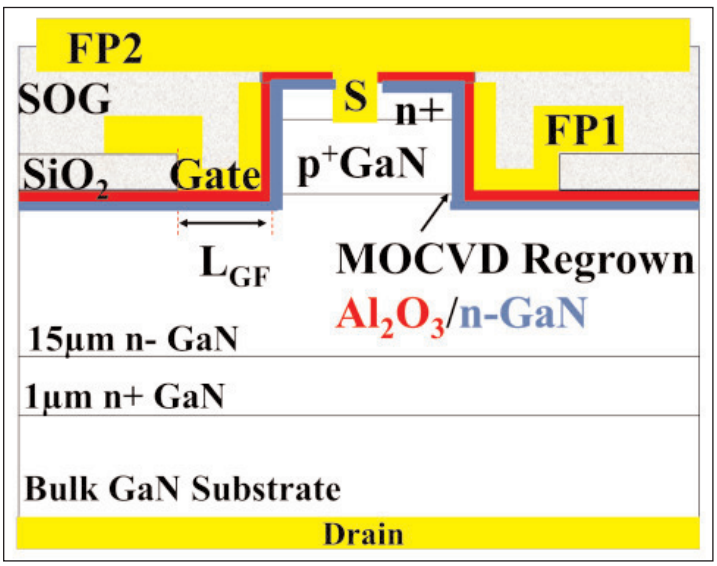


Figure 3. Schematic cross section of GaN OG-FET with double field-plate structure.

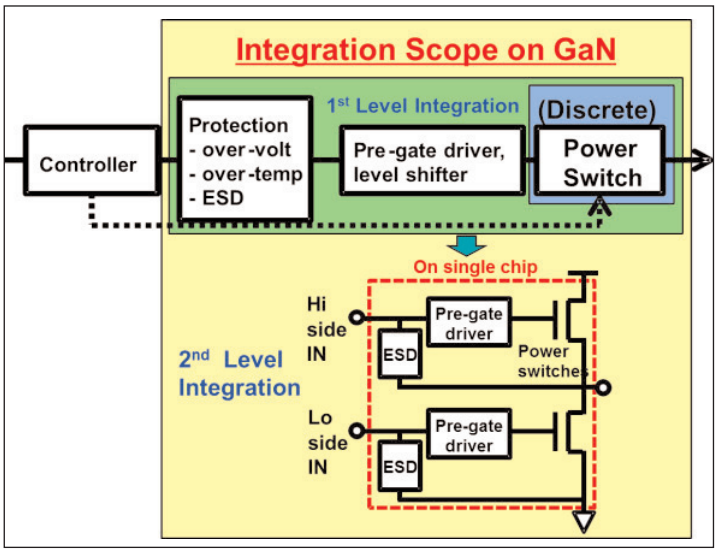


Figure 4. Expanding scope of GaN-on-Si integration.

Lateral GaN

Taiwan Semiconductor Manufacturing Company presented its view on the 'next stage' for GaN power devices integrated with peripheral low voltage active and passive devices on silicon (Si) [session 33.1]. According to TSMC this involves two levels: first, protection/control/driving circuits; second, adding high/low-side on-chip integration to a 100V technology platform (Figure 4). The scheme would eliminate channel modulation due to substrate bias sharing, along with wiring parasitics.

The team fabricated enhancement-mode FETs (E-) and depletion-mode (D-) metal-insulator-semiconductor FETs on 6-inch GaN-on-Si wafers. The E-FET ratings were 100V and 650V, while the D-FETs were rated at 650V. The researchers also developed 12V E/D-HEMTs rectifiers, 2DEG resistors, and capacitors as part of the 1st-level development.

An electrostatic discharge circuit achieved more than 5kV surge sustainability. A DC–DC buck step-down converter operating at 800kHz showed on-resistance reduced by ~25% by biasing the bulk semiconductor dynamically rather than setting it at the ground potential.

University of Padova, ON Semiconductor, and CMST imec/Ghent University have used 3MeV proton irradiation to reduce dynamic on-resistance to zero in GaN power HEMTs [session 33.5]. The researchers claim their work as the first demonstration of the effect.

Negative charge ionizing the carbon (C) acceptors reduces the drain current, which increases dynamic resistance after exposure to high off-state bias. By contrast, positive charge in the buffer increases drain currents. The proton irradiation enables more efficient electron detrapping by providing leakage from the buffer to the 2DEG channel in the off-state (Figure 5). The researchers write: "Since the C-doped GaN is highly resistive, the increase in the conductivity of the uid[unintentionally doped]-GaN layer does not lead to an increase in the drain and vertical leakage current."

The static characteristics of the devices such as threshold voltage were not affected up to $1.5x10^{14}/cm^2$ proton fluence. However, high irradiation at the $10^{15}/cm^2$ level shifted the threshold +2V. At $1.5x10^{14}/cm^2$ fluence, the dynamic on-resistance was completely suppressed in 600V/150ºC operation, according to the team.

Massachusetts Institute of Technology has been working to improve linearity of GaN-based high-electron-mobility transistors (HEMTs) using fin-like structures to give transconductance compensation [session 25.3]. The fins allow different threshold voltages across the device that can increase linearity, as desired for 5G-LTE, WIMAX, Sat-Com, CAT-TV and radar applications. The researchers used Wolfspeed's GaN-on-SiC fabrication process on wafers from IQE to create two parallel 250nm GaN HEMTs. Some of the resulting devices achieved 20dB reduction in harmonics and 6dB increase in the third-order output intercept point (OIP3), compared with a baseline device without compensation.

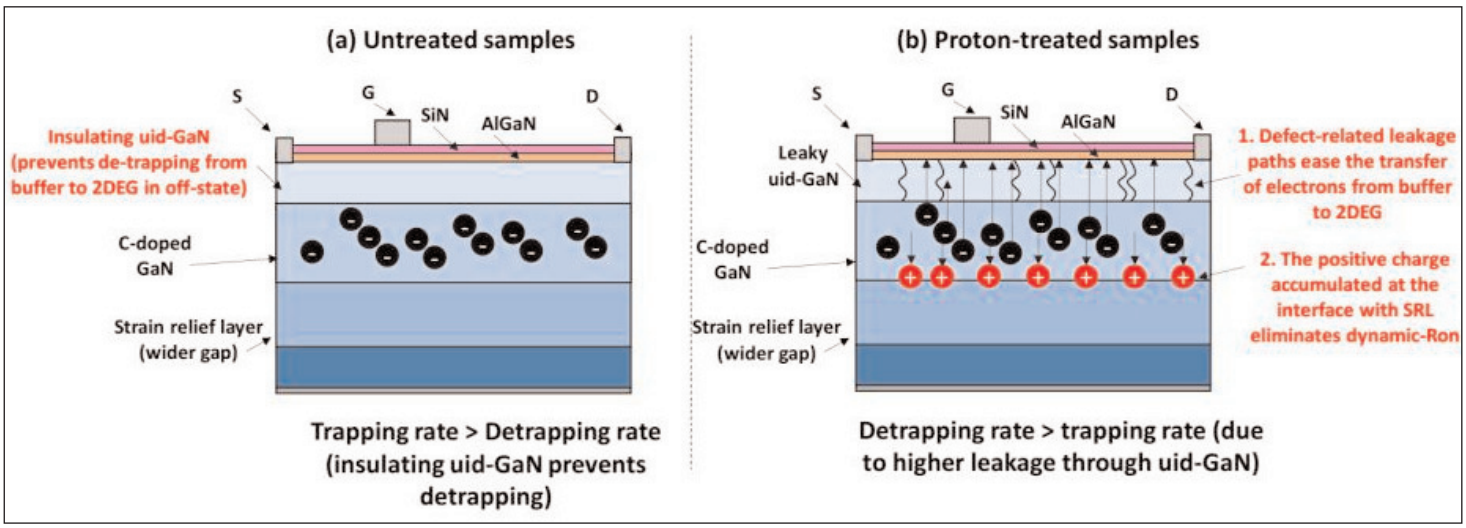


Figure 5. Schematic of effect of proton irradiation.

High-speed nanowires

KU Leuven, IMEC and Lam Research Belgium claimed record performance from indium gallium arsenide ($In_{0.53}Ga_{0.47}As$) vertical nanowire (VNW) and nanosheet gate-all-around FET and transmission line measurement (TLM) devices [session 17.1]

The top-down VLSI-compatible fabrication (Figure 6) scaled the effective oxide thickness and used ammonium sulfide ($(NH_4)_2S$) passivation and hydrogen/nitrogen 'forming' gas annealing to improve device performance. The researchers also claim the first TLM structures on top-down n-type $In_{0.53}Ga_{0.47}As$ vertical nanowire arrays. Such structures are used to study contact resistance contributions.

A range of gate oxide layers were tested, but the best performing involved passivation before atomic layer deposition of 1nm aluminium oxide and 3nm hafnium dioxide. The capacitive equivalent thickness of the dielectric was 1.62nm.

One device with 45nm NWs achieved an off current as low as 100pA/μm with 0.5V drain bias. and a Q value (transconductance/subthreshold swing) of 16. Reducing the diameter to 30nm gave a subthreshold swing of 63mV/decade, which is described as the best reported in the literature for any type of III–V device.

Forming gas annealing increased the Q to 21 with a peak transconductance (G_{mMAX}) of 1.6mS/μm. "These values for G_{mMAX} and Q are the best reported in literature for vertical III–V device and are only outperformed by lateral devices due to the contact resistance penalty at the VNW top," the team comments.

The forming gas anneal did, unfortunately increase the off-current to 100nA/μm. On the plus side, the on-current was 397μA/μm, also claimed as a record. The forming gas anneal is thought to reduce the Schottky barrier and contact resistance between the InGaAs and molybdenum used as the top contact.

Vertical device configurations can offer more compact footprints, compared with the mainstream planar structures. The vertical format could also allow longer gate lengths, which could be beneficial for high-mobility III–V compound semiconductor devices with hard-to-control off-current leakage.

Massachusetts Institute of Technology [session 17.2] also claimed records, this time for the "first" sub-10nm-diameter VNW MOSFETs "of any kind in any semiconductor system". Reactive ion etch, alcohol-based digital etch and Ni alloyed contacts were used to fabricate top-down InGaAs MOSFETs (Figure 7).

Records for a 7nm-diameter device included an on-current of 350μA/μm with off-current 100nA/μm in 0.5V operation. Other characteristics of the device were a peak transconductance of 1.7mS/μm, also claimed as a record, and minimum subthreshold swing (SS) of 90mV/dec, giving a maximum Q factor of 19, the highest reported in vertical nanowire transistors, according to the team (but apparently beaten by the presentation just above).

The researchers see the 7nm diameter (D) as being the 'design point' for a future 5nm technology node. "A remarkable result, is that the performance of these devices continues to improve as D shrinks, with a record g_m achieved at D=7nm," they add.

The team had previously used water-based digital etch but had found that surface tension effects had resulted in nanowire breakage when attempting to reduce diameters below 10nm. By contrast, sulfuric acid (H_2SO_4) in methanol enabled fabrication of 5.5nm-diameter wires with 90% yield.

The nickel alloying involved the formation of highly

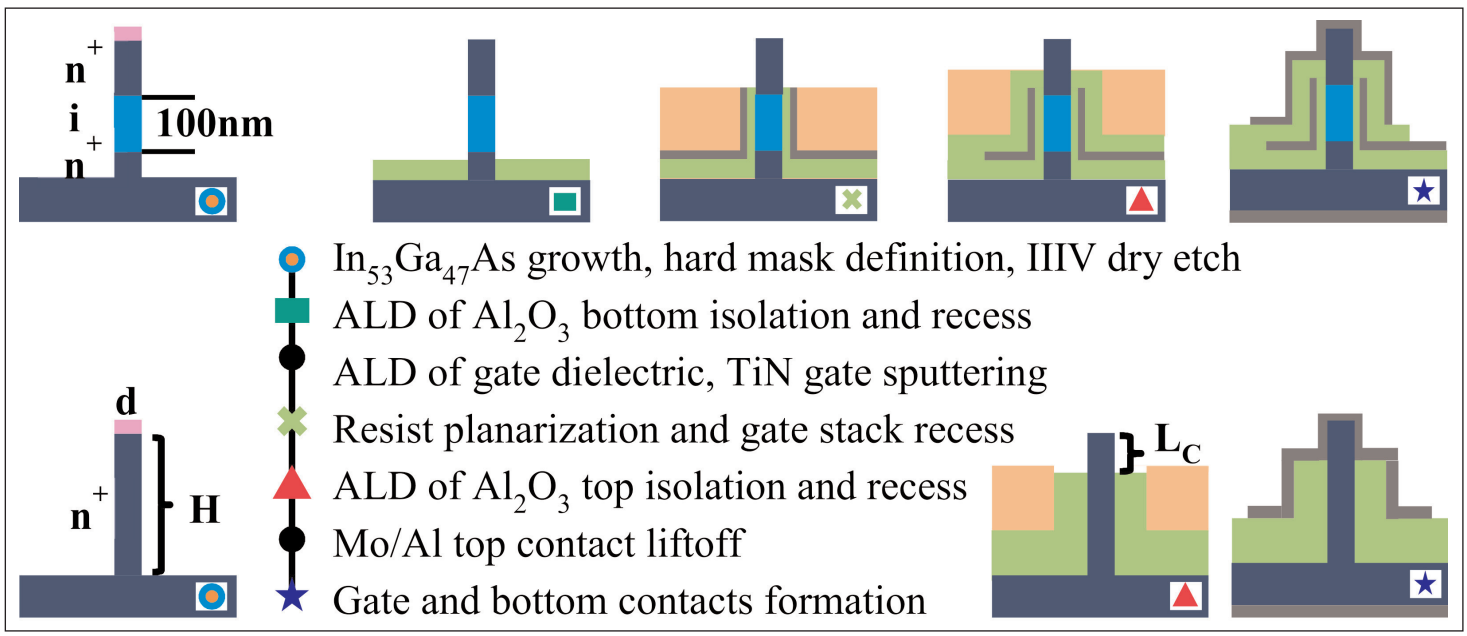


Figure 6. Key process steps from both VNW FET (top row) and VNW TLM (bottom row); d, H and L_C are NW diameter, NW height and contact opening length, respectively.

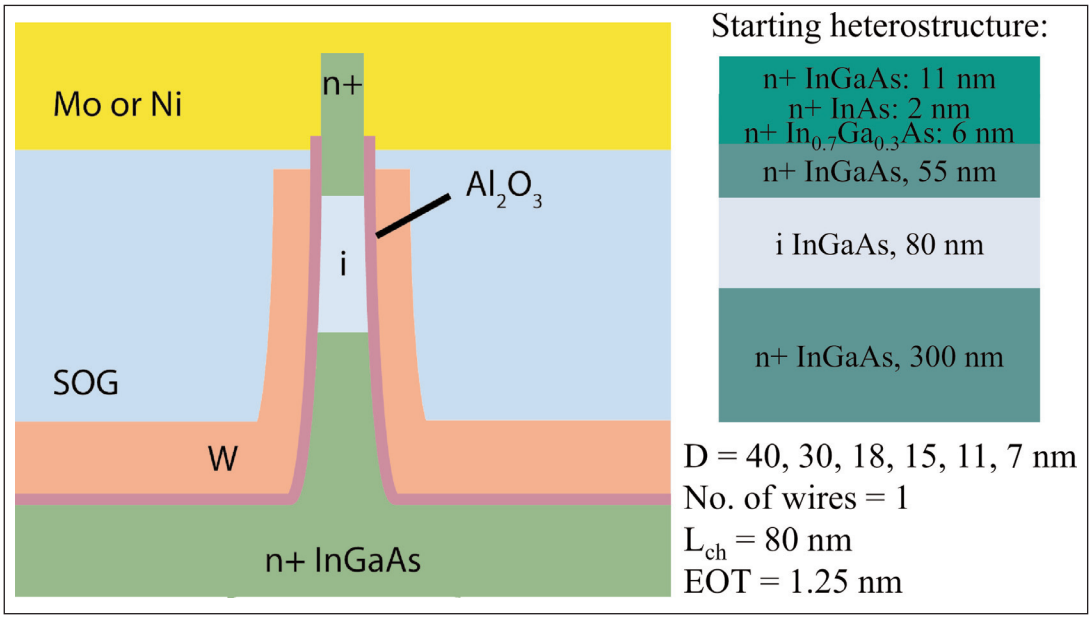


Figure 7. Schematics of device cross section, starting heterostructure and design parameters.

conducting NiInGaAs, avoiding molybdenum/tungsten mushroom-shaped top contacts, which can increase fragility and makes processing more complicated. The reported devices had an 80nm channel length. A forming gas anneal was also found useful in boosting on-current and gate control.

Lund University have boosted the transconductance of InGaAs VNW MOSFETs on Si to 2.4mS/μm [session 17.3]. The devices had gate lengths ranging from 25nm to 140nm. One device achieved an on-current of 407μA/μm at 100nA/μm off-current with 0.5V operation, also claimed as a record.

The nanowires were grown by MOCVD using gold seed particles on an InAs layer. The wires consisted of 100nm InAs, 100nm $In_{0.5}Ga_{0.5}As$, 300nm highly doped $In_{0.5}Ga_{0.5}As$. The doped $In_{0.5}Ga_{0.5}As$ also forms a shell around the unintentionally doped $In_{0.5}Ga_{0.5}As$. The core was approximately 30nm wide and the total core/shell structure was 50nm.

Fabrication involved electron-beam lithography on spin-coated hydrogen silsesquioxane (HSQ) resist. Different electron doses allowed different gate lengths to be achieved by varying the amount of top metal residue and thickness of spacer (Figure 8). The gate region was defined with digital etch that removed the shell region. The gate stack consisted of aluminium oxide/hafnium dioxide and tungsten metal.

The Q value also seems good at 22 on the basis of a peak transconductance of 1.9mS/μm and SS at 86mV/decade.

High speed FinFETs

IBM Research GmbH Zürich Laboratory, Switzerland, University of Udine, Italy, and ETH Zurich, Switzerland, achieved a claimed record of 249μA/μm for a 13nm-long replacement-metal-gate InGaAs-on-insulator n-FinFET on Si [session 17.5]. The fixed off-current was 100nA/μm at 0.5V drain bias.

The fin width was 17nm, while the 13nm gate length is seen as a target for sub-7nm technology nodes.

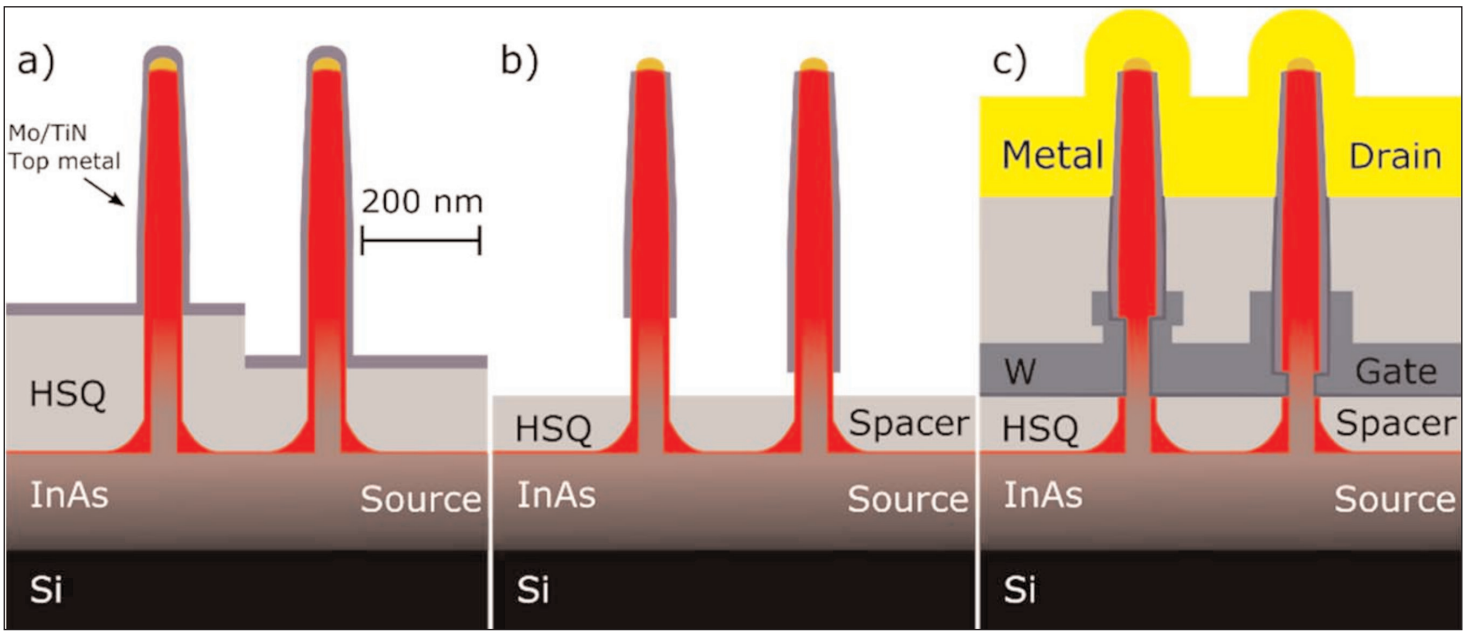


Figure 8. Fabrication after top metal deposition (a), first spacer deposition (b) and final contacts (c).

The 20nm InGaAs channel material was wafer bonded to the silicon. Regrowth was used to give raised source–drain material for lower access resistance (Figure 9). The gate stack used aluminium oxide and hafnium dioxide with 1.25nm capacitive equivalent thickness. Titanium nitride provided the work-function-defining metal, followed by tungsten fill.

Massachusetts Institute of Technology and Korea Institute of Science and Technology presented the first use of digital etch (DE) on indium gallium antimonide (InGaSb) transistors of any kind, enabling the first finFETs with widths down to 10nm [session 17.7]. The self-aligned devices (Figure 10), with ohmic contacts fabricated first, managed a transconductance of 160μS/μm at 0.5V drain, claimed as a record. The channel height was 23nm, giving a height/width aspect ratio of 2.3. Normalized according to fin width, the specific transconductance was 704μS/μm.

Antimonides have high hole mobility, creating opportunities for these materials as the p-type component of complementary MOS (CMOS) circuitry, while arsenides have high electron mobility. However, antimonides have processing challenges arising from their high chemical reactivity. Apart from the digital etch, the researchers also used nickel ohmic contacts.

The digital etch involved exposure to oxygen at room temperature for three minutes and 30s wet etching in hydrochloric acid in isopropyl alcohol. The digital etch was performed after reactive ion etch, giving fins down to 15nm wide.

The heterostructure was grown by molecular beam epitaxy on semi-insulating GaAs. The hole mobility was measured at 1175cm^2/V-s.

The researchers admit that the turn-off characteristics of the finFETs are presently "insufficient", but "nevertheless, the results here represent a significant improvement over earlier InGaSb FinFETs due to the new DE technique."

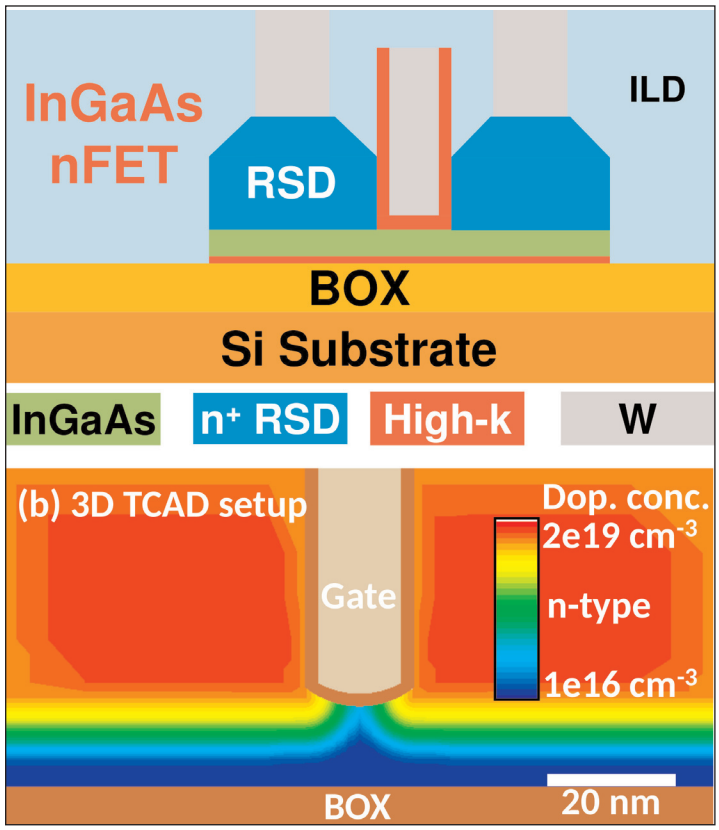


Figure 9. (a) Cross-sectional schematic of self-aligned spacer-free replacement metal gate InGaAs-on-insulator devices; (b) three-dimensional simulation setup shown across gate with doping profile.

Optoelectronics on silicon

University Grenoble Alpes and STMicroelectronics presented the "first integrated hybrid III–V/Si laser in a fully CMOS-compatible 200mm technology" [session 24.1]. The III–V epitaxial material was directly bonded with 100nm silicon dioxide interlayer to the silicon-on-insulator (SOI) substrate (Figure 11). The SOI wafer was prepared by adding to the 310nm to silicon layer to make a 500nm-thick waveguide structure in the region of the

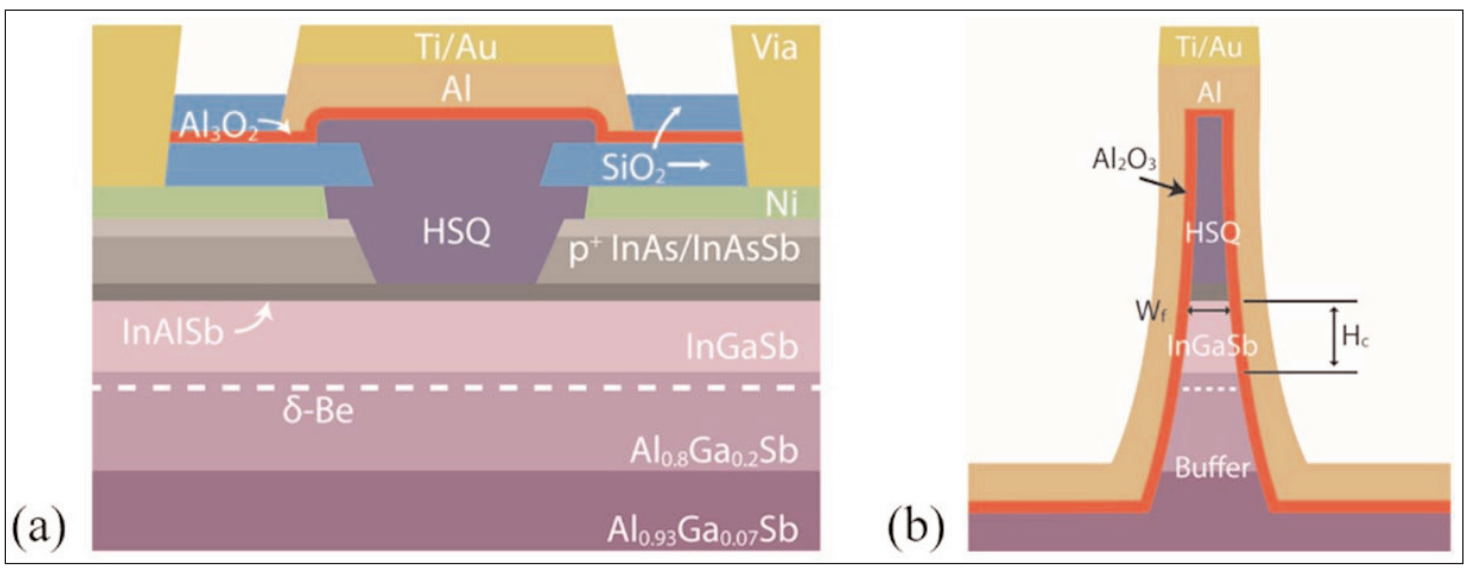


Figure 10. Schematic FinFET cross sections (a) along and (b) across fin.

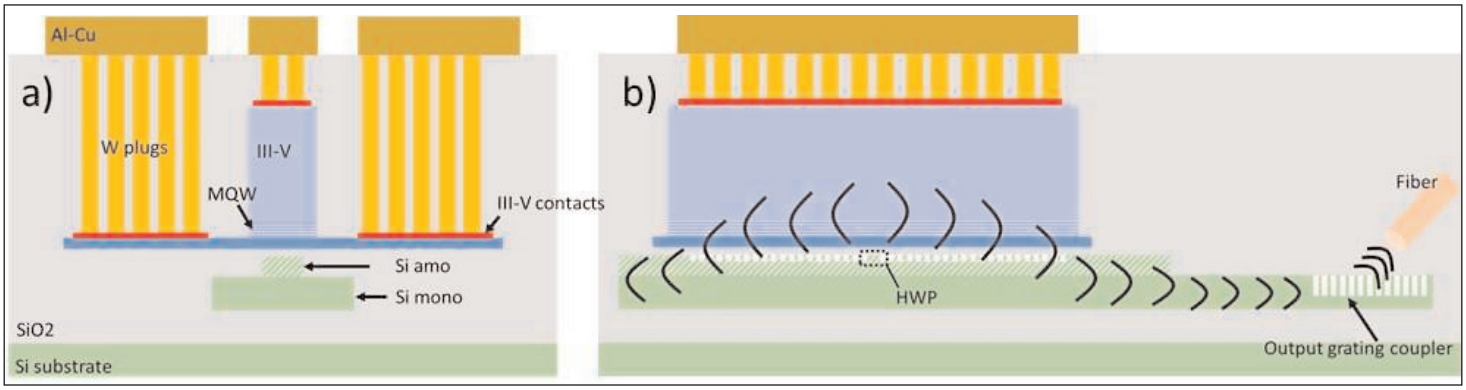


Figure 11. Transversal (a) and longitudinal (a) schematic views of laser. Active region consists of InGaAsP multiple QWs surrounded by p- and n-doped InP layers.

laser. A half wave plate (HWP) distributed feedback (DFB grating) was etched along the silicon waveguide. Since gold is unwanted in CMOS processing facilities, the researchers used nickel contacts instead.

The side mode suppression ratio (SMSR) of the laser reached 50dB and the maximum output power coupled into the waveguide was 4mW. The 1300nm central wavelength of the laser emission was slightly offset from the optimum of the output grating coupler, which resulted in power loss. The fabrication flow is fully planar and compatible with large-scale integration of silicon photonics circuits.

University of Stuttgart and University of Massachusetts reported "the first demonstration" of a germanium directly tunnel-modulated LED/laser light source on (100)Si [session 24.4]. The source was part of a silicon photonic device that emitted light under reverse bias and detected under zero/forward bias. The emission and detection used low-voltage switching tunnel Zener/Esaki tunnel diodes (TDs).

The team claims: "The devices enable for the first time monolithic, highly efficient electrical-to-optical (E/O; C_S = 114mV/dec) and optical-to-electrical (O/E; C_S = 31mV/dec) signal conversion since the TDs control carrier injection and extraction."

The LED achieved modulation frequencies of 1GHz. With a laser cavity, output power reached 1.6mW with added optical pumping from a supercontinuum lamp injector. The wavelength was in the range 1670–1690nm.

Band-to-band tunneling was used to inject electrons into the higher energy direct valley of the conduction band structure, enabling light emission in the indirect Ge semiconductor material (Figure 12). ■

www.ieee-iedm.org

Author:
Mike Cooke is a freelance technology journalist who has worked in the semiconductor and advanced technology sectors since 1997.

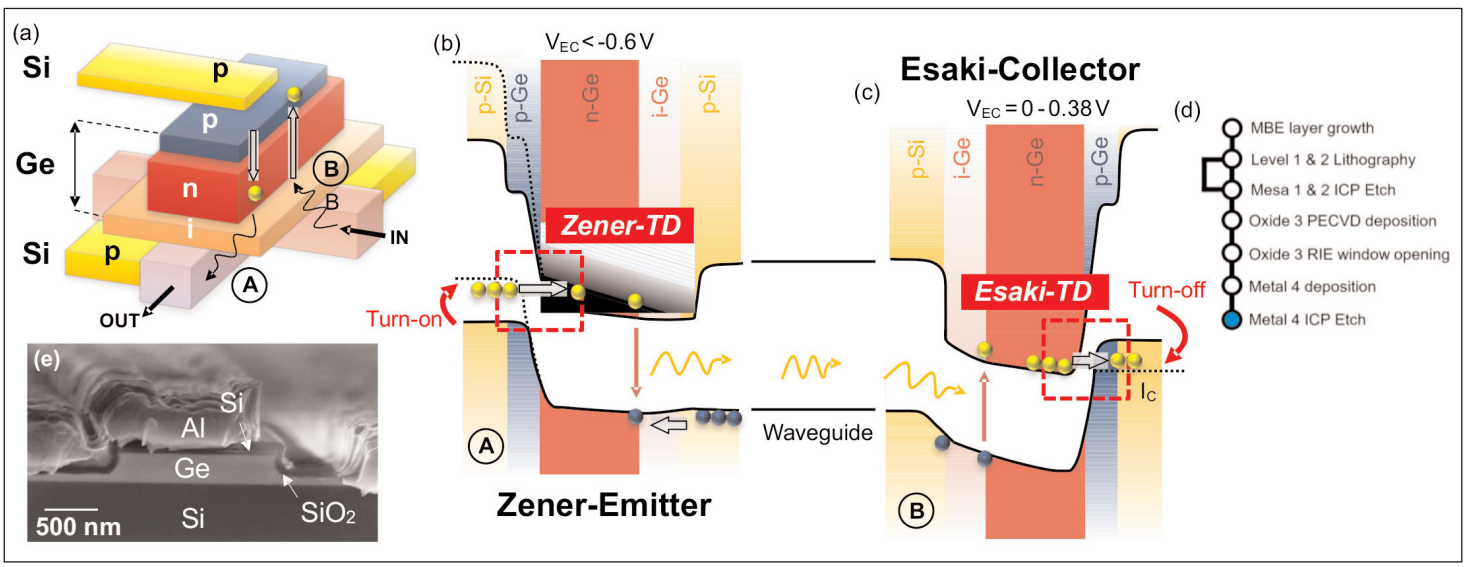


Figure 12. (a) Schematic of Zener-emitter/Esaki-collector monolithic photonic device. (b) Electrons injected by reverse biased Ge p–n Zener tunnel diode to direct conduction, while holes drift from forward biased n–i–p diode, creating modulated, in-plane optical response, which can be transferred by Si waveguide. (c) Light absorbed in i-Ge of zero biased Esaki-collector. Generated electrons drift to n–p Esaki diode collector. (d) CMOS process compatible process sequence and (e) scanning electron microscope image of device.

semiconductorTODAY

COMPOUNDS & ADVANCED SILICON

www.semiconductor-today.com

Join our LinkedIn group: Semiconductor Today

Follow us on Twitter: Semiconductor_T

Choose *Semiconductor Today* for . . .

MAGAZINE

Accurate and timely coverage of the compound semiconductor and advanced silicon industries

Targeted 82,000+ international circulation

Published 10 times a year and delivered by e-mail and RSS feeds

WEB SITE

Average of over 26,000 unique visitors to the site each month

Daily news updates and regular feature articles

Google-listed news source

E-BRIEF

Weekly round-up of key business and technical news

E-mail delivery to entire circulation

Banner and text marketing opportunities available

Practical gallium nitride vertical field-effect transistors

Dr Quanzhong Jiang of Gate Source Drain Semiconductor Ltd discusses practical ways of exploiting the advantages of vertical field-effect transistors over existing lateral gallium nitride high-electron-mobility transistors.

The advent of gallium nitride (GaN) material and device technologies has led to novel lateral transistors. These include gallium nitride on silicon carbide (GaN-on-SiC) high-electron-mobility transistors (HEMTs) for high-power radio frequency (RF) amplifiers, and gallium nitride on silicon (GaN-on-Si) HEMTs for energy-efficient convertor/invertor circuits. However, due to the use of expensive, high-resistivity SiC substrates (~$2000 per 4" wafer), GaN-on-SiC RF transistors are very expensive (~$100–200 per 50W chip). GaN-on-Si HEMTs could break down at a few hundred volts or after a limited period of operation, and the breakdown mechanisms may be related to their high density of defects, the off-state electric field, and the use of thermally insulating AlGaN in the buffer for stress control and mitigation of buffer leakage.

Therefore, it is inevitable that vertical transistor designs have been proposed, such as the current-aperture vertical electron transistor (CAVET) [1] and trenched metal-oxide-semiconductor field-effect transistor (MOSFET) [2] etc. Like silicon or silicon carbide (SiC) vertical transistors, these require p-type materials acting as a current-blocking layer. However, it is problematic to incorporate p-type Mg:GaN into GaN vertical transistors due to magnesium diffusion and contamination during metal-organic vapour phase epitaxy (MOVPE) growth. This may lead to reduced electron mobility for two-dimensional electron gas (2DEG) channels or GaN drift layers. Alternative methods such as molecular beam epitaxy (MBE) incur high costs.

The recently published patent application (ref. PCT/GB2017/050316) describes the practical ways forward to form GaN vertical field-effect transistors (VFETs), and Figure 1 shows VFETs on Si(211) substrates for RF amplifiers and switching applications, respectively. The VFETs employ epitaxial lateral overgrown (ELOG) GaN to form an AlGaN/GaN two-dimensional free electron gas channel and a drift region in the drain for high-voltage applications. The use of ELOG GaN ensures a small on-resistance due to the large electron mobility for the 2DEG channel and the drift layer. Furthermore, the 2DEG channels are arranged in parallel with vertical GaN strips to facilitate easy heat dissipation into thermally conductive ELOG GaN [3],

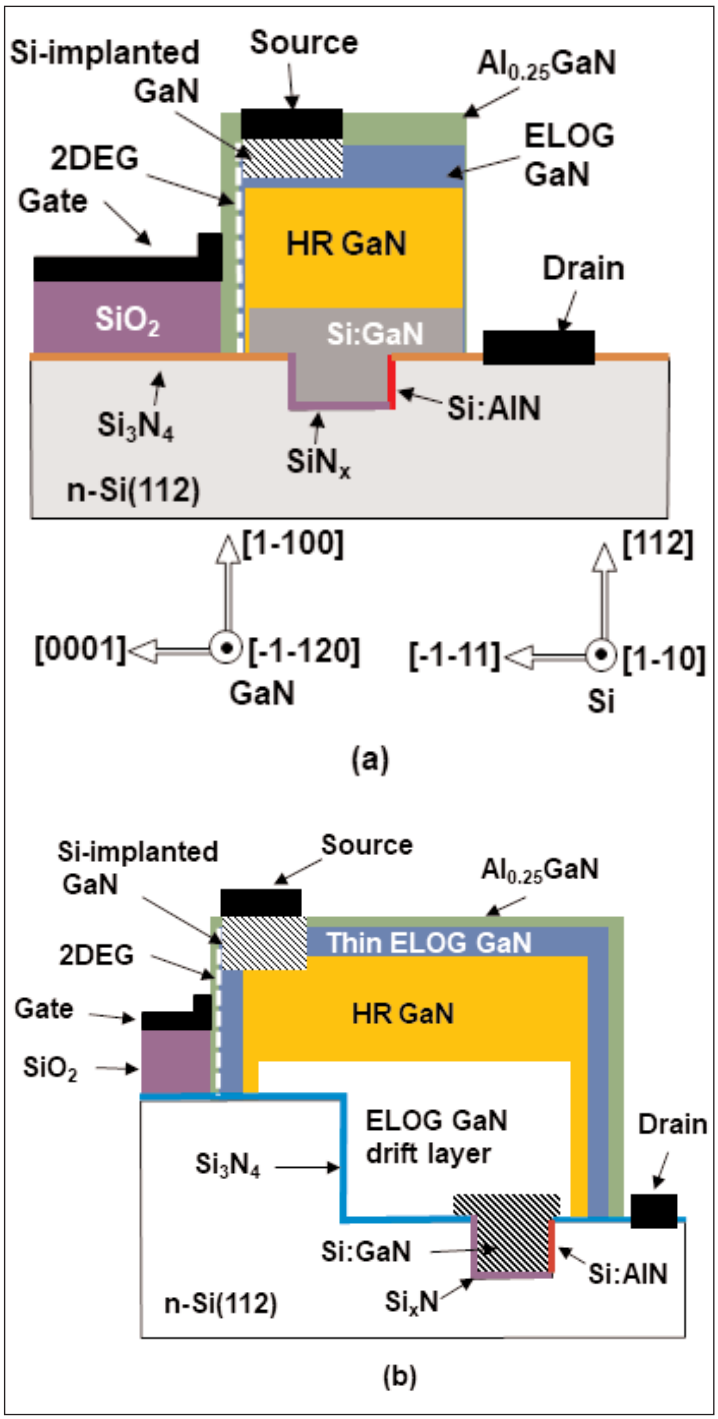


Figure 1 Sketches show VFETs formed on Si(211): (a) RF VFET with crystallographic relationship between Si(211) and GaN(1$\bar{1}$00); (b) VFET switching applications.

and subsequently the heat may be taken away through packaging material or the silicon substrate.

The formation procedure for the VFETs (Figure 1) begins with standard silicon processing (Bosch process and light KOH treatment). Provided that a Si ion implantation can be used to form the source, two separate MOVPE runs are sufficient for the structures shown in Figure 1: one is short to form a thin aluminium nitride (AlN) nucleation layer on Si($\bar{1}\bar{1}1$) facets and the other is to grow the whole structure by varying growth conditions to control lateral and vertical growth rates [4]. The source and drain electrodes can be easily formed without any difficulties. A narrow gate electrode may be fabricated by utilizing the huge difference between the deposition rates on the surfaces that face an electron-beam source crucible and on the other surface that is normal to an e-beam source crucible. For example, the formation of a gate could comprise: (i) depositing a base (SiO_2) (Figure 1) for the gate with a device template facing an e-beam source crucible — the thin SiO_2 layer deposited on the (0001) face may be briefly dissolved in HF solutions; (ii) depositing gate metals with the device template facing an e-beam source crucible at an angle of 45º; (iii) repeating step (i) to deposit a second layer of SiO_2 onto the gate metal layers to define the gate length; and (iv) dissolving exposed gate metals and removing the second layer of SiO_2 to complete the gate. So, a narrow gate may be formed without resorting to e-beam lithography and precise mask alignments.

The structures shown in Figure 1 may be optimized in different ways. For example, the silicon surface may be passivated with p-type dopants to reduce the current leakage from the GaN drift layer to n-type silicon substrates; also, Mg-doped GaN may be inserted into a highly resistive (HR) GaN layer without damaging the 2DEG channel, since the lateral growth of Mg-doped GaN will be minimized by adjusting MOVPE growth conditions [4]. ■

References

1 Chowdhury et al., IEEE Electron Device Letters 33(2012)41–43
2 Chowdhury et al., Trenched Vertical Power Field-Effect Transistors With Improved On-Resistance and Breakdown Voltage, US patent pub. No. US2017125574 (A1).
3. www.kymatech.com/about/faqs/427-what-is-the-story-behind-kyma-s-name-4
4. https://engineering.ucsb.edu/insights2006/pdf/presentations/insights2006_jim_speck.pdf

Dr Quanzhong Jiang, Gate Source Drain Semiconductor Ltd,
E-mail: Contact@gsdsemiconductor.com
www.gsdsemiconductor.com

Improving efficiency of V-band indium gallium nitride transistors and MMICs

Device with 48% efficiency achieved at 59GHz gives "best combination" known of power and PAE, according to researchers.

HRL Laboratories in the USA has reported V-band (57–64GHz) aluminium gallium nitride (AlGaN) double heterojunction field-effect transistors (DHFETs), claiming "to the best of our knowledge, the best combination of power and PAE reported to date at this frequency [59GHz] for a solid-state device" [M. Micovic et al, IEEE Electron Device Letters, published online 17 October 2017].

The work was supported by Boeing Co. Potential applications in the V-band millimeter-wave radio frequency (RF) electromagnetic radiation band include 5G wireless, collision avoidance radar, and satellite and unmanned aerial vehicle (UAV or 'drone') cross links. Increasing efficiency of such devices reduces the thermal management complexity of systems.

The semiconductor materials (Figure 1) were grown on silicon carbide (SiC) by molecular beam epitaxy (MBE). Silicon carbide is presently the material of choice for III-nitride transistors due to its high thermal conductivity.

The $Al_{0.08}Ga_{0.92}N$ buffer also acted as a back-barrier for the device, suppressing hot-electron diffusion and increasing electron confinement in the GaN channel layer through polarization effects. The source and drain regions were etched back and n^+-GaN selectively re-grown by MBE for low-resistance access to the channel. The source-drain spacing was 1.4μm.

The T-gate fabrication involved plasma-enhanced chemical vapor deposition (PECVD) silicon nitride passivation, tri-layer resist electron-beam lithography gate definition, dry etch of the silicon nitride for the gate foot, gate metal evaporation, and metal lift-off. The gate metal was protected with a second PECVD silicon nitride passivation layer. The 40nm gate was centered between the source and drain. Previous research by HRL suggests that this gate process flow minimizes current collapse effects from high-frequency signals.

The wafer was thinned and metal applied to the back side, giving an RF and direct current (DC) ground plane. Through-substrate vias were used to connect grounded

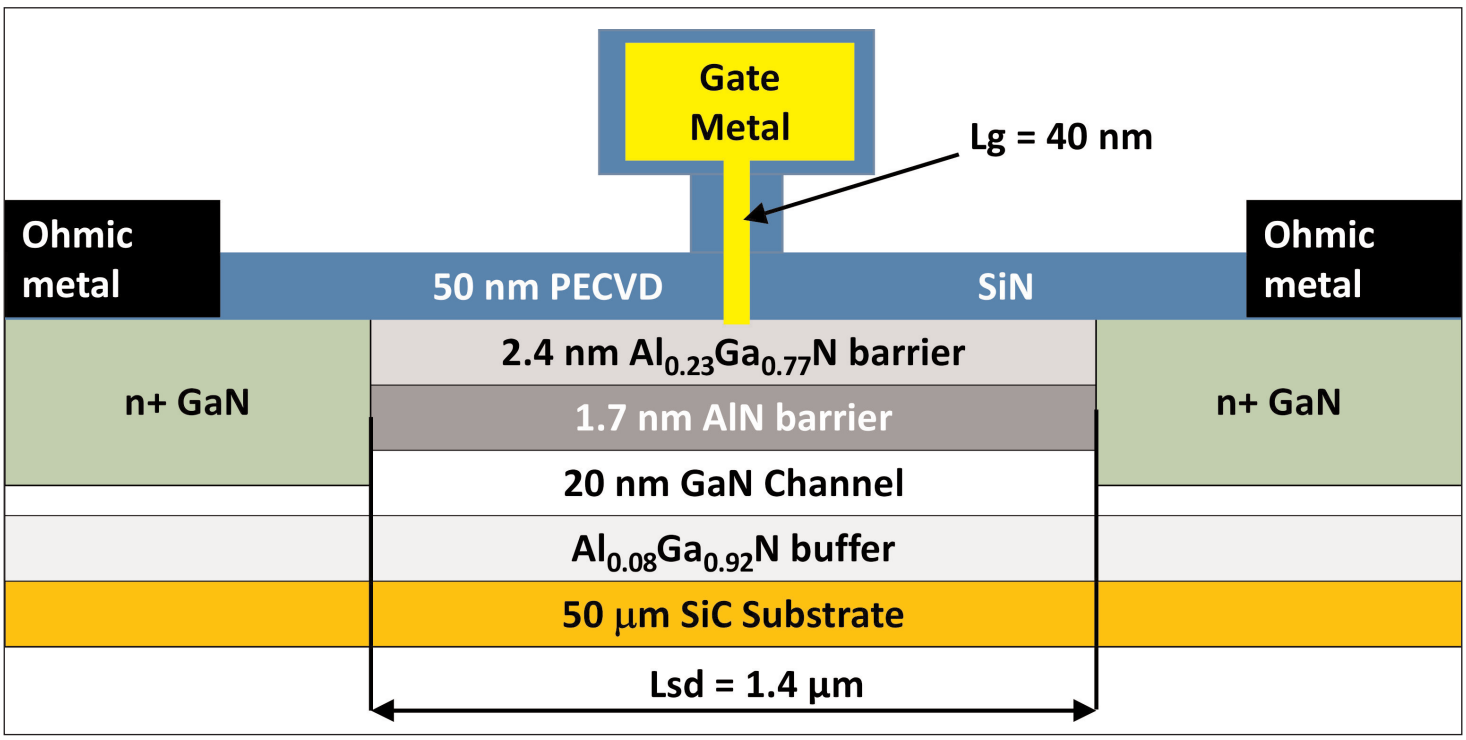


Figure 1. Schematic cross section of scaled GaN DHFET.

terminals and passive components to the ground plane. The thinning was down to 50μm, compatible with monolithic microwave integrated circuit (MMIC) technology.

Devices consisted of 4x50μm finger gates, giving a total gate width of 200μm.

The maximum drain current under 10V drain bias was 1.45A/mm. The peak transconductance was 660mS/mm. The threshold and pinch-off voltages for 1mA/mm drain current were −1.04V and −2V, respectively. The negative voltages indicate normally-on depletion-mode behavior.

The 1mA/mm device breakdown was more than 55V when the gate was at −5V. In pulsed operation, current collapse of about 40% was observed. This was greater than in the previous work by HRL on less aggressively scaled devices with 140nm gate length. Also, the barrier layer was thicker — 22nm. The researchers blame surface and passivation traps, arising from the passivation interface being much closer to the channel. The collapse unfortunately reduces the output RF power relative to the available DC input.

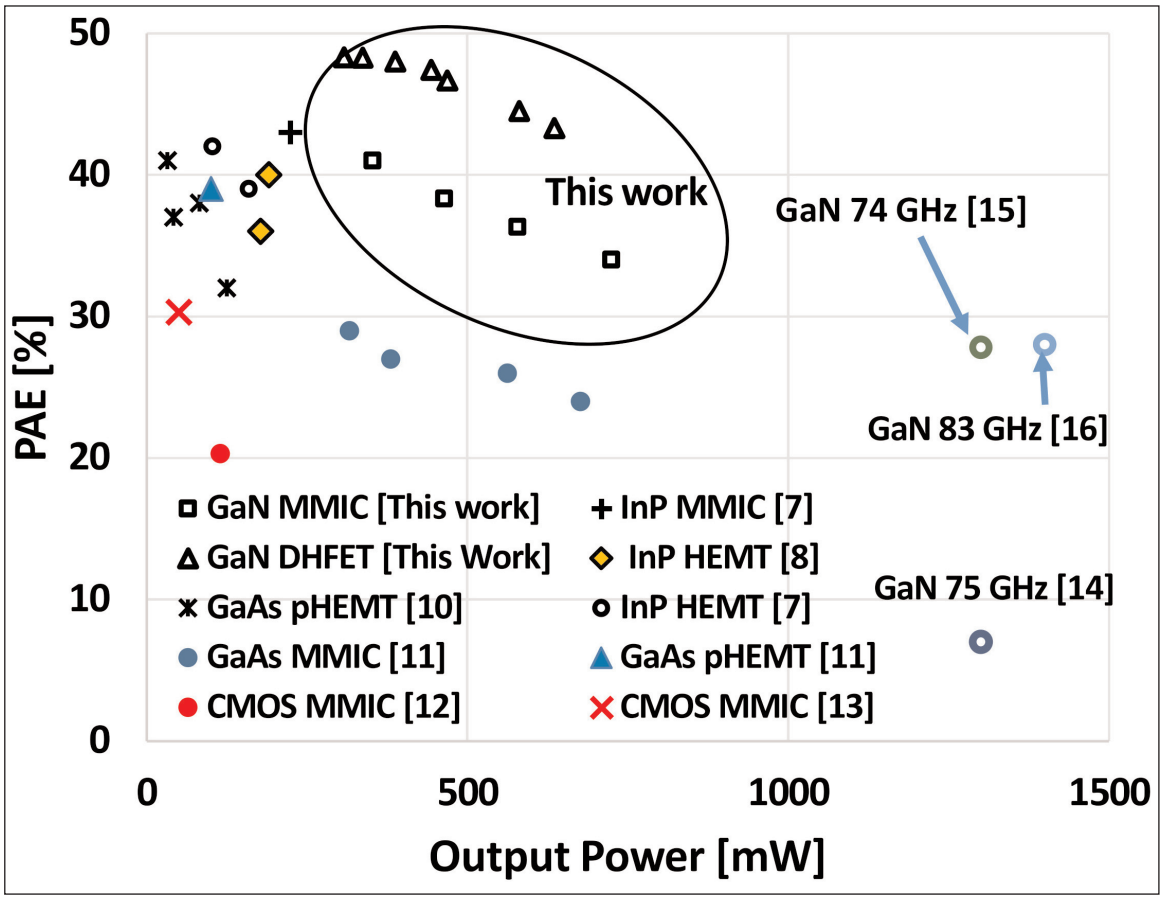


Figure 2. Comparison of V-band PAE versus output power of best reported high-efficiency transistors and MMICs.

The team comments: "Despite relatively high DC to pulsed current collapse of reported devices, we show in this work that aggressive scaling of GaN HEMT results in excellent power performance at V-band."

With 12V drain bias and 267mA/mm quiescent drain current, testing over the range 50MHz–110GHz gave cut-off and maximum oscillation frequencies of 140GHz and 280GHz, respectively.

A pre-matched 4x50μm-wide transistor circuit was used for V-band power characterization. Measurements at peak power-added efficiency (PAE) gave an output power of more than 23.5dBm (1dBm = 1mW) with associated power gain of more than 5.5dB over 57–64GHz. The maximum power of 25.5dBm was at 59GHz, where the power-added efficiency was 41%. The team states: "The circuit-level PAE of 41% compares favorably to the highest PAE numbers reported for three-terminal solid-state devices in this frequency range (InP HEMT)."

At the device level, the PAE was 48%. Further measurements and calculations gave associated drain efficiency (DE) of 57%, associated power of 26.17dBm (1.88W/mm) and associated power gain of 8.1dB. Varying the drain bias between 4V and 16V, the peak PAE was greater than 35% (45% for 6–16V).

The circuit peak PAE output power was 19dBm (0.4W/mm) at 4V drain, increasing to 27.64dBm (2.9W/mm) at 16V. At the device level, the 16V-bias output power was 28dBm (3.17W/mm) at input power drive 1 dB past the peak PAE point.

The researchers comment: "These results show that a 40nm GaN DHFET is a very attractive device for envelope-tracking V-band power amplifiers, because it maintains excellent PAE over a broad range of drain bias voltages even at fixed matching conditions." Envelope tracking adjusts the power supply in RF transmission power amplifiers to maintain peak efficiency.

The HRL devices have performance comparable with the best reported high-efficiency transistors and MMICs at V-band (Figure 2).

The team concludes: "We anticipate that power performance of the reported GaN DHFETs can be potentially improved by roughly 40% by reducing current collapse using improved surface passivation techniques." ■

https://doi.org/10.1109/LED.2017.2763940

Author: Mike Cooke

Fujitsu bonds single-crystal diamond and SiC substrate at room temperature, boosting GaN HEMT performance

Cooling efficiency improvement in power amplifier transmitter increases radar range by about 1.5x.

At the IEEE Semiconductor Interface Specialists Conference (SISC2017) in San Diego, CA, USA (6–9 December), Fujitsu Ltd and its subsidiary Fujitsu Laboratories Ltd presented what is claimed to be the first technology for room-temperature bonding of single-crystal diamond to a silicon carbide (SiC) substrate, which are both hard materials but with different coefficients of thermal expansion.

Using this technology for heat dissipation allows high-efficiency cooling of high-power gallium nitride (GaN) high-electron-mobility transistors (HEMTs), enabling stable operations of power amplifiers at high power levels.

In GaN-HEMT power amplifiers, some of the input power is converted to heat (Figure 1), which is dispersed into the SiC substrate. Since boosting the range and power in radar and wireless communications also increases the heat produced by devices, this adversely affects their performance and reliability, creating a need to efficiently carry device heat to a cooling structure (heat sink).

Although the SiC substrate has relatively high thermal conductivity, a material with even better thermal conductivity is needed for devices with increasingly higher power output to efficiently carry device heat to the cooling structure. Single-crystal diamond has extremely good thermal conductivity — almost five times that of a SiC substrate — and is known as a material that can efficiently spread heat.

To bond a single-crystal diamond to a device as a cooling material, normal production processes use an

Figure 1: Structure of conventional GaN HEMT power amplifier.

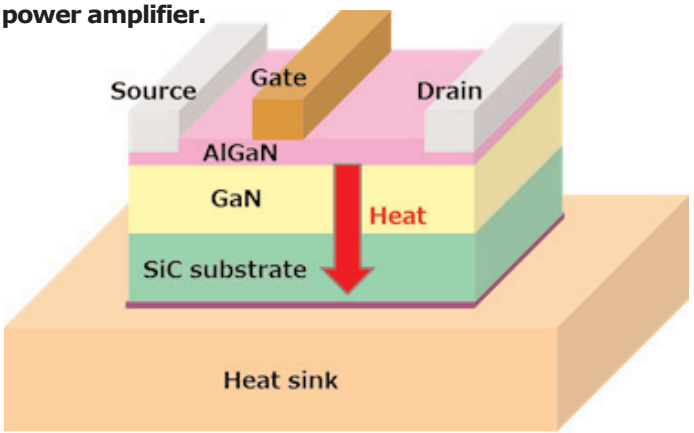
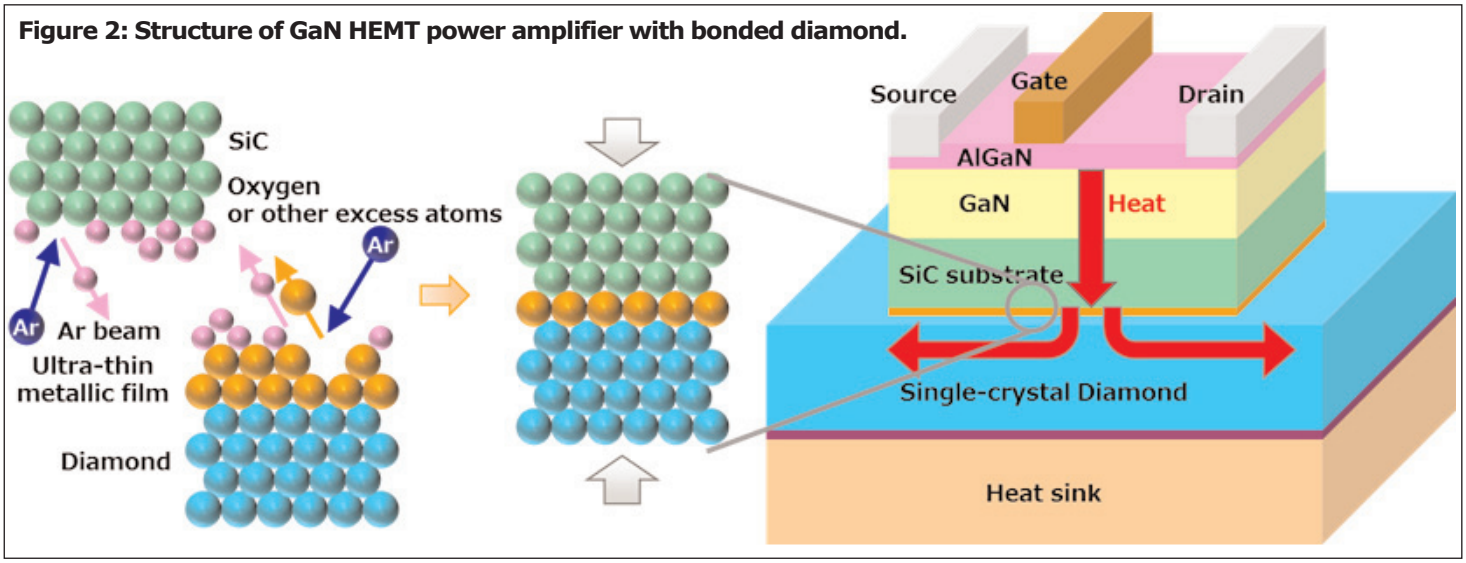


Figure 2: Structure of GaN HEMT power amplifier with bonded diamond.



argon (Ar) beam to remove impurities. However, this creates a low-density damaged layer on the surface, which weakens the bonds that the single-crystal diamond can form. Also, using an insulating film such as silicon nitride (SiN) for bonding impairs the thermal conductivity due to the thermal resistance of SiN.

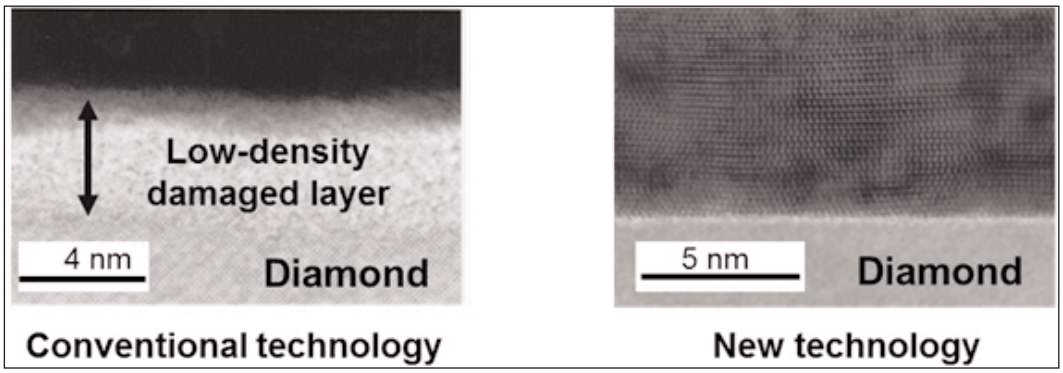


Figure 3: Diamond cross section after Ar beam exposure.

To prevent the Ar beam from forming a damaged layer on the diamond surface, Fujitsu has developed a technique that protects the surface with an extremely thin metallic film before it is exposed to the Ar beam (see Figure 2). To ensure that the surface is planar (for good bonding at room temperature), the metallic film's thickness is limited to 10nm or less.

This technology was confirmed to prevent the formation of the damaged layer on the diamond surface after Ar beam exposure (Figure 3), resulting in improved bonding strength and hence single-crystal diamond bonded at room temperature to a SiC substrate.

Thermal resistance was measured in samples bonded at room temperature, and the SiC/diamond interface was found to have an extremely low thermal resistance of $6.7 \times 10^{-8} m^2K/W$ (square-meter kelvins per watt). Simulations using this measured parameter show that this technology would significantly reduce the thermal resistance of 200W-class GaN-HEMT devices, to 61% that of existing devices (equivalent to an 80°C reduction in surface temperature) — see Figure 5.

Use of this technology hence promises to yield GaN HEMT power amplifiers for transmitters with even higher power output. When used in systems such as weather radars, GaN-HEMT power amplifiers for transmitters can be expected to increase the radar's observable range by a factor of 1.5. This would allow quicker detection of the cumulonimbus clouds that can produce sudden rainstorms, contributing to greater disaster readiness, says Fujitsu.

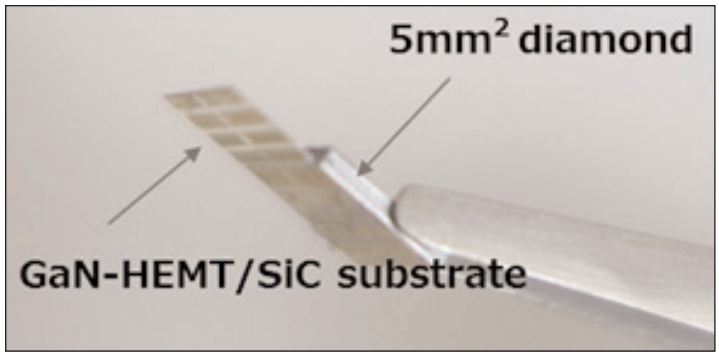


Figure 4: A GaN-HEMT/SiC substrate with diamond bonded using this technology.

Fujitsu plans to assess the thermal resistance and output performance of GaN-HEMTs using this technology, aiming to implement it in high-output, high-frequency power amplifiers in fiscal 2020, for application in weather radar and 5G wireless communications systems.

The research was conducted in part with support from the Innovative Science and Technology Initiative for Security, established by the Acquisition, Technology & Logistics Agency (ALTA) of Japan's Ministry of Defense.

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

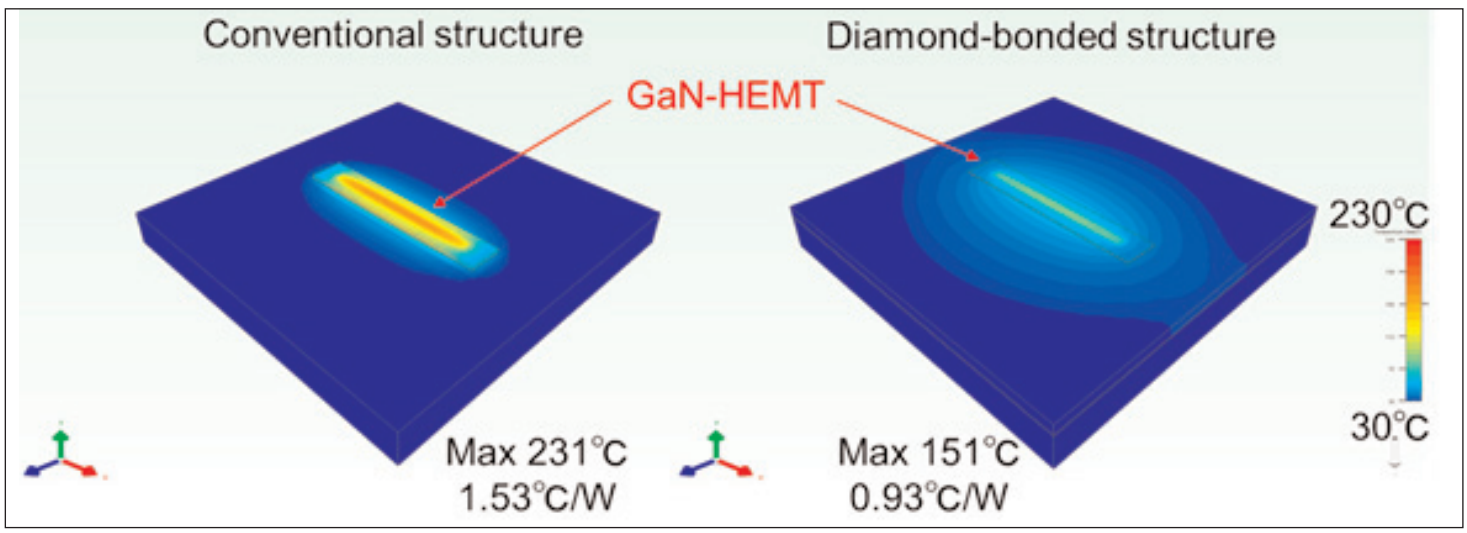


Figure 5: Simulated comparison of heat in 200W-class GaN HEMT power amplifiers.

suppliers' directory

Index

To have your company listed in this directory, e-mail details (including categories) to mark@semiconductor-today.com
Note: advertisers receive a free listing. For all other companies, a charge is applicable.

1 Bulk crystal source materials

Mining & Chemical Products Ltd (part of 5N Plus, Inc)
1-4, Nielson Road,
Finedon Road Industrial Estate,
Wellingborough,
Northants NN8 4PE,
UK
Tel: +44 1933 220626
Fax: +44 1933 227814
www.MCP-group.com

Umicore Indium Products
50 Simms Avenue,
Providence, RI 02902,
USA
Tel: +1 401 456 0800
Fax: +1 401 421 2419
www.thinfilmproducts.umicore.com

United Mineral & Chemical Corp
1100 Valley Brook Avenue,
Lyndhurst, NJ 07071,
USA
Tel: +1 201 507 3300
Fax: +1 201 507 1506
www.umccorp.com

2 Bulk crystal growth equipment

MR Semicon Inc
PO Box 91687,
Albuquerque,
NM 87199-1687,
USA
Tel: +1 505 899 8183
Fax: +1 505 899 8172
www.mrsemicon.com

3 Substrates

AXT Inc
4281 Technology Drive,
Fremont,
CA 94538,
USA
Tel: +1 510 438 4700
Fax: +1 510 683 5901
www.axt.com
Supplies GaAs, InP, and Ge wafers using VGF technology with manufacturing facilities in Beijing and five joint ventures in China producing raw materials, including Ga, As, Ge, pBN, B_2O_3.

CrystAl-N GmbH
Dr.-Mack-Straße 77,
D-90762
Fürth,
Germany
Tel: +49 (0)911 650 78 650 90
Fax: +49 (0)911 650 78 650 93
E-mail: info@crystal-n.com
www.crystal-n.com

Crystal IS Inc
70 Cohoes Avenue
Green Island, NY 12183, USA
Tel: +1 518 271 7375
Fax: +1 518 271 7394
www.crystal-is.com

Freiberger Compound Materials
Am Junger Loewe Schacht 5,
Freiberg, 09599, Germany
Tel: +49 3731 280 0
Fax: +49 3731 280 106
www.fcm-germany.com

Kyma Technologies Inc
8829 Midway West Road,
Raleigh, NC, USA
Tel: +1 919 789 8880
Fax: +1 919 789 8881
www.kymatech.com

MARUWA CO LTD
3-83, Minamihonjigahara-cho,
Owariasahi, Aichi 488-0044,
Japan
Tel: +81 572 52 2317
www.maruwa-g.com/e/products/ceramic

MARUWA is a global supplier of ceramic substrates and wafers made of aluminium nitride (AlN), alumina (Al_2O_3), ZTA and silicon nitride (Si_3N_4). Products meet required properties such as high thermal conductivity and bending strength for power devices, especially wafers are suitable as a bonding wafer (GaN, SOI) for epi wafers.

sp3 Diamond Technologies
2220 Martin Avenue,
Santa Clara, CA 95050, USA
Tel: +1 877 773 9940
Fax: +1 408 492 0633
www.sp3inc.com

Sumitomo Electric Semiconductor Materials Inc
7230 NW Evergreen Parkway,
Hillsboro, OR 97124,
USA
Tel: +1 503 693 3100 x207
Fax: +1 503 693 8275
www.sesmi.com

III/V-Reclaim
Wald 10,
84568 Pleiskirchen, Germany
Tel: +49 8728 911 093
Fax: +49 8728 911 156
www.35reclaim.de
III/V-Reclaim offers reclaim (recycling) of GaAs and InP wafers, removing all kinds of layers and structures from customers' wafers. All formats and sizes can be handled. The firm offers single-side and double-side-polishing and ready-to-use surface treatment.

Umicore Electro-Optic Materials
Watertorenstraat 33,
B-2250 Olen, Belgium
Tel: +32-14 24 53 67
Fax: +32-14 24 58 00
www.substrates.umicore.com

Wafer World Inc
1100 Technology Place, Suite 104,
West Palm Beach, FL 33407,
USA
Tel: +1-561-842-4441
Fax: +1-561-842-2677
E-mail: sales@waferworld.com
www.waferworld.com

4 Epiwafer foundry

Spire Semiconductor LLC
25 Sagamore Park Drive,
Hudson, NH 03051,
USA
Tel: +1 603 595 8900
Fax: +1 603 595 0975
www.spirecorp.com

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

Intelligent Epitaxy Technology Inc
1250 E Collins Blvd,
Richardson,
TX 75081-2401,
USA
Tel: +1 972 234 0068
Fax: +1 972 234 0069
www.intelliepi.com

IQE
Cypress Drive,
St Mellons, Cardiff
CF3 0EG,
UK
Tel: +44 29 2083 9400
Fax: +44 29 2083 9401
www.iqep.com
IQE is a leading global supplier of advanced epiwafers, with products covering a diverse range of applications within the wireless, optoelectronic, photovoltaic and electronic markets.

OMMIC
2, Chemin du Moulin B.P. 11,
Limeil-Brevannes, 94453,
France
Tel: +33 1 45 10 67 31
Fax: +33 1 45 10 69 53
www.ommic.fr

Soitec
Place Marcel Rebuffat, Parc de Villejust, 91971 Courtabouef, France
Tel: +33 (0)1 69 31 61 30
Fax: +33 (0)1 69 31 61 79
www.picogiga.com

5 Deposition materials

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

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

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

Matheson Tri-Gas
6775 Central Avenue,
Newark, CA 94560,
USA

Tel: +1 510 793 2559
Fax: +1 510 790 6241
www.mathesontrigas.com

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

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

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

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

6 Deposition equipment

AIXTRON SE
Dornkaulstr. 2,
52134 Herzogenrath,
Germany
Tel: +49 2407 9030 0
Fax: +49 2407 9030 40
www.aixtron.com

AIXTRON is a leading provider of deposition equipment to the semiconductor industry. The company's technology solutions are used by a diverse range of customers worldwide to build advanced components for electronic and optoelectronic applications (photonic) based on compound, silicon, or organic semiconductor materials and, more recently, carbon nanotubes (CNT), graphene and other nanomaterials.

Evatec AG
Hauptstrasse 1a,
CH-9477 Trübbach, Switzerland
Tel: +41 81 403 8000
Fax: +41 81 403 8001
www.evatecnet.com

Ferrotec-Temescal
4569-C Las Positas Rd,
Livermore,
CA 94551,
USA
Tel: +1 925 245 5817
Fax: +1 925 449-4096
www.temescal.net

Temescal, the expert in metallization systems for the processing of compound semiconductor-based substrates, provides the finest evaporation systems available. Multi-layer coatings of materials such as Ti, Pt, Au, Pd, Ag, NiCr, Al, Cr, Cu, Mo, Nb, SiO_2, with high uniformity are guaranteed. Today the world's most sophisticated handsets, optical, wireless and telecom systems rely on millions of devices that are made using Temescal deposition systems and components.

Oxford Instruments Plasma Technology
North End, Yatton,
Bristol, Avon BS49 4AP, UK
Tel: +44 1934 837 000
Fax: +44 1934 837 001
www.oxford-instruments.co.uk

We provide flexible tools and processes for precise materials deposition, etching and controlled nanostructure growth. Core technologies include plasma and ion-beam deposition and etch and ALD.

Plasma-Therm LLC
10050 16th Street North,
St. Petersburg, FL 33716, USA
Tel: +1 727 577 4999
Fax: +1 727 577 7035
www.plasmatherm.com

Plasma-Therm, LLC is an established leading provider of advanced plasma processing equipment for the semiconductor industry and related specialty markets.

Riber
31 rue Casimir Périer, BP 70083,
95873 Bezons Cedex, France
Tel: +33 (0) 1 39 96 65 00
Fax: +33 (0) 1 39 47 45 62
www.riber.com

SVT Associates Inc
7620 Executive Drive,
Eden Prairie, MN 55344, USA
Tel: +1 952 934 2100
Fax: +1 952 934 2737
www.svta.com

Veeco Instruments Inc
100 Sunnyside Blvd.,
Woodbury, NY 11797,
USA
Tel: +1 516 677 0200
Fax: +1 516 714 1231
www.veeco.com

Veeco is a world-leading supplier of compound semiconductor equipment, and the only company offering both MOCVD and MBE solutions. With complementary AFM technology and the industry's most advanced Process Integration Center, Veeco tools help grow and measure nanoscale devices in worldwide LED/wireless, data storage, semiconductor and scientific research markets—offering important choices, delivering ideal solutions.

7 Wafer processing materials

Air Products and Chemicals Inc
7201 Hamilton Blvd.,
Allentown, PA 18195, USA
Tel: +1 610 481 4911
www.airproducts.com/compound

MicroChem Corp
1254 Chestnut St. Newton,
MA 02464, USA
Tel: +1 617 965 5511
Fax: +1 617 965 5818
www.microchem.com

Praxair Electronics
(see section 5 for full contact details)

8 Wafer processing equipment

EV Group
DI Erich Thallner Strasse 1,
St. Florian/Inn, 4782,
Austria
Tel: +43 7712 5311 0
Fax: +43 7712 5311 4600
www.EVGroup.com
Technology and market leader for wafer processing equipment.
Worldwide industry standards for aligned wafer bonding, resist processing for the MEMS, nano and semiconductor industry.

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

Oxford Instruments Plasma Technology
(see section 6 for full contact details)

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

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

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

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

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

9 Materials & metals

Goodfellow Cambridge Ltd
Ermine Business Park,
Huntingdon,
Cambridgeshire
PE29 6WR,
UK
Tel: +44 (0) 1480 424800
Fax: +44 (0) 1480 424900
www.goodfellow.com
Goodfellow supplies small quantities of metals and materials for research, development, prototyping and specialised manufacturing operations.

10 Gas and liquid handling equipment

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

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

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

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

11 Process monitoring and control

Conax Technologies
2300 Walden Avenue,
Buffalo, NY 14225, USA
Tel: +1 800 223 2389
Tel: +1 716 684 4500
E-mail: conax@conaxtechnologies.com
www.conaxtechnologies.com
Ideas. Solutions. Success.
Conax Technologies is a designer and manufacturer of standard and custom-engineered temperature sensors, compression seal fittings and feedthroughs, probes, wires, electrodes and fiber-optic cables. The company is headquartered in Buffalo, New York, with locations on the US West Coast, Canada, Europe and Asia.

k-Space Associates Inc
2182 Bishop Circle
East, Dexter,
MI 48130,
USA
Tel: +1 734 426 7977
Fax: +1 734 426 7955
www.k-space.com
k-Space Associates Inc specializes in in-situ, real-time thin-film process monitoring tools for MBE, MOCVD, PVD, and thermal evaporation. Applications and materials include the research and production line monitoring of compound semiconductor-based electronic, optoelectronic, and photovoltaic devices.

KLA-Tencor
One Technology Dr,
1-2221I, Milpitas, CA 95035, USA
Tel: +1 408 875 3000
Fax: +1 408 875 4144
www.kla-tencor.com

LayTec AG
Seesener Str. 10–13,
10709 Berlin,
Germany
Tel: +49 30 89 00 55 0
Fax: +49 30 89 00 180
www.laytec.de

LayTec develops and manufactures optical in-situ and in-line metrology systems for thin-film processes with particular focus on compound semiconductor and photovoltaic applications. Its know-how is based on optical techniques: reflectometry, emissivity corrected pyrometry, curvature measurements and reflectance anisotropy spectroscopy.

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

12 Inspection equipment

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

13 Characterization equipment

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

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

14 Chip test equipment

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

15 Assembly/packaging materials

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

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

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

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

16 Assembly/packaging equipment

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

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

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

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

17 Assembly/packaging foundry

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

18 Chip foundry

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

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

19 Facility equipment

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

20 Facility consumables

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

21 Computer hardware & software

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

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

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

22 Used equipment

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

23 Services

Henry Butcher International
Brownlow House, 50–51
High Holborn,
London WC1V 6EG,
UK
Tel: +44 (0)20 7405 8411
Fax: +44 (0)20 7405 9772
www.henrybutcher.com

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

24 Consulting

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

25 Resources

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

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

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

event calendar

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

4–8 February 2018
IEEE International Solid-State Circuits Conference (ISSCC 2018)
San Francisco, CA, USA
E-mail: Isscinfo@yesevents.com
www.isscc.org

13–15 February 2018
Strategies in Light/The LED Show 2018
Long Beach Convention Center, Long Beach, CA, USA
E-mail: registration@pennwell.com
www.strategiesinlight.com

4–6 March 2018
Europe's SEMI Industry Strategy Symposium (ISS Europe 2018)
Clontarf Castle Hotel, Dublin, Ireland
E-mail: aniedballa@semi.org
www.semi.org/eu/iss-europe-2018

4–8 March 2018
IEEE Applied Power Electronics Conference and Exposition (APEC 2018)
San Antonio, TX, USA
E-mail: apec@apec-conf.org
www.apec-conf.org

14–16 March 2018
SEMICON China 2018
Shanghai New International Expo Centre, China
E-mail: semichina@semi.org
www.semiconchina.org

14–16 March 2018
LASER World of PHOTONICS CHINA 2018
Shanghai New International Expo Centre, China
E-mail: info@world-of-photonics-china.com
www.world-of-photonics-china.com

12–13 April 2018
UK MBE 2018 — Nottingham
University of Nottingham, UK
E-mail: i.farrer@sheffield.ac.uk
https://ukmbe.wordpress.com

15–19 April 2018
SPIE Defense + Commercial Sensing
Gaylord Palms Resort & Convention Center, Orlando, Florida, USA
E-mail: customerservice@spie.org
http://spie.org/conferences-and-exhibitions/defense--commercial-sensing

16–18 April 2018
14th International Conference on Concentrator Photovoltaics (CPV-14)
La Central Puertollano Ferial, Puertollano, Spain
E-mail: info@cpv-14.org
www.cpv-14.org

22–25 April 2018
UV LED Technologies & Applications
MELIÃ Hotel Berlin, Germany
E-mail: conference@advanced-uv.de
www.iuva.org/BerlinConference

advertisers' index

22–26 April 2018
SPIE Photonics Europe 2018
Strasbourg Convention & Exhibition Centre, France
E-mail: info@spieeurope.org
http://spie.org/SPIE_Photonics_Europe_Conference

7–10 May 2018
2018 International Conference on Compound Semiconductor Manufacturing Technology (CS ManTech)
Hyatt Regency, Austin, TX, USA
E-mail: registration@csmantech.org
www.csmantech.org

13–17 May 2018
30th IEEE International Symposium on Power Semiconductor Devices and ICs (ISPSD 2018)
Palmer House Hilton Hotel, Chicago, IL USA
E-mail: info@ispsd.org
www.ispsd2018.org

16–18 May 2018
IEEE Workshop on Wide Bandgap Power Devices and Applications in Asia (WiPDA Asia 2018)
Xi'an, Shaanxi, China
E-mail: xiaotian@xjtu.edu.cn
www.wipda-asia.org

20–24 May 2018
2018 International Power Electronics Conference (IPEC-Niigata 2018 – ECCE Asia)
TOKI MESSE Niigata Convention Center, Japan
E-mail: ipec2018@jtbcom.co.jp
www.ipec2018.org

23–24 May 2018
Imec Technology Forum (ITF Belgium 2018)
Antwerp, Belgium
E-mail: Annouck.Vanrompay@imec.be
www.itf2018.com/en

5–7 June 2018
PCIM Europe (Power conversion and Intelligent Motion) 2018
Nuremberg Messe, Germany
E-mail: daniela.kaeser@mesago.com
www.mesago.de/en/PCIM/main.htm

12–14 June 2018
ANGACOM 2018 Exhibition & Congress for Broadband, Cable and Satellite
Messe Köln, Cologne, Germany
E-mail: info@angacom.de
www.angacom.de/en.html

18–22 June 2018
2018 IEEE Symposium on VLSI Technology and Circuits
Hilton Hawaiian Village,
Honolulu, HI, USA
E-mail: vlsi@vlsisymposium.org
www.vlsisymposium.org

20–22 June 2018
Intersolar Europe 2018
Messe München,
Munich, Germany
E-mail: info@intersolar.de
www.intersolar.de

24–29 June 2018
IEEE 45th Photovoltaic Specialists Conference (PVSC 2018)
Washington DC, USA
E-mail: info@ieee-pvsc.org
www.ieee-pvsc.org

9–11 July 2018
IEEE Photonics Society's 2018 Summer Topicals Meeting Series
Waikoloa, Hawaii, USA
E-mail: i.donnelly@ieee.org
www.sum-ieee.org

10–12 July 2018
Intersolar North America
San Francisco, CA, USA
E-mail: info@intersolar.de
www.intersolar.us

19–23 August 2018
SPIE Optics + Photonics 2018
San Diego Convention Center, California, USA
E-mail: customerservice@spie.org
http://spie.org/Optics_Photonics

17–21 September 2018
EPE'18 ECCE Europe (20th European Conference on Power Electronics and Applications)
Riga, Latvia
E-mail: info@epe2018.com
www.epe2018.com

23–28 September 2018
13th European Microwave Integrated Circuits Conference (EuMIC 2018), part of 21st European Microwave Week (EuMW 2018)
IFEMA, Madrid, Spain
E-mail: eumwreg@itnint.com
www.eumweek.com/conferences/eumic.html

semiconductorTODAY

COMPOUNDS & ADVANCED SILICON

www.semiconductor-today.com

Join our LinkedIn group: Semiconductor Today

Follow us on Twitter: Semiconductor_T

Choose *Semiconductor Today* for . . .

MAGAZINE

Accurate and timely coverage of the compound semiconductor and advanced silicon industries

Targeted 82,000+ international circulation

Published 10 times a year and delivered by e-mail and RSS feeds

WEB SITE

Average of over 26,000 unique visitors to the site each month

Daily news updates and regular feature articles

Google-listed news source

E-BRIEF

Weekly round-up of key business and technical news

E-mail delivery to entire circulation

Banner and text marketing opportunities available