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semiconductorTODAY

COMPOUNDS & ADVANCED SILICON

Vol. 12 • Issue 4 • May/June 2017

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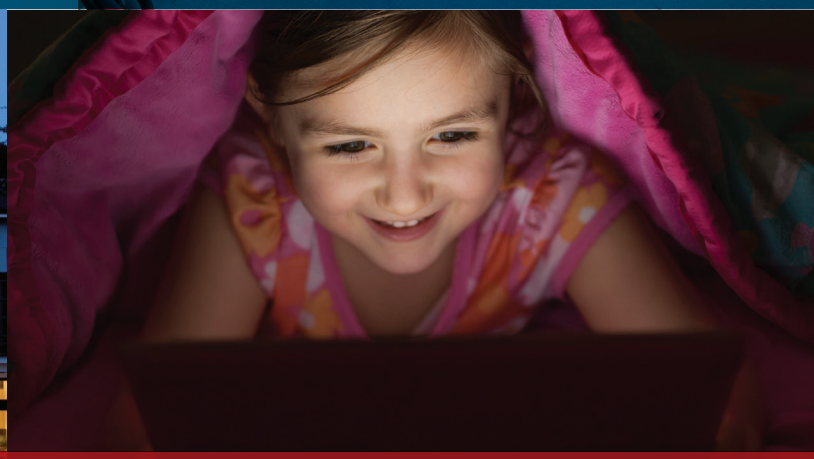
Umicore expands production in Germany

Aixtron selling ALD/CVD memory line • IMS & PCIM Europe 2017
Cree chairman & CEO stepping down • Siva Power raises $25m

Lower Cost LEDs



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

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Veeco's New TurboDisc EPIK700 GaN MOCVD System

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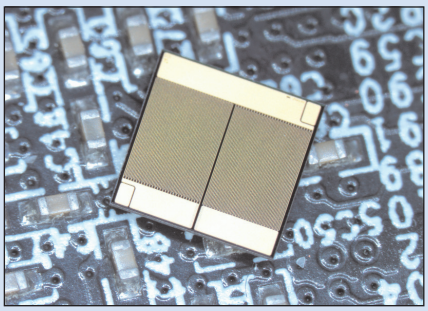
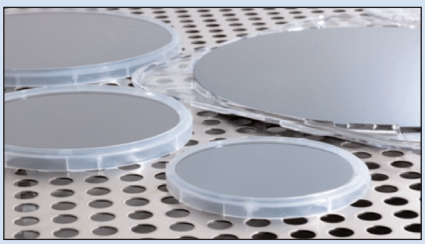


p22 Fraunhofer IAF has claimed the first monolithically integrated half-bridge circuit for the 600V class.



p32 EpiGaN has showcased the latest enhancements of its GaN-on-Si epi family for 650V HEMTs.

p43 EVG is expanding production capacity at its corporate headquarters in Austria.

Cover: Umicore's business unit Precious Metals Chemistry in Germany has inaugurated its production unit for metal-organic precursor technologies used in the semiconductor and LED markets, respectively TMGa (trimethylgallium) and TEGa (triethylgallium). **p39**

editorial

Convergence and integration

In this issue we report further news from the Power Conversion and Intelligent Motion (PCIM) Europe event in mid-May (pages 17–24) and from the IEEE MTT International Microwave Symposium (IMS) in June (pages 25–27), which are increasingly focusing on wide-bandgap semiconductors including (respectively) silicon carbide for power module applications and gallium nitride on silicon (GaN-on-Si) for RF & power applications (as exhibited by MACOM, for example). According to ABI Research, GaN's share of RF high-power semiconductor revenue is forecasted to double over 2016–2022, becoming the main technology in wireless infrastructure (slotting between the high-frequency performance of GaAs and power handling capabilities of silicon LDMOS) — see page 7.

Such high-frequency, high-power-density devices are driving the development and use of CVD diamond material (to exploit its electrical and thermal conductivity), such as that provided by AKHAN Semiconductor and Element Six (see page 33). The market for diamond materials for semiconductor applications will rise at a compound annual growth rate (CAGR) of over 19% over 2017–2021, forecasts Technavio (page 8).

GaN MMIC development is also driving the design and thermal analysis of not only circuits but also packages, as exemplified by Europe's MAGNUS project, which is using the EDA software of NI AWR (see page 31), whose Version 13.02 of its Design Environment suite is now available, focusing on highly integrated RF/microwave components (page 34). In addition, StratEdge has expanded its family of high-power laminate copper-moly-copper (CMC) base packages to include both GaN transistor and MMIC device packages and package assembly services, accommodating larger die sizes and higher frequencies, up to 63GHz (page 36).

Packaging is also an area of expansion for thin-film etch & deposition process equipment maker Veeco Instruments, having completed its acquisition of Ultratech, which makes lithography, laser-processing and inspection systems for manufacturing both LEDs and microelectronic devices, including advanced packaging (see page 38).

Meanwhile, fellow MOCVD system maker Aixtron is selling its US-based atomic layer deposition (ALD) and chemical vapor deposition (CVD) memory product line (to a US subsidiary of South Korea's Eugene Technology) as it refocuses on core business.

In addition to power & RF microelectronic applications and optoelectronic applications, the rebound in the MOCVD market is being driven by rising demand for LED lighting, as evidenced by increased MOCVD equipment utilization rates in the Asia-Pacific region. According to Technavio, the MOCVD market is increasing at a CAGR of 14% over 2017–2021, rising from $614.8m in 2016 to $1162.8m in 2021 (see page 6), citing production capacity expansions planned by several Chinese LED makers in particular.

A key development where both microelectronics and optoelectronics and wafer processing and packaging converge is where III-V materials are being grown on silicon, or where different types of III-V devices are being integrated on the same substrate. In this issue we cover developments in GaN power devices on silicon (pages 98–99), III-V photodetectors on silicon (pages 86–87 and 88–89), direct growth of lasers on silicon (pages 76–77), the monolithic integration of amber-green-blue LEDs on unpatterned sapphire (pages 94–95), and finally the monolithic integration of GaN vertical transistors and LEDs on patterned sapphire (pages 96–97).

Mark Telford, Editor

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

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- conference reports;
- event calendar and event previews;
- suppliers' directory.

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HVM: High Volume Manufacturing

MOCVD market growing at 14% CAGR to 2021

Equipment utilization up in Asia Pacific, driven by LED lighting market

The global metal-organic chemical vapor deposition (MOCVD) market is increasing at a compound annual growth rate (CAGR) of 14% over 2017–2021, rising from $614.8m in 2016 to $1162.8m in 2021, according to a report by Technavio.

Since MOCVD is used to produce high-brightness LEDs, it is expected that the increasing demand for high-brightness LEDs will fuel growth. "There are different factors driving the global MOCVD market growth, of which the increasing demand for high-brightness LEDs in the global LED lighting market is the major one," says Sunil Kumar Singh, a lead analyst specializing in research on semiconductor equipment sector. "The rapid decline in the average selling price (ASP) of LEDs has led to an increase in the adoption of LEDs for lighting applications."

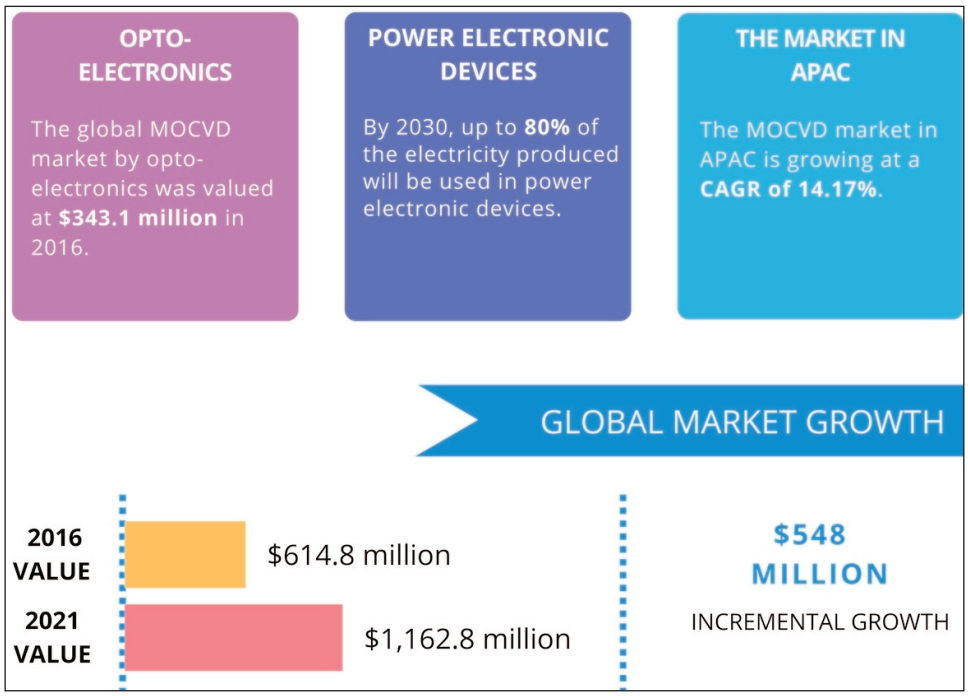
Furthermore, the increasing demand for renewable sources of energy such as solar energy is another major driver. Semiconductor manufacturers are using MOCVD to manufacture high-efficiency triple-junction photovoltaic cells that can maximize the efficiency of photovoltaic cells in converting sunlight to electricity.

According to Technavio, the top three emerging trends driving the MOCVD market are as follows.

The need for energy conservation

Vendors offer various power electronic devices for a range of applications, with the main focus being energy conservation. Many vendors are engrossed in increasing power density, affecting the cost of power electronic devices and associated applications. The cost is expected to increase during the forecast period.

"The increase in power density leads to an increase in the power efficiency of the devices, thus helping end-users conserve energy," says Sunil. "Depletion and rising cost of fossil fuels make energy conservation a requirement and a trend that can trigger the market growth over the next few years."



Chinese LED makers such as Tsinghua Tongfan, HC SemiTek, Hangzhou Silan Azure Technology, and Zhongke Semiconductor Lighting have production capacity expansion plans in the country by 2020

Emergence of high-powered electronic devices

Consumers of electronic devices have high expectations, wanting products that are fast, innovative, lightweight, energy-efficient, and small. For silicon, all these demands are tough to achieve without compromising on performance. It has already reached its saturation stage, says Technavio.

Gallium nitride (GaN)-based devices have opened up new opportunities for users and vendors alike. For users, GaN offers high-powered electronics that are mobile, prompt, energy-efficient, and save on time.

Increasing MOCVD equipment utilization rates in APAC

Increasing lighting demands and the subsidies offered by local governments on MOCVD equipment in the Asia Pacific (APAC), particularly in China, present strong growth potential for the global MOCVD equipment market. The increasing demand for LED-based components and accessories such as LED-based displays, along with the increasing demand for LEDs in the general lighting segment, has increased the MOCVD equipment utilization rate in APAC.

For instance, Chinese LED makers such as Tsinghua Tongfan, HC SemiTek, Hangzhou Silan Azure Technology, and Zhongke Semiconductor Lighting have production capacity expansion plans in the country by 2020.

www.technavio.com/report/global-semiconductor-equipment-global-mocvd-market

UV LED market growing at 34% CAGR from $288m in 2017 to $526m in 2020

South Korean and Japanese suppliers dominant, but Taiwanese blue LED makers turning to higher-growth UV LED market

The global UV LED market will increase from $288m in 2017 to $526m in 2020 while it rises at a compound annual growth rate (CAGR) of 34% during 2015–2020, projects LEDinside (a division of TrendForce).

UV LEDs are used particularly in industry for curing, printing, exposure and other major applications, maintaining strong demand that is expected to grow further as most countries worldwide have endorsed energy-saving policies and ratified the Minamata Convention on mercury.

"The largest source of revenue for UV LED suppliers in 2016 was the sales of UV-A LEDs," notes research manager Joanne Wu. "Because UV-A LEDs are mainly used for curing, some UV LED suppliers have entered the curing module market to further increase their profitability in this business."

LED companies from South Korea and Japan were the dominant UV LED package suppliers by revenue in 2016. The top five were Nichia, Nitride Semiconductors, Seoul Viosys, LG Innotek and USHIO/Epitex. However, in 2017 South Korean LED companies are launching new series of UV-C LED products, contributing to growth in South Korean suppliers' revenues and possibly affecting this ranking.

Taiwanese LED firms are also keen to move away from the highly competitive blue LED market and into the UV LED market due to the higher growth potential, notes the report.

For example, Lextar has released UV LEDs for curing and printing applications. The firm is expected to accelerate product development and grow its client base this year. Likewise, LED chip maker High Power Lighting (HPL) and package supplier Epileds have formed a joint venture company Bioraytron that sells branded UV-C LED products. Bioraytron will also launch new UV-C LED products in second-half 2017, and HPL anticipates that 30% of its annual revenue for 2017 will come from UV LEDs.

Looking at demand by applications, the largest segment of demand for UV-A LEDs comes from curing. UV printing systems need LED modules that can produce a high level of irradiance, while UV exposure machines require LED modules that can achieve a high level of collimated light. In addition, UV LEDs are also being deployed in some special curing applications that have recently emerged on the market.

Finally, recent technical advances in UV-LED manufacturing have allowed them to be deployed in more applications, including consumer appliances such as air conditioners, air purifiers and still-water purifiers, which may be first to reach the consumer market, concludes the report.

www.ledinside.com

GaN to drive its share of RF high-power semiconductor revenue to more than double by 2022

Overall RF high-power semiconductor market exceeded $1.4bn in 2016 despite wireless infrastructure sector continuing to flatten

Spending on RF high-power semiconductors for the wireless infrastructure markets continues to flatten out in 2017, despite the fact that the overall market hit well over $1.4bn in 2016, according to ABI Research. While certain market and sub-market segments are showing moderate growth, gallium nitride (GaN) is capturing meaningful market share of RF high-power semiconductors, especially in wireless infrastructure. The technology will drive GaN's share of RF power semiconductor revenue to more than double between 2016 and 2022.

"GaN is again increasing its market share in 2017, and we believe it will be the major technology force in wireless infrastructure RF high-power semiconductors by 2022," says research director Lance Wilson. "This now mainstream technology bridges the gap between two older technologies, exhibiting the high-frequency performance of gallium arsenide and power handling capabilities of silicon LDMOS," he adds.

Outside of wireless infrastructures in the RF high-power semiconductor business, defense-oriented and commercial avionics/air traffic control (ATC) market segments show the strongest performance.

"Despite the ongoing poor press for defense-oriented electronic hardware, the actual performance in 2016 was better than originally thought for some sub-segments," says Wilson. "In total, the defense-oriented and commercial ATC segments will be a significant long-term market and one to keep an eye on moving forward."

www.abiresearch.com/research/service/high-power-rf-active-devices

Diamond materials market to increase at a compound annual growth rate of 19.26% to 2021

The market for global diamond materials for semiconductor applications will rise at a compound annual growth rate (CAGR) of 19.26% over 2017–2021, forecasts a report by Technavio.

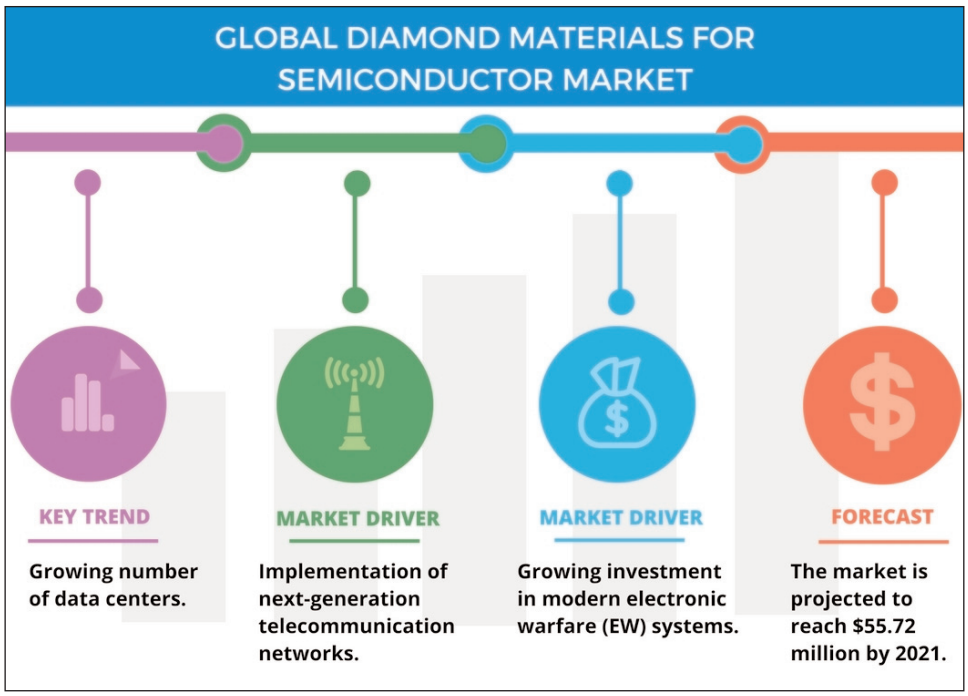
Diamond materials for semiconductors are crystalline or amorphous solids with conductivity between conductors and insulators, making them a good medium for the control of electric current. "The use of diamond as a material in the semiconductor industry is gaining the attention of semiconductor manufacturers because of its unique properties such as biocompatibility, exceptional hardness, excellent hole and electron mobility, high stiffness, low friction, and outstanding thermal conductivity," notes Raghu Raj Singh, a lead semiconductor equipment research analyst at Technavio.

As the miniaturization of electronic devices is leading to the development of compact and high-performance semiconductor components (active and passive), a large amount of heat is generated within electronic devices, leading to low performance. As well as exceptionally high thermal diffusivity diamond also has greater thermal conductivity than the other semiconductor materials.

According to the report 'Global Diamond Materials for Semiconductor Market 2017–2021', the top three emerging trends driving the market are as follows.

Growing number of IoT devices

Different vendors across the market are working collectively to address the need of connecting several products such as gateways, home appliances, and entertainment systems for smart homes, sensors, and set-top boxes (STBs) with a common networking standard that provides interoperability with the widest range of smart devices. One of the alliance is AllSeen Alliance, which was founded in 2013 with an objective to create a larger ecosystem of vendors and products.



"Since diamond materials have higher electron mobility and higher thermal conductivity, the manufacturers will adopt diamond materials for IC fabrication." says Raghu. "This will provide consumers high-performance devices, which will run higher-bandwidth applications at a faster speed without degrading the performance of the device."

Growing number of data centers

With the rise of M2M (machine-to-machine) communication, Internet of Things (IoT) applications are generating a tremendous amount of new data every minute that must be managed, retrieved and stored between an enormous number of data centers located around the world. The increasing amount of data in the cloud necessitates the development of data centers.

The growing number of data centers is driving demand for high-performance electronic modules that could address the need for increasing bandwidth and minimize the cost associated with power consumption and cooling. Data centers consume about 3% of global electricity consumption, and this is expected to grow with increasing adoption of cloud computing platforms.

Connected cars

Growing demand for safety features in automotive vehicles has forced automotive OEMs to give high importance to the safety features in their vehicles. This is acting as a major driver of demand for the integration of smart features into vehicles. Automotive OEMs are hence providing connectivity solutions in their vehicles that incorporate communication technologies in order to create an automatic system.

The report states that key vendors include AKHAN Semiconductor, Advanced Diamond Technologies, Element Six, IIa Technologies, Morgan Technical Ceramics, and Sumitomo Electric. Other prominent vendors include Diamond Materials, Evince Technology, Microwave Enterprises, NeoCoat, and Scio Diamond Technology.

www.technavio.com/report/global-diamond-materials-for-semiconductor-market

www.wiseguyreports.com/sample-request/1339060-global-diamond-materials-for-semiconductor-market

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Qorvo launches first high-power BAW filter for 5G

Qorvo Inc of Greensboro, NC, USA (which provides core technologies and RF solutions for mobile, infrastructure and defense applications) has launched what it claims is the smallest bulk acoustic wave (BAW) filter available that can handle 5W of RF average input power, with peaks up to 40W. The new filter is said to solves reliability, assembly, test and space constraint challenges involved in designing massive MIMO telecom infrastructure for 5G migration.

Telecom providers are implementing massive MIMO equipment to boost LTE networks and prepare for 5G performance in large traffic areas. This results in additional capacity and better signal quality, and improves usage of the existing network spectrum, says Qorvo.

The QPQ1300 leverages the firm's solidly mounted resonator (SMR) BAW technology, which supports the highly reliable thermal power dissipation required for massive MIMO infrastructure equipment. At 5mm x 5mm x 1mm, it also represents a 90% saving in space over ceramic filters, it is reckoned. The QPQ1300 is optimized for 2575–2635MHz, a sub-band for Band 41. Prototype samples are available now to qualified customers.

"The size and power-handling capabilities of the QPQ1300 differentiate it from every other filter on the market," reckons James Klein, president, Qorvo Infrastructure and Defense Products. "Smaller filters enable telecom equipment manufacturers to design printed circuit boards for space-constrained applications such as massive MIMO in order to improve network capacity using existing LTE network infrastructure."

The QPQ1300 expands Qorvo's line of BAW filters for base stations, which solve difficult interference and coexistence challenges worldwide. They also enable operators and manufacturers to deliver higher speeds and greater bandwidth with more efficient use of existing spectrum, the firm adds.

Qorvo showcased its wireless infrastructure products at the IEEE MTT International Microwave Symposium (IMS 2017) in Honolulu, Hawaii (4–9 June).

www.ims2017.org
www.qorvo.com/innovation/technology/baw

Qorvo's new Wi-Fi bulk acoustic wave filters triple range for smart home and enterprise applications

Qorvo has announced new bulk acoustic wave (BAW) filters that greatly expand Wi-Fi range and coverage in smart home and enterprise applications. The products enable the maximum power allowed by the Federal Communications Commission (FCC) in the industrial, scientific & medical (ISM) band, delivering more capacity and resulting in improved service quality for consumers, organizations and internet service providers, says Qorvo.

Leveraging the firm's BAW technology, the new band-edge and coexistence Wi-Fi filters address the stringent thermal challenges of multi-user multiple-input/multiple-output (MU-MIMO) systems, without compromising harmonic compliance and emissions performance (critical for reliable coverage across the full allocated spectrum). They also offer size reductions to help designers create smaller, more attractive end-user devices for homes and office environments, says Qorvo.

"A high proportion of the more than 1.5 billion Wi-Fi-enabled smartphones that will ship this year will be able to operate in Western Europe, China, and/or North America using LTE B7, B38, B40, or B41," according to Christopher Taylor, director of RF & Wireless Components at market research firm Strategy Analytics. "These bands lie directly above and below the 2400–2483MHz global Wi-Fi band, requiring compact, low-temperature-drift filters to prevent interference between Wi-Fi and LTE. Qorvo's filters meet the needs of the mobile and customer premises markets very effectively," he comments.

Qorvo claims to be the only supplier of band-edge bulk acoustic wave filters at 2.4GHz

"Qorvo has shipped 1 billion cellular coexistence filters optimized for consumer premises use and power handling," says Cees Links, general manager of Qorvo's Wireless Connectivity business. "These new band-edge and coexistence filters expand our product line and deliver the highest quality of service in high-density environments. Qorvo offers the most compact and most efficient solutions for MU-MIMO configurations of Wi-Fi networks," he claims. "Designers no longer have to compromise on issues of performance or size, and consumers can connect to more devices across triple the range."

Band-edge and coexistence filters improve quality of service for Wi-Fi systems. Band-edge filters allow systems to maintain maximum power and capacity for all channels in the Wi-Fi band. Qorvo claims to be the only supplier of band-edge BAW filters at 2.4GHz. Coexistence filters separate Wi-Fi signals from adjacent LTE signals to avoid interference. When maximum power for all Wi-Fi channels and LTE coexistence is required, both filters can be used together.

www.qorvo.com/products/integrated-modules/wifi

Qorvo's 28GHz RF products available for 5G base stations

Qorvo has announced broad commercial availability of four 28GHz RF products for 5G base stations. The optimized architectures leverage its field-proven gallium nitride on silicon carbide (GaN-on-SiC) and gallium arsenide (GaAs) process technologies to deliver performance in miniaturized product footprints.

"Qorvo has collaborated with leading telecom OEMs to support more than 20 5G field trials worldwide," says Roger Hall, general manager of Qorvo's High Performance Solutions business unit. "With the broad availability of our 28GHz portfolio, telecom providers can leverage the performance, low noise, high efficiency and small footprint of Qorvo's field-proven line-up to quickly and cost-effectively deploy 5G millimeter-wave networks."

The 28GHz range includes the QPC1000 phase shifter, which integrates phase resolution with the ability to switch between transmit/receive functions; two transmit products (the TGA4030-SM GaAs medium-power amplifier/multiplier and the TGA2594 GaN-on-SiC power amplifier); and the QPA2628 GaAs low-noise amplifier. Qorvo says that the complete suite of 28GHz transmit and receive solutions improves power efficiency and optimizes size to help telecom equipment providers build out 5G trial systems and accelerate the deployment of full millimeter-wave 5G base-station networks.

According to Joe Madden, founder of industry research firm Mobile Experts, the deployment of 5G will enable mobile operators to deliver mobile data more cost effectively. Madden reckons it costs operators over $1000 to deliver 1Mb/s of LTE network capacity, and 5G is expected to reduce operator costs significantly. "Our cost model tells us that 5G should be able to achieve a 10x reduction in cost per bit, compared with LTE," Madden says.

First dual-channel GaN front-end module for 39GHz 5G wireless

Qorvo has launched what it claims is the first gallium nitride on silicon carbide (GaN-on-SiC) front-end module (FEM) for the 39GHz 5G frequency band (37–40.5GHz). The firm says that the FEM's unique design — a small footprint of 4.5mm x 6mm in an AC-EHSL package that integrates two multi-function GaN monoltihic microwave integrated circuits (MMICs) — addresses the complex challenges faced by telecom equipment manufacturers designing 5G base stations.

"Continuing advances in mobile device technology and applications will require network infrastructure to support ever-increasing data rates and significantly lower latencies," comments Eric Higham, director of Strategy Analytics' Advanced Semiconductor Applications Service. "FEMs such as the Qorvo QPF4005 address challenges of next-generation millimeter-wave systems," he adds.

The first dual-channel GaN front-end module for 39GHz is a key enabler for 5G fixed wireless networks," reckons James Klein, president, Qorvo Infrastructure and Defense Products. "The QPF4005 combines our millimeter-wave expertise and field-proven GaN-on-SiC process technology to help telecom providers quickly and cost-effectively deliver more data to homes and mobile hotspots."

Built on Qorvo's highly efficient 0.15μm GaN-on-SiC technology, the dual-channel QPF4005 integrates two identical, multi-function GaN MMICs into a small footprint, optimized for phased-array element spacing at 39GHz. Each of the MMICs contains a three-stage low-noise amplifier, a low-loss single-pole, double-throw (SPDT) transmit/receive switch and a three-stage power amplifier.

Engineering samples of the 39GHz QPF4005 FEM are available now.

www.qorvo.com/gan

Skyworks' latest Bluetooth Low Energy/802.15.4/Thread/ZigBee FEM

Skyworks Solutions Inc of Woburn, MA, USA has launched the SKY66113-11, its newest 2.4GHz fully integrated RF front-end module (FEM) supporting Bluetooth Low Energy/Bluetooth Smart, 802.15.4, Thread and ZigBee applications.

The new high-performance device is claimed to be the world's most efficient front-end solution for Internet of Things (IoT) applications, especially within the connected home, wearable and industrial markets. It is suitable for voice assistants, sensors, beacons, smart watches, thermostats, wireless cameras/headphones, medical pendants, hearing aids etc.

The FEM includes an integrated high-gain, low-noise amplifier (LNA) with transmit bypass path and digital controls and operates on a wide supply voltage range from 1.7V to 3.6V, allowing for use in a broad spectrum of battery powered applications.

The solution also more than doubles the wireless range compared with a standalone system-on-chip (SoC) and boasts a fast switch-on/off time within a compact footprint (16-pin, 2.4mm x 2.4mm x 0.8mm package). Compared with the performance of a SoC solution alone, the new SKY66113-11 FEM delivers a receive sensitivity boost of up to 7dB improvement.

www.skyworksinc.com/Product/3153/SKY66113-11

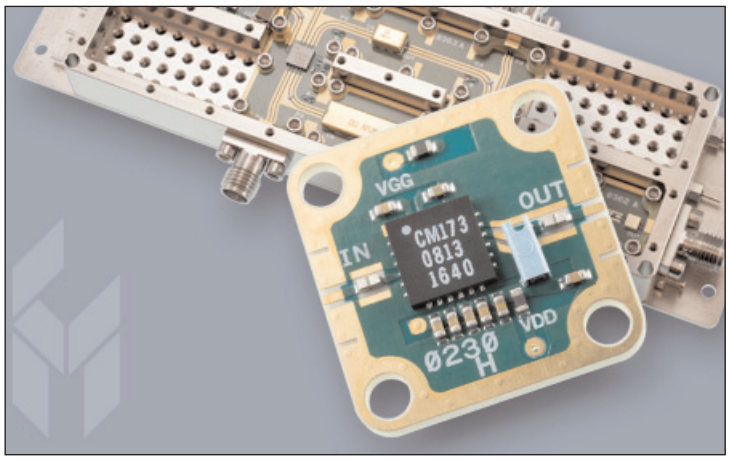
Custom MMIC expands partnership with X-Microwave

More than 35 MMICs added to modular simulation, prototyping and production system

Monolithic microwave integrated circuit developer Custom MMIC of Westford, MA, USA has announced an expanded collaboration with X-Microwave LLC, a developer of a modular/drop-in simulation, prototyping and production system for solderless and reconfigurable RF/microwave circuits up to 67GHz. The X-MWblock system enables efficient and expedient microwave and millimeter-wave circuit development and testing, using industry-grade non-linear online simulation tools powered by Keysight's Genesys Spectrasys engine.

The expanded partnership will bring over 35 of Custom MMIC's low-noise amplifiers (LNAs), power amplifiers (PAs), distributed amplifiers, driver amplifiers, low-phase-noise amplifiers, phase shifters, switches and mixers to the X-Microwave system. The firms plan to add more of the 100-plus products available from Custom MMIC to the X-MWBlock system in the near future.

"Their X-MWsystem is a cost-effective, rapid prototyping system which saves our customers in development time and expense,"



comments Custom MMIC's VP sales & marketing John Greichen.

X-Microwave's system leverages a unique grid-based modular architecture that facilitates drop-in component configuration of a complete RF, microwave or millimeter-wave system. Initially, the X-Parameter and S-Parameter models of each X-MWblock can be assembled and analyzed in X-Microwave's free online system simulation tool. Once the desired performance is achieved, the necessary X-MWblock components can be purchased with a modular prototype platform. After testing and verification, these same components can be seamlessly integrated into a final production assembly housing. The X-MWsystem provides what is claimed to be unprecedented ease of simulation, design, prototyping and integration of microwave and millimeter-wave components, such as Custom MMIC's widbroade range of RF and microwave MMICs.

"Custom MMIC products, such as their latest low-phase-noise packaged amplifiers to 22GHz and in die form to 40GHz, are filling industry gaps and are exciting additions to our portfolio of drop-in components," comments X-Microwave's founder & president John Richardson.

Custom MMIC's products easily work within the X-Microwave modular platform, and provide distinct features that even further reduce system design time and complexity, it is claimed.

www.xmicrowave.com

Custom MMIC receives Raytheon 4-Star Supplier Excellence Award

Custom MMIC received a 4-Star Supplier Excellence Award from Raytheon Company of Waltham, MA during the Raytheon Integrated Defense Systems (IDS) 2017 Supplier Excellence Conference in Boston, MA on 2 May.

Raytheon IDS business of Tewksbury, MA instituted the Supplier Excellence Award to recognize suppliers that have provided outstanding service and partnership in exceeding customer requirements. Award candidates are judged on certain criteria, including overall quality and on-time delivery. Custom MMIC

was one of 84 companies recognized by Raytheon's Integrated Defense Systems business for 4-Star honors.

"Our team strives continually to provide Raytheon with timely, innovative solutions to address system challenges and reduce cost," says Custom MMIC's VP operations Dave Folding. "Collectively, our number-one goal is to support our service men and women with market-leading products to enable mission assurance in the field," he adds.

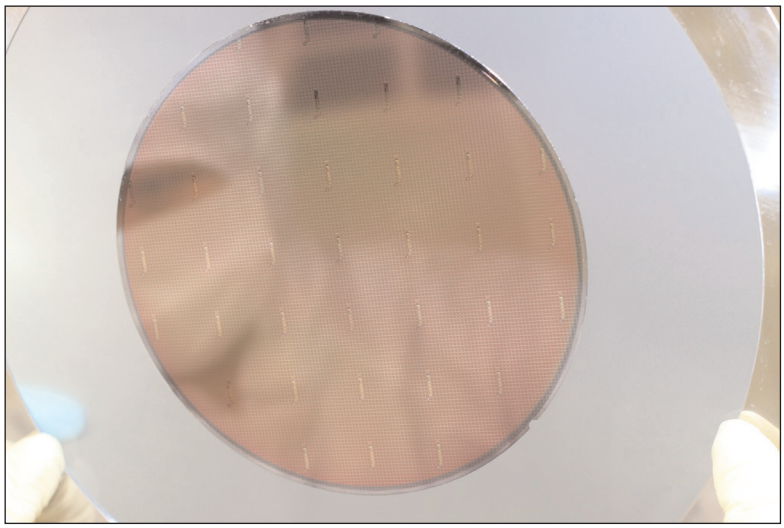
www.custommmic.com

WIN develops 150mm GaAs PIN diode MMIC process

Flexible 3µm process targets high-frequency switch and limiter applications where GaAs PIN diodes provide performance advantages

WIN Semiconductors Corp of Taoyuan City, Taiwan — the largest pure-play compound semiconductor wafer foundry — has developed a gallium arsenide (GaAs) PIN diode MMIC process for high-frequency switch and monolithic power limiter applications. Fabricated on 150mm semi-insulating GaAs wafers, the 3µm i-layer PIN diodes are said to offer several performance advantages including near-constant junction capacitance through 50GHz, low insertion loss, and high isolation required for high-frequency applications.

The PIN3-00 GaAs PIN diode MMIC process uses a humidity-robust architecture with low-k dielectric crossovers, and three interconnect metal layers with up to 7µm-thick gold (Au) metallization for high Q-factor passive elements. Standard through-wafer vias enable flexible ground connections and optional RF hot via supports placement of RF ports on the backside of the MMIC.



WIN Semiconductors' 3µm PIN diode MMIC GaAs wafer.

"This advanced PIN diode MMIC fabrication process offers significant design flexibility for multiple applications and end-markets," says senior VP David Danzilio. "The PIN3-00 process can be used for receive-path limiters in radar Tx/Rx modules, power switching as well as high-frequency 5G switch functions," he adds. "WIN is the first compound semiconductor foundry to offer this high-performance technology on 150mm wafers, and at the scale required for high-volume markets," claims Danzilio.

www.winfoundry.com

IXYS' MwT launches GaAs/AlGaAs pHEMT MMIC high-power amplifier for wireless 4G/5G infrastructure

MicroWave Technology Inc (MwT) of Fremont, CA, USA (a division of IXYS Corp that makes RF and microwave discrete devices, MMICs, hybrid modules and connecterized amplifiers for wireless communication infrastructure, military/aerospace, industrial and medical applications) has launched its gallium arsenide/aluminium gallium arsenide (GaAs/AlGaAs) pseudomorphic high-electron-mobility transistor (pHEMT)-based Ka-band monolithic microwave integrated circuit (MMIC) high-power amplifier, which has been used by a major wireless communication equipment manufacturer for high-data-rate links in 4G/5G wireless infrastructure applications.

The MMA-273336-M5 Ka-band MMIC power amplifier is a standard MMIC product available in volume production. Operating at 27–33GHz, it provides a P1dB (output power at a 1dB gain compression point) of 35dBm (over 3W) and what is claimed to be an exceptional P3dB (output power at a 3dB gain compression point) of 36dBm (4W). Typical small-signal gain is 22dB across the band. The level of third-order intermodulation (IM3) distortion is –40dBc at 20dBm output power per tune. The DC bias conditions are 6V and 2.8A on the drain and –0.9V on the gate.

"The applications of this MMIC high-power amplifier include 4G/5G wireless infrastructure, very small aperture terminal (VSAT) transmitters, and point-to-point (PtP) microwave links for high-data-rate communications, as well as military and space applications," says MwT general manager Dr Greg Zhou. "The exceptional power level from the MMA-273336-M5 exceeds the output power specification demanded by today's emerging Ka-band (30GHz) high-data-rate applications," he adds.

The MMA-273336-M5 is fully matched for both input and output terminals for easy cascade and is packaged in a low-cost M5 (5mm x 5mm) surface-mount package with what are claimed to be excellent thermal characteristics. The mean time before failure (MTBF) is over 100 years at 85°C ambient temperature.

Evaluation boards for this and other power amplifiers are available now.

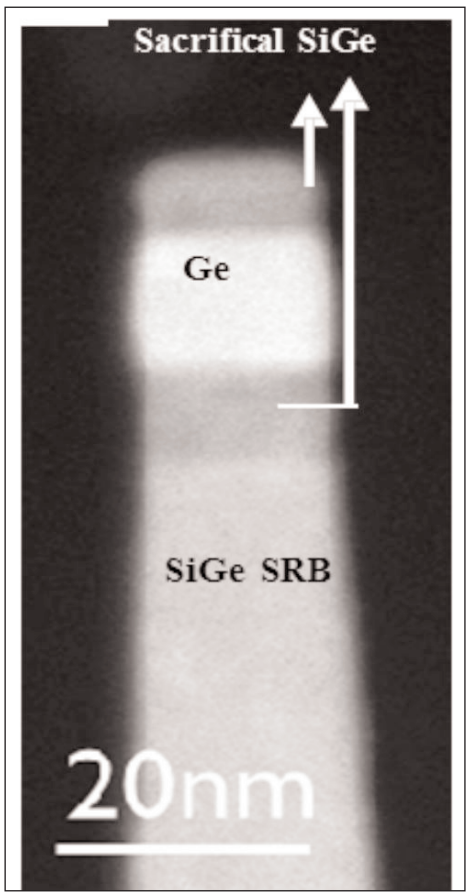
www.mwtinc.com

Imec demonstrates first sub-10nm germanium gate-all-around FETs

High-pressure anneal used to boost performance of both Ge FinFET and GAA devices

At the 2017 Symposia on VLSI Technology and Circuits in Kyoto, Japan (5–8 June), nanoelectronics and photovoltaics research centre Imec of Leuven, Belgium unveiled new process improvements for next-generation devices. For the first time it is claimed, scaled strained germanium p-channel gate-all-around (GAA) field-effect transistors (FETs) have been demonstrated with a sub-10nm diameter, integrated on a 300mm platform. In addition, Imec has achieved a significant improvement in device performance and electrostatic control with high-pressure anneal (HPA) for both strained germanium p-channel FinFET and GAA devices.

High-mobility materials such as germanium and III-Vs have been considered as potential solutions for deeply scaled devices, due to their higher intrinsic carrier mobility. However, these materials have a larger permittivity and a smaller bandgap than silicon, making it more difficult to apply the necessary electrostatic control at scaled gate lengths. To mitigate this issue, new device architectures with better electrostatics are necessary. Imec says that its results bring significant improvements for both strained germanium p-channel FinFET and GAA devices.



Nadine Collaert, Distinguished Member of Technical Staff at Imec, says that her team "adapted the process flow of our previously published 14/16nm-node strained germanium p-finFETs to study the benefit of strained germanium GAA p-FETs at short gate lengths and sub-10nm diameter." The team managed to process GAA p-FETs with the shortest gate lengths (L_G=40nm) and smallest nanowire diameter (d=9nm) reported to date. At these shortest gate lengths, the devices maintain excellent electrostatic control with a drain-induced barrier lowering of 30mV/V and a sub-threshold slope of 79mV/dec.

In a second paper, Imec reported on the use of high-pressure anneal as a new performance booster for both germanium FinFETs and GAA devices. In their test, the researchers measured an improved interface quality and hole mobility (~600cm^2/Vs) as a result of a HPA at 450°C. The optimized HPA is also shown to significantly improve the electrostatics and overall performance of GAA devices, reaching a subthreshold swing (SSLIN) of 65mV/dec at L_G=60nm and a Q factor of 15 with a low off-current (I_{OFF}) of ~3x10^{-9}A/μm.

Imec's research into advanced logic scaling is performed in cooperation with key partners in its core CMOS programs including GlobalFoundries, Huawei, Intel, Micron, Qualcomm, Samsung, SK Hynix, Sony Semiconductor Solutions and TSMC.

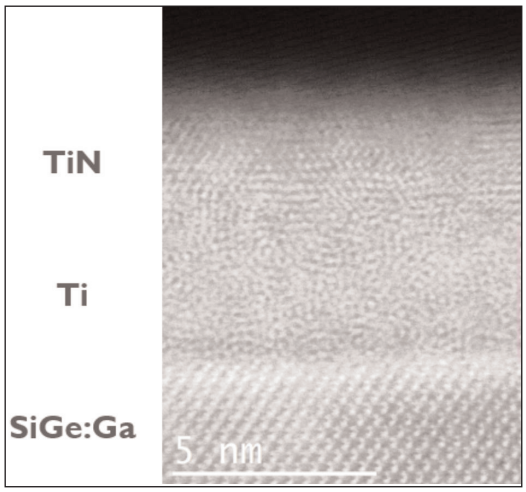
www.vlsisymposium.org
www.imec.be

Imec achieves record-low source/drain contact resistivity for PMOS transistors

Shallow gallium implantation on p-type SiGe source/drain contacts then pulsed nanosecond laser anneal yields sub-$10^{-9}\Omega.cm^2$ contact resistivity

At the 2017 Symposia on VLSI Technology and Circuits in Kyoto, Japan (5–8 June), nanoelectronics and photovoltaics research centre Imec of Leuven, Belgium reported record values below $10^{-9}\Omega.cm^2$ for PMOS source/drain contact resistivity. Results were obtained through shallow gallium implantation on p-type silicon-germanium (p-SiGe) source/drain contacts with subsequent pulsed nanosecond laser anneal.

In future N7/N5 nodes, the source/drain contact area of the transistors becomes so small that the contact resistance threatens to become the dominating parasitic factor, resulting in suboptimal transistor functioning. Researchers have therefore been working on techniques to reduce the contact resistance on highly doped n-Si and p-SiGe source/drain contacts, aiming for values below $10^{-9}\Omega.cm^2$. Together with colleagues from the Katholieke Universiteit Leuven (KU Leuven) in Belgium, Fudan University in Shanghai, China, and Applied Materials in Sunnyvale, CA, USA, Imec concentrated on p-SiGe contacts, comparing the effects of high-dose boron and gallium doping.



For comparison, the researchers implanted SiGe separate wafers with a high dose of gallium or boron and applied various anneal processes. They then fabricated multi-ring circular transmission line model (TLM) structures, which are highly sensitive to contact resistance. Subsequent measurements revealed the lowest contact resistance for the gallium-implanted structures annealed with Applied Material's nanosecond laser anneal. This process uniquely causes a Ge/Ga surface segregation, which is responsible for the ultralow sub-$10^{-9}\Omega.cm^2$ contact resistivity. This result shows a possible way to process next-generation technology nodes.

"This breakthrough achievement in our search to develop solutions for next-generation deeply scaled CMOS provides a possible path for further performance improvement using the current source/drain schemes in N7/N5 nodes," says Naoto Horiguchi, distinguished member of the technical staff at Imec.

Imec's research into advanced logic scaling is performed in cooperation with key partners in its core CMOS programs including GlobalFoundries, Huawei, Intel, Micron, Qualcomm, Samsung, SK Hynix, Sony Semiconductor Solutions and TSMC.

www.vlsisymposium.org
www.imec.be

Anokiwave showcases products for 5G, radar & SatComs

At the IEEE MTT International Microwave Symposium (IMS 2017) in Honolulu, Hawaii (6–8 June), 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 — participated in the 5G Summit session and the 5G backhaul technologies workshop, as well as exhibiting two recently introduced products for the mmW 5G market in booth 1558.

The AWMF-0123/5 silicon ICs are claimed to be the first commercially available 39GHz active antenna quad core ICs. They operate at 37.1–40GHz, support four radiating elements, and include 5-bit phase control and 5-bit gain control for analog RF beam steering. The firm's patent-pending IP blocks implemented in silicon technology enable low-cost hybrid beam forming with high energy efficiency and low-latency beam steering.

The AWMF-0129-IK is claimed to be the first commercially available 28GHz 5G phased-array active antenna. As a 64-element, single-polarization 5G phased-array antenna designed to cover the 27.5-30GHz frequency band, it is a planar antenna that can be used either as a stand-alone component, or combined and synchronized with other arrays to support hybrid beamforming and MIMO functionality as part of larger array. The array is driven by the AWMF-0108 28GHz 5G silicon quad core IC with embedded functions for remote telemetry and low-latency steering.

"Anokiwave has over a decade of experience designing silicon mmW active antenna ICs and is proud to be the first to market with products for mmW 5G networks," says founder & chief technology officer Dr Nitin Jain.

www.ims2017.org
www.anokiwave.com/ims2017

Analog Devices launches small isolated gate drivers for SiC and GaN power switch technology

Analog Devices Inc (ADI) of Norwood, MA, USA (which provides mixed-signal ICs for cable access, ranging from data converters through clocking and control/power conditioning) has launched small-form-factor isolated gate drivers designed for the higher switching speeds and system size constraints required by power switch technologies such as silicon carbide (SiC) and gallium nitride (GaN), while still providing reliable control over switching characteristics for insulated-gate bipolar transistor (IGBT) and metal-oxide-semiconductor field-effect transistor (MOSFET) configurations. The ADuM4120 and ADuM4121 series leverages ADI's proven iCoupler isolation technology combined with high-speed CMOS and monolithic transformer technology to enable ultra-low propagation delay without sacrificing common mode transient immunity (CMTI) performance.

While legacy alternatives such as optocouplers or pulse transformers struggle to deliver shorter delay and maintain CMTI performance, the robust ADuM4120 and ADuM4121 are designed to enable the higher switching speeds of the new inverter architectures, says ADI. In systems requiring multiple power switches, the small SOIC packaged isolated gate drivers minimize PCB layout space, subsequently reducing cooling requirements. Also, their small size allows the gate drivers to be located close to the power switches to reduce the parasitic inductance between the driver and the switch. Operating over a high temperature range and high working voltages, the ADuM4120 and ADuM4121 are suitable for improving the energy efficiency and timing performance stability of solar inverters, motor controllers, and industrial inverter applications, says ADI.

All four devices in the new series are 2A output, single-channel gate drivers that provide 5kV rms isolation with low propagation delay and CMTI performance of >150kV/μs. Operating with an input supply ranging from 2.5V to 6.5V, the isolated gate drivers provide compatibility with lower-voltage systems with the benefit of true galvanic isolation between the input and the output.

The ADuM4120 and ADuM4120-1 (supplied in 6-lead SOIC packages, costing $1.58 each in 1000-unit quantities) provide thermal shutdown for over-temperature protection. The ADuM4120 (with input glitch filter) reduces system noise on the input pin that could trigger a false output, while the ADuM4120-1 (without glitch filter) supports low 33ns typical propagation delay. The ADuM4121 and ADuM4121-1 (in 8-lead SOIC packages, costing $1.87 each in 1000-unit quantities) are available with an internal Miller clamp for added protection. The ADuM4121 device is also available with the thermal shutdown.

Analog Devices and X-Microwave partner on design and evaluation

Analog Devices has entered into a collaboration with X-Microwave LLC, a provider of RF and microwave modular blocks, to help designers more quickly and effectively evaluate RF components and prototype complete signal chains. As a first phase of the collaboration, X-Microwave will feature over 250 of ADI's RF, microwave and millimeter-wave products as drop-in modular blocks.

ADI offers a portfolio of over 1000 RF, microwave and millimeter-wave components, in addition to the software and support tools needed to help RF engineers develop complete signal chain solutions for their applications from DC to 100GHz. X-Microwave's resources allow engineers to evaluate new RF components and build signal chains simply by arranging the 'modular building blocks' and simulating the designed system with X-Microwave's online tools. This is in contrast to traditional system development methods that require a designer to connect multiple evaluation boards using dozens of cables.

"X-Microwave is committed to adding products and capabilities with the single purpose of optimizing the engineering design experience of our customers, and this collaboration with ADI does just that by providing designers with a simpler way to evaluate and use ADI's broad range of industry leading parts," says X-Microwave's CEO John Richardson.

"By adding X-Microwave to our design ecosystem we are further enhancing the 1000+ ways for our customers to develop quickly market-leading RF and microwave solutions," says Greg Henderson, VP of ADI's RF & Microwave Group. "Analog Devices is committed to not just providing RF, microwave and millimeter-wave products, but also to simplifying the way designers build their applications. We believe the collaboration between ADI and X-Microwave will further simplify our customers' design experience and time to market."

X-Microwave is the founder of the innovative modular building block system called X-MWsystem. X-Microwave's modular drop-in components and industry leading online tools address every phase of the RF and microwave development process from concept to prototype to production hardware.

www.xmicrowave.com
www.analog.com

Microsemi and Analog Devices collaborate on scalable silicon carbide MOSFET drivers

Microsemi Corp of Aliso Viejo, CA, USA (which makes chips for aerospace & defense, communications, data-center and industrial markets) and Analog Devices Inc (ADI) of Norwood, MA, USA (which provides mixed-signal ICs for cable access, ranging from data converters through clocking and control/power conditioning) have announced a scalable silicon carbide (SiC) driver reference design based on a range of Microsemi SiC MOSFET products and Analog Device's ADuM4135 5kV isolated gate driver.

The dual SiC MOSFET driver reference design provides user-friendly design guides enabling faster time to market for customers using Microsemi SiC MOSFETs and supports the transition to Microsemi's next-generation SiC MOSFETs.

The new reference design provides a highly isolated SiC MOSFET dual-gate driver switch to provide a means for evaluating SiC MOSFETs in a number of topologies. This includes modes optimized for half-bridge switching with synchronous dead time protection and asynchronous signal transfer with no protection. It can also be configured to provide concurrent drive with the requirement to study unclamped inductive switching (UIS) or double pulse testing. The reference design was developed for Microsemi SiC MOSFET discrete devices and modules and serves as an engineering tool for the evaluation of its portfolio of SiC devices. The board supports the modification of gate resistor values to accommodate most Microsemi discretes and modules.

"The dual SiC MOSFET driver reference design not only enables Microsemi customers to accelerate their product development efforts, but also accommodates the roll-out of our next-generation SiC MOSFETs to ensure a smooth transition for the end user," says Microsemi's strategic marketing manager Jason Chiang. "Customers taking a holistic view at power electronics design can utilize our new SiC driver solution to select the best driver and components for their designs, with the ability to scale to their specific SiC MOSFET needs."

The dual SiC MOSFET driver reference design is suitable for a wide range of end markets and applications, including aerospace (actuation, air conditioning and power distribution), automotive (hybrid/electric vehicle powertrains, electric vehicle battery chargers, DC-to-DC converters, and energy recovery), defense (power supply and high-power motor drive), industrial (photovoltaic inverters, motor drives, welding, uninterruptible power supply, switched-mode power supply, induction heating and oil drilling) and medical (MRI and X-ray power supply).

Analog Devices collaborates with Microsemi as part of the Accelerate Ecosystem, which is designed to reduce time to market for end customers and time to revenue for ecosystem participants. Microsemi's Accelerate Ecosystem brings together silicon, intellectual property (IP), systems, software and design experts to deliver validated board and system-level solutions for end customers.

The dual SiC driver reference design (MSCSICMDD/REF1), which includes an evaluation board, is available for purchase orders now.

The device was showcased at the Power Conversion and Intelligent Motion (PCIM 2017) Europe exhibition in Nuremburg, Germany (16–18 May) in Microsemi's booth and in Analog Devices' booth.

www.microsemi.com/product-directory/mosfet/3539-sic-mosfet#documentation

www.analog.com/en/products/power-management/isolated-gate-drivers.html

Infineon begins volume production of first full-SiC module, and adds to CoolSiC family

Infineon Technologies AG of Munich, Germany is commencing volume production of the EASY 1B, which is claimed to be the first full-silicon carbide (SiC) module after it was announced at the 2016 Power Conversion and Intelligent Motion (PCIM) Europe expo. Now, at this year's PCIM 2017 in Nuremberg, Germany (16–18 May), the firm showcased additional module platforms and topologies for the 1200V CoolSiC MOSFET family.

"Silicon carbide has reached a tipping point: taking cost-benefit analysis into account, it is ready for use in a variety of applications," believes Dr Peter Wawer, Division President Industrial Power Control at Infineon. "To make the new semiconductor technology a revolution to rely on however, it needs a partner like Infineon. Products tailored to the application, our own production capacities, comprehensive technology portfolio and system understanding: these four building blocks have made us the market leader for power semiconductors," he claims. "We want and will also achieve this with our SiC product portfolio."

The new 1200V SiC MOSFETs have been optimized to combine high reliability with performance. They show dynamic losses that are an order of magnitude lower than 1200V silicon IGBTs. First products will initially support upcoming system challenges in applications such as photovoltaic inverters, uninterruptible power supplies (UPS) and charging/storage systems. The new configurations will also enable new solutions in industrial drives, medical technology or auxiliary power supplies in the railway sector in the near future, it is reckoned.

A major advantage of the trench technology with the 1200V SiC MOSEFT lies in extended robustness. This is due to the lower failure in time (FIT) rate and the short-circuit capability, which can be adapted to the respective application. Thanks to a threshold voltage (V_{th}) of 4V and the recommended switch-on threshold (V_{GS}) of +15V, the transistors can be controlled like an IGBT and safely switched off in the event of a fault. The SiC MOSFETs enable very fast switching transients. In addition, Infineon's technology offers easy adjustability of the transients via gate series resistors, says the firm. The EMC behavior can thus be easily optimized.

Easy1B with Six-Pack topology.

Silicon carbide has reached a tipping point: taking cost-benefit analysis into account, it is ready for use in a variety of applications. To make the new semiconductor technology a revolution to rely on however, it needs a partner like Infineon

Already last year, Infineon announced the lead products EASY 1B (half-bridge/booster) as well as the discrete TO-247-3pin and -4pin solutions. The EASY 1B platform is well established and a suitable module platform for fast-switching devices. At PCIM 2017, Infineon exhibited additional module platforms and topologies based on the 1200V SiC MOSFET technology, extending the performance spectrum of the CoolSiC MOSFETs step by step. Among others, Infineon is showcasing the following SiC modules:

- EASY 1B with B6 (Six-Pack) topology: the module is characterized by the proven Infineon module configuration with an on-resistance ($R_{DS(ON)}$) of only 45mΩ. An integrated body diode ensures a low-loss freewheeling function. The EASY 1B is suitable for applications in drives, solar or welding technology.
- EASY 2B with Half-Bridge topology: this larger EASY device offers enhanced performance with an $R_{DS(ON)}$ of 8mΩ per switch. The low-inductance module concept is suitable for applications with more than 50kW and fast-switching operations. These include solar inverters, quick-charging systems or UPS solutions.
- 62mm with Half-Bridge topology: an additional half-bridge configuration featuring even higher power with an $R_{DS(ON)}$ of 6mΩ per switching function. This module platform offers the possibility of low-inductance connection of systems in the medium-power range. A great variety of applications make use of this, including medical technology or auxiliary power supplies in the railway sector, says Infineon. Because of the large number of possible applications, Infineon anticipates rapid spread of this module.

The lead products introduced at PCIM 2016, EASY 1B and the two discrete devices TO-247-3pin and -4pin, are gradually entering volume production during 2017. The Half-Bridge configuration for the EASY 1B is available now. Its market launch is supported by various driver modules and demonstration boards (also available now). The new product configurations are available as samples, and the serial start is planned for 2018.

www.infineon.com/coolSiC

Wolfspeed achieves first all-SiC 1.2kV power module harsh environment qualification

Wolfspeed of Research Triangle Park, NC, USA has launched what it claims is the first power module that passes the harsh environment qualification test for simultaneous high-humidity, high-temperature and high-voltage conditions.

The reliability benchmark enables system designers to use the device in outdoor applications such as transportation, wind, solar and other renewables where extreme environmental conditions have historically challenged safe device operation. Rated for 300A and 1.2kV blocking, the new all-SiC module was stressed in an 85% relative humidity, 85°C ambient while biased at 80% of rated voltage (960V). Success in harsh environment testing under bias provides further confidence in the overall ruggedness of SiC device technology for all applications, says Wolfspeed.

"SiC components enable the design of compact, lightweight, low-loss converters required for railway transport applications," says Michel Piton, semiconductor master expert at Alstom, a supplier of systems, equipment and services for the railway market. "Achieving the benchmark for temperature and humidity under high bias voltage is a key milestone for SiC devices in its adoption into our demanding market."

Powered by new Wolfspeed MOSFETs (CPM2-1200-0025A) and Gen5 Schottky diodes that also pass the harsh environment test at the die level, the new module retains the low 4.2mΩ on-resistance and more than five times lower switching losses than similarly rated latest-generation insulated-gate bipolar transistor (IGBT) modules, claims Wolfspeed. Module construction utilizes high-thermal-conductivity aluminum nitride substrates and optimized assembly methods to meet industry thermal and power cycling requirements.

"The latest 1200V module demonstrates our commitment to enabling markets and applications by meeting the anticipated system requirements for 2020 and beyond," says chief technology officer John Palmour.

The module (WAS300M12BM2) can be driven using Wolfspeed gate drivers for 62mm modules. The new module was exhibited at the 2017 Power Conversion and Intelligent Motion (PCIM) Europe expo in Nuremberg, Germany (16–18 May).

www.wolfspeed.com

Littelfuse launches its first GEN2 1200V SiC Schottkys

At the PCIM (Power Conversion and Intelligent Motion) Europe 2017 exhibition in Nuremberg, Germany (16–18 May), Littelfuse Inc, which provides circuit protection technologies (including fuses, semiconductors, polymers, ceramics, relays and sensors), introduced its first GEN2 Series of 1200V silicon carbide Schottky diodes.

They are the first in a series of products based on the technology platform created through a partnership with SiC diode and MOSFET power device start-up Monolith Semiconductor Inc of Round Rock, TX, USA (in which it is the majority owner). Additional SiC products based on the technology platform, including 1200V SiC MOSFETs, will be introduced in the near future.

GEN2 SiC Schottky diodes are available in ratings of 1200V at currents from 5A to 10A in either TO-220-2L (packed in tubes in quantities of 1000) or TO-252-2L (DPAK) packages (in tape-&-reel packaging in quantities of 2500). Compared with standard silicon bipolar power diodes, they allow circuit designers to greatly reduce switching losses and enable large increases in the efficiency and robustness of power electronics systems. They can accommodate large surge currents without thermal runaway, and operate at higher junction temperatures than their silicon counterparts.

Typical applications include power factor correction (PFC), buck/boost stages in DC–DC converters, freewheeling diodes in inverter stages (switch-mode power supplies, solar, UPS, industrial drives) and high-frequency output rectification — wherever improvements in efficiency, reliability and thermal management are desired. Designers and manufacturers of industrial power supplies, solar inverters, industrial drives, welding and plasma cutting equipment and hybrid electric vehicle (EV/HEV) charging stations can also use them.

"The merged p-n Schottky (MPS) device architecture of these new silicon carbide Schottky diodes offers circuit designers enhanced surge capability and extremely low leakage," says Michael Ketterer, product marketing manager, Power Semiconductors at Littelfuse. "Compared to conventional silicon power diodes, these silicon carbide Schottky diodes boost converter efficiency and power density while helping to reduce system-level costs."

GEN2 Series SiC Schottky diodes are said to offer the following benefits:

- Best-in-class capacitive stored charge and negligible reverse recovery, making them suitable for high-frequency power switching. They also ensure negligible switching losses and reduced stress on the opposing switch.
- Best-in-class forward voltage drop ensures low conduction losses.
- A maximum junction temperature of 175°C provides for a larger design margin and relaxed thermal management requirements.

www.monolithsemi.com

ROHM expands full-SiC power module lineup

New 1200V/400A & 600A models aid efficiency and miniaturization in high-power applications

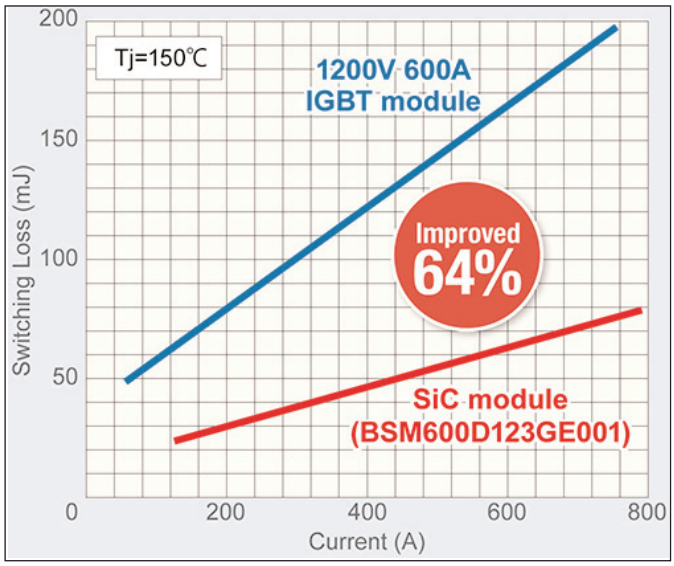
Japan's ROHM Semiconductor has developed 1200V 400A/600A-rated full-silicon carbide power modules [BSM400D12P3G002/BSM600D12P3G001] — available in June (for samples and OEM quantities) — optimized for inverters and converters in solar power conditioners, uninterruptible power supplies (UPS) and power supplies for industrial equipment.

The BSM600D12P3G001 achieves a rated current of 600A by utilizing a new package featuring an original internal structure and optimized heat radiation design, enabling support for higher-power applications such as large-scale power supplies for industrial equipment.

In addition, switching loss is reduced by 64% (at a chip temperature of 150°C) compared with insulated-gate bipolar transistor (IGBT) modules at the same rated current, improving energy savings considerably.

Also, along with reducing the size of peripheral components through high-frequency operation, the effects of reducing switching loss are greater when driving at high frequencies, contributing to the miniaturization of cooling and other systems. For example, from preliminary calculations based on loss simulation in cooling systems, adopting SiC modules can reduce the size of water-cooled heat sinks by up to 88% compared with equivalently rated IGBT modules.

In recent years, SiC has seen increased adoption in a greater number of markets, including the automotive and industrial sectors, due to its superior energy-saving performance, and products that can handle larger currents are being demanded. However, to maximize the high-speed switching characteristics of SiC — particularly in products with large current ratings such as power modules — it is necessary to develop a new package that suppresses the effects of surge voltage during switching.



ROHM says that, in March 2012, it was first to mass produce full-SiC power modules integrating power semiconductor elements composed entirely of silicon carbide. Since then, it has developed high-power products up to 1200V/300A that have been adopted in a variety of fields. The latest modules utilize a new package design that expands the firm's SiC module lineup to cover the key current range from 100A to 600A to meet the growing demand in the IGBT market.

Reduced switching loss aids energy savings

Achieving full-SiC power modules equipped with ROHM's silicon carbide Schottky barrier diodes (SBDs) and metal-oxide-semiconductor field-effect transistors (MOSFETs) makes it possible to reduce switching loss by 64% (at a chip temperature of 150°C) versus IGBTs at the same current rating. This minimizes power conversion loss in applications, contributing to increased energy savings.

High-frequency drive supports smaller peripheral components

Loss simulations conducted with PWM inverter drive resulted in a 30% reduction at 5kHz drive and an even more substantial reduction in total loss of 55% at 20kHz PWM vs equivalently rated IGBT modules. In the case of 20kHz operation the size of the heat sink can be reduced by 88%. High-frequency drive also supports the use of smaller passive peripheral components.

Technical challenges for achieving larger currents

1. Reducing package inductance

Increasing the current rating of power modules also increases the surge voltage during switching, making it necessary to minimize inductance within the package. However, optimizing the internal placement of the SiC device along with terminal configuration and pattern layout has allowed ROHM to reduce internal inductance by 23% versus conventional products. The new G Type package suppresses surge voltage by 27% at the same loss compared with standard packages, enabling the development of the 400A and 600A modules. This new package also decreases switching loss by 24% under the same surge voltage drive conditions.

2. Improving package heat dissipation

Achieving a rated current of 600A entails not only reducing internal inductance but heat generation as well. By improving the flatness of the base-plate section that significantly contributes to the heat dissipation of the module, ROHM was able to reduce the thermal resistance between the cooling mechanism and the customer's base plate by 57%.

In addition to SiC modules, ROHM also offers a gate driver board that enables quick and easy evaluation.

www.rohm.com

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Fraunhofer IAF develops first monolithically integrated half-bridge for 600V-class

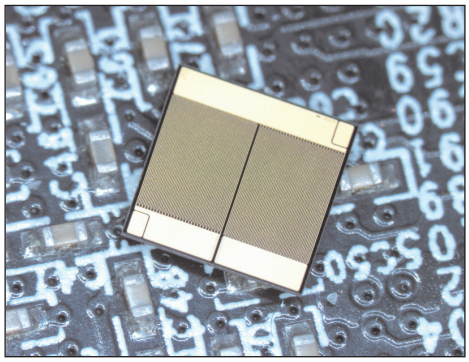
GaN-based voltage converters target e-mobility applications

Fraunhofer Institute for Applied Solid State Physics (IAF) of Freiburg, Germany has developed what is claimed to be the first half-bridge circuit for the important 600V class in which all the electronic components are monolithically integrated on one chip. Monolithically integrated half bridges are key building blocks of compact voltage converters and significantly increase the efficiency of power electronics devices.

Used in mains adapters and chargers for smartphones, laptops and low-voltage household appliances, voltage converters are in increasingly widespread demand as more and more electrical devices are being plugged into mains power supplies. The energy transition and e-mobility are also increasing the demand for reliable and, above all, efficient and compact voltage converters of all kinds. Half-bridge circuits are the centerpiece of many voltage converters.

In power electronics components, 600V is the standard volt class for grid-connected electrical devices, ranging from tablets and washing machines to e-bikes and electric cars.

Besides being very compact, monolithically integrated half-bridge circuits have much better electronic properties, e.g. the switching frequency can be improved by a factor of about 10 compared with conventional voltage converters. "A switching frequency of up to 3MHz allows us to achieve a much greater power density. This is very important in areas such as e-mobility, where many converters which are as efficient as possible have to be fitted in very little space," says Richard Reiner, research associate in Fraunhofer IAF's Power Electronics business unit. Monolithically integrated half-bridges are more compact, are easier to assemble and improve reliability.



Fraunhofer IAF's monolithically integrated half-bridge circuit.

High-performance on-board chargers for electric cars

The German government has set itself the target of putting 1 million electric cars on the country's roads by 2020. Covering long distances without generating any emissions requires not only powerful batteries but also the development of lightweight electric cars that generate as little energy as possible. This can only be accomplished using electronic components based on materials such as gallium nitride (GaN), which in contrast to silicon carbide (SiC) can be grown as an epitaxial layer on cost-effective, large-area silicon substrates. When used in electronic components for electric vehicles, GaN enables higher power densities to be achieved more energy efficiently. The aim of car makers and users is to develop extremely efficient on-board chargers for electric vehicles that take up as little space as possible.

Their compact design minimizes negative influences such as line impedances, improving the electrical switching characteristics. Integration of additional sensor technology, such as a thermal monitoring system, improves operation even further. "This innovative approach brings a new level of power density, efficiency, robustness, functionality and reliability to e-mobility," says Dr Patrick Waltereit, deputy head of Fraunhofer IAF's Power Electronics business unit.

Design of monolithically integrated half-bridge circuit

Fraunhofer IAF's half-bridge circuit comprises two GaN high-electron-mobility transistors (HEMTs) and two integrated freewheeling diodes. The HEMTs have a breakdown voltage of more than 600V and an on-state resistance of 120mΩ. A folded chip layout enables the DC link capacitance to be tightly connected between the supply voltage and ground. This design creates an optimized power path and allows clean, stable switching at high frequencies. Operation of this circuit was demonstrated at the 4th IEEE Workshop on Wide Bandgap Power Devices and Applications (WiPDA 2016) in Fayetteville, AR, USA last November in a down-converter from 400V to 200V at a switching frequency of 3MHz.

Even more complex circuits, such as a monolithically integrated multi-level inverter, have already been produced using this GaN-on-Si technology. In this topology, ten GaN power devices are placed on one chip with an area of 2mm x 3mm. Each switch has a breakdown voltage of 400V in the off state and a resistance of 350mΩ in the on state. Compared with conventional converters, multi-level inverters generate less noise during DC/AC conversion. This means that they require smaller output filters. Monolithic integration therefore not only reduces costs, but also makes voltage converters more compact and lightweight. This converter was demonstrated in inverters operating at the mains voltage level used in the USA (120V).

Fraunhofer IAF presented its monolithically integrated half-bridge circuit at the PCIM (Power Conversion Intelligent Motion) Europe 2017 trade show in Nuremberg, Germany (16–18 May).

www.iaf.fraunhofer.de/en.html
www.mesago.de/en/PCIM/main.htm

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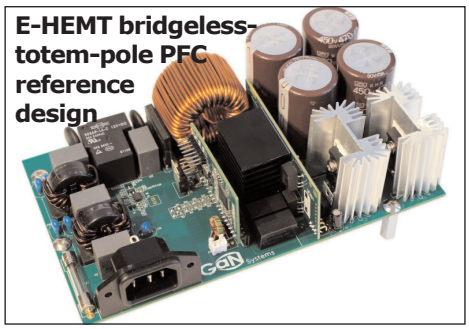
GaN Systems releases first E-HEMT bridgeless-totem-pole PFC reference design

To provide design engineers with a platform to demonstrate the performance of gallium nitride high-electron-mobility transistors (HEMTs), GaN Systems Inc of Ottawa, Ontario, Canada — a fabless developer of gallium nitride-based power switching semiconductors for power conversion and control applications — has released the GS665BTP-REF, the first 3kW continuous current mode (CCM) E-HEMT-based BTPPFC reference design.

To achieve efficiencies greater than 98% in conventional power factor correction (PFC) circuits, the major hurdle is fixed diode bridge losses. An option for overcoming this is to use silicon MOSFETs in place of the diodes to achieve efficiencies of 99% or more. However, this bridgeless-totem-pole power factor correction (BTPPFC) approach suffers from poor reverse recovery performance, is suitable only for low power, and requires complicated control parameters. GaN Systems mitigates these drawbacks by replacing silicon MOSFETs with GaN E-HEMTs that eliminate the body diode (zero Q_{rr}) and exhibit very fast switching.



E-HEMT bridgeless-totem-pole PFC reference design

The new 3kW GS665BTP-REF reference design compares the switch-on losses of a silicon-based CoolMOS CFD2 with losses exhibited by a GaN Systems 650V E-HEMT. The results show that GaN has superior reverse recovery, says firm. Operating the CCM BTPPFC at 50kHz, GaN dissipates only 0.75W switching loss due to the Q_{oss} loss at turn-on, while the CoolMOS CFD2 exhibits a loss of 20W, solely due to Q_{rr}. The result is excellent hard-switching performance in a CCM BTPPFC with maximized efficiency, says GaN Systems.

Comprehensive documentation for the GS665BTP-REF reference design ('High-Efficiency CCM Bridgeless Totem Pole PFC Design using GaN E-HEMT') — including includes the motivation, operating principles, and design considerations for the BTPPFC using 650V GaN E-HEMTs — is available for download from GaN Systems' website. Also included are discussions pertaining to test setup, test results (i.e. efficiency, power factor, waveforms, thermal measurements), and applications.

"Now, power design engineers have a tool to help them leverage the increased efficiencies and reductions of space, weight and BOM costs provided by GaN transistors," says Paul Wiener, GaN Systems' VP of strategic marketing. "Today we are seeing these benefits show up in products as diverse as battery chargers, energy storage systems and power supplies in enterprise applications," he adds. "As design engineers explore ways to improve power system performance, we expect that this reference design will play an instrumental role in the development of many more commercial products."

www.gansystems.com

GaN Systems exhibits customer-built systems using its transistors

At the Power Conversion and Intelligent Motion (PCIM 2017) Europe exhibition in Nuremberg, Germany (16–18 May), GaN Systems demonstrated dozens of customers' commercial systems that are optimized using its GaN transistors for consumer, industrial, transportation and wireless power transfer applications such as DC/DC converters, energy storage systems, electric vehicle (EV) traction inverters, power modules, PWM motor controllers, and LED drivers. The systems on show include:

- an airborne drone flying with power generated only by a 150W wireless transmitter operating at 13.56MHz;
- a 200W AC adapter one third the size of conventional adapters;
- a half-bridge topology comparison that shows how GaN outperforms silicon carbide (SiC);
- a best-in-class AirFuel Alliance-based wireless transmitting platform capable of charging multiple phones, pads, and laptops;
- a universal motherboard and four daughterboard platform for easily evaluating GaN transistor performance in any half-bridge-based topology;
- a 48V DC–DC evaluation kit that shows what is said to be outstanding efficiency, suitable for automotive and data-center applications;
- a 3-phase motor controller that operates at optimal efficiency;
- a highly efficient, 3kW power factor correction (PFC) reference design and full documentation for GaN Systems' GS66508T transistors;
- several on-board chargers that have 3x the power density of conventional chargers;
- a high-power half-bridge building block equipped with an IMS board, eight GaN transistors and a matching driver card, forming a complete building block for high-power systems; and
- an ultra-small, highly integrated 1MHz LED driver, constructed in a novel architecture that can only be enabled by GaN.

www.mesago.de/en/PCIM/main.htm

First AC–DC power supply using Transphorm FETs

Transphorm Inc of Goleta, near Santa Barbara, CA, USA — which designs and manufactures JEDEC-qualified 650V gallium nitride (GaN) field-effect transistors (FETs) for high-voltage power conversion applications — says that the recently announced high-efficiency AC-to-DC front-end TET3000-12-069RA power supply developed by power management device maker Bel Power Solutions (a Bel group company) uses its TPH3205WSB 49mΩ GaN FETs in a bridgeless totem-pole power factor correction (PFC) topology to achieve over 96% efficiency.

The TET3000 is a 3kW power supply designed for enterprise reliability server, router and network switching subsystems. Bel Power designed the supply using GaN to serve three critical needs: power density, size and performance reliability. The TET3000's volume power density is 31.7W/in^3. The device size is 2.72" x 1.59" x 21.85", small enough to meet 1U end-system design requirements. Lastly, the TET3000 is certified for 80 Plus Titanium efficiency and has earned a CE Mark per the European Commission's Low Voltage Directive (an initiative ensuring European citizen protection from electrical equipment).

GaN designs implementing the bridgeless totem-pole PFC topology are said to achieve a number of system benefits compared with a standard interleaved boost converter:

- Smaller size/higher power density: Lower component count and EMI filter size, delivering the same power in a smaller footprint.
- Higher efficiency: Faster switching speeds lower crossover losses and increase system efficiency, while removing the bridge rectifier decreases losses by 20–30%.
- Lower cost: GaN enables better performance and higher power density using twice the on-resistance as silicon to help reduce system cost.

"After considerable R&D weighing various semiconductor materials and power system designs, Transphorm's GaN within a totem-pole PFC configuration proved the most reliable, highest-performing solution possible today," comments Bel Power's chief technology officer Alain Chapuis. "In turn, our customers gain access to a next-generation power supply that stands to outperform incumbent solutions while delivering a greater ROI."

Bel's new power supply was displayed at the Power Conversion and Intelligent Motion (PCIM) Europe expo in Nuremberg, Germany (16–18 May) in a co-located showcase in the HY-LINE Power Components booth.

www.transphormusa.com

Mitsubishi Electric, Nokia Bell Labs, UC San Diego develop first ultra-fast GaN envelope-tracking PA

At the IEEE MTT International Microwave Symposium (IMS) 2017 in Honolulu, Hawaii, USA (6-8 June), Tokyo-based Mitsubishi Electric Corp, Nokia Bell Labs and the Center for Wireless Communications at University California San Diego jointly presented what is claimed to be the first ultra-fast gallium nitride envelope-tracking power amplifier, which supports modulation bandwidth up to 80MHz and is expected to reduce energy consumption in next-generation wireless base stations.

To help meet the demand for increasing wireless capacity, mobile technologies are shifting to next-generation systems that use complex modulated signals with large peak-to-average power ratio (PAPR) and extra-wide modulation bandwidth. This will require power amplifiers to operate most of the time at backed-off power levels well below their saturation levels. Generally, power amplifiers achieve high efficiency near their saturation power levels, but much degraded efficiency at backed-off levels, as in the case of 4G LTE signals (>6dB PAPR). Envelope-tracking power amplifiers have been studied extensively as a means to enhance power-amplifier efficiency (PAE), but so far the supply-modulator circuit has been the bottleneck limiting modulation bandwidth for advanced wireless communications, such as LTE-Advanced.

The newly developed ultra-fast GaN envelope-tracking power amplifier achieves what is said to be state-of-art performance due in part to Mitsubishi Electric's high-frequency GaN transistor technology and design innovation for the GaN supply-modulator circuits (which enable high-speed operation). Using Nokia Bell Labs' real-time digital pre-distortion (DPD) system, the power amplifier has demonstrated efficient operation even with 80MHz modulated LTE signals (the world's widest modulation bandwidth for this purpose, it is claimed — four times wider than the signals used in other envelope-tracking power amplifiers).

The technology achieves a drain efficiency of 41.6% in such wide-bandwidth operation, reducing base-station energy consumption while increasing wireless communication speed and capacity.

Further, the real-time DPD system enables pre-distortion for wideband signals to correct the output signal from the power amplifier, resulting in an adjacent channel leakage ratio (ACLR) of –45dBc for LTE 80MHz signals, which satisfies the wireless communication standards.

www.nokia.com
www.ece.ucsd.edu
www.MitsubishiElectric.com

Mitsubishi Electric and NanoSemi demonstrate ultra-wide-band linearized Doherty amplifier

At the IEEE MTT-S International Microwave Symposium (IMS2017) in Honolulu, Hawaii (6–8 June), Mitsubishi Electric US Inc of Cypress, CA presented a hands-on mini lab showcasing its high-efficiency, wide-band gallium nitride (GaN) Doherty amplifier.

Mitsubishi Electric Corp (Information Technology R&D Center and High Frequency and Optical Device Works), along with Mitsubishi Electric Research Laboratories, presented a paper at January's Radio Wireless Week describing this wide-band Doherty power amplifier design technique for next generation LTE base stations using GaN transistor technology. The demonstration at IMS will further illustrate 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.

Proliferation of smartphones and tablets will require a dramatic rise in the wireless capacity of base stations, notes Mitsubishi Electric. To meet this demand, mobile technologies are moving to next-generation LTE in which capacities are increased by allocating multiple simultaneous frequency bands (carrier aggregation) above 3GHz. 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 wide-band carrier aggregation. Using NanoSemi's digital pre-distortion (DPD) technology, Mitsubishi Electric's wide-band 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 the L-, S-, C-, and Ku-bands at outputs ranging from 2W to 100W, supports a variety of end-communications applications including cellular base-station, satellite, ground station and point to point.

www.nanosemitech.com
www.MitsubishiElectric.com

MACOM demos RF Energy Toolkit to speed time-to-market of GaN-on-Si-based RF systems for commercial applications

MACOM Technology Solutions Holdings Inc of Lowell, MA, USA (which makes semiconductors, components and subassemblies for analog RF, microwave, millimeter-wave and photonic applications) has unveiled a development kit targeted at helping commercial OEMs to quickly and easily adapt their product designs to incorporate gallium nitride (GaN)-based RF energy sources for a wide range of applications spanning cooking, lighting, industrial heating/drying, medical/pharmaceutical, automotive ignition systems etc. Leveraging solid-state RF energy as a highly efficient and precise energy source, commercial OEMs can achieve new levels of performance and affordability for future product generations, says the firm.

The new RF Energy Toolkit (for which the Beta version is now available) helps system designers to simplify and accelerate their product development cycles by making it easy for them to fine tune RF energy output levels to maximize efficiency and performance. Combining the benefits of MACOM's GaN-on-Si power transistors with intuitive, flexible software and signal control capabilities, the RF Energy Toolkit takes the guesswork out of the RF power source design and enables faster time to market, the firm claims.

GaN-on-Si power transistors supplied with the RF Energy Toolkit are said deliver up to 10% greater power efficiency than comparably priced silicon LDMOS-based transistors — a benefit for continuous-wave RF energy applications, where every incremental gain in power efficiency translates to less power consumption and lower operating costs over sustained usage. System designers can select from a range of power transistors to meet power level requirements spanning from 30W to 1000W, and the Toolkit supports coherent channel operation allowing multiple RF energy channels to be easily combined (e.g. 3x300W or 2x500W etc). Supported frequency bands range from 915MHz to 2.45GHz.

"Commercial OEMs are eager to seize the massive market opportunity for higher-performing RF energy-based systems enabled by GaN-on-Si, but they don't want to invest the resources to architect the RF power elements themselves," says Mark Murphy, senior director, RF Power at MACOM. "The RF Energy Toolkit lifts this design burden from the OEMs, and will help them get to market faster with their RF energy-based systems by providing an affordable, easy-to-use platform that streamlines system design and lowers development costs," he adds.

"The current RF Energy Toolkit offers the industry 'a first' in a number of ways: the kit is an easy-to-use, compact, very flexible controller that can run all alone based on a very fast, hardware-based reflection coefficient optimization scheme," comments Klaus Werner, managing director of MACOM design partner pinkRF. "Alternatively, the kit can run complex recipes alone or in conjunction with other controllers, programmed remotely or embedded with any number of RF vectors (power, phase, frequency, time, energy) to control complex or variable processes. The tool hooks up to the power amplifier — no special integration is needed," he adds. "I view it as an RF Energy engineer's 'Swiss army knife' to master, optimize and industrialize RF energy applications and their associated controllers."

Beta-version RF Energy Toolkits are available now to qualified customers, with broader availability planned in Fall 2017.

www.macom.com/rfenergy

MACOM showcases RF and microwave portfolio at IMS

At the IEEE International Microwave Symposium (IMS 2017) in Honolulu. Hawaii (6–8 June), MACOM showcased its GaN-on-Si portfolio and other MMIC and diode products, including new products optimized for commercial, industrial, scientific and medical RF applications.

- Enabling basestations: GaN 60W average power Doherty module
- RF Energy: MACOM's Beta Toolkit enabling RF energy applications
- High-power GaN-on-Si portfolio: Delivering performance and reliability for rugged Aerospace and Defense Applications
- E-Band Solutions: Demonstrating MACOM's E-Band ½W Power Amplifier, along with a display of the new E-band Tx and Rx SMD Modules and the portfolio of other wideband millimeter-wave products addressing the emerging 5G access, connectivity and backhaul markets.
- The Trusted Name in High-Performance Diodes: diode design and application-specific solutions
- Wideband Voltage Controlled Oscillators: Demonstrating leading performance and functionality of MACOM's new platform of wideband VCOs, octave band operation, low phase noise, stable power over temperature and improved sensitivity for test & measurement, A&D and ISM applications;
- Wideband Power Amplifier MMIC: High-performance TWA Power amplifier covering DC–50GHz
- Hi-Rel and Component Devices: The latest screened products for mission critical space and aerospace applications

EPC appoints Wolfram Krueger as VP of European sales

Efficient Power Conversion Corp (EPC) of El Segundo, CA, USA, which makes enhancement-mode gallium nitride on silicon (eGaN) power field-effect transistors (FETs) for power management applications, has appointed Wolfram Krueger as VP of European sales, based in Cologne, Germany. Krueger, who has over 30 years of sales experience within the semiconductor industry, will be responsible primarily for creating and implementing sales & marketing strategies

throughout Europe.

"Krueger is an electronics engineer by background and has extensive experience in leading edge power semiconductors with extensive experience in the industrial, automotive, and Telecommunications markets," says Nick Cataldo, EPC co-founder and senior VP of global sales & marketing.

Krueger joins EPC from Ioxus, where he was VP of sales for Europe, Middle East, and Africa. He previously held senior sales & marketing leadership positions with several companies, including Maxwell Technologies, Mitsumi Electronics, and Rohm Electronics.

EPC is "a company that is revolutionizing the power conversion industry with leading-edge gallium nitride FETs and integrated circuits," comments Krueger.

www.epc-co.com

EPC launches high-frequency monolithic GaN half bridge enabling 12V to 1.8V system efficiency over 85% at 5MHz at 14A output

EPC has launched the EPC2111, a 30V enhancement-mode monolithic GaN transistor half bridge. By integrating two eGaN power FETs into a single device, interconnect inductances and the interstitial space needed on the PCB are eliminated, says the firm. This increases both efficiency (especially at higher frequencies) and power density, while reducing assembly costs to the end user's power conversion system.

EPC2111 is suitable for high-frequency 12V to point-of-load DC–DC conversion. Each device within the EPC2111 half-bridge component has a voltage rating of 30V. The upper FET has a typical $R_{DS(on)}$ of 14mΩ, and the lower FET has a typical $R_{DS(on)}$ of 6mΩ. EPC2111 comes in a chipscale package for improved switching speed and thermal performance, and is 3.5mm x 1.5mm for increased power density.

A primary application for this device is for notebook and tablet computing. The power conversion circuitry in these systems occupy nearly half of the space and define the height of the motherboard. The high-frequency capability of GaN reduces the size required for power conversion and thus will drive significant size reductions of next-generation mobile computing, says the firm.

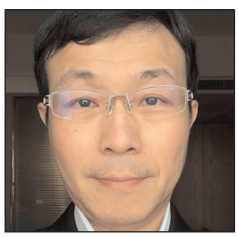
Priced at $1.62 each in 1000-unit quantities, the EPC2111 is available for immediate delivery from distributor Digi-Key.

EPC appoints VP sales for Greater China & Southeast Asia

To support its accelerating sales growth in Asia Pacific, Roy Chang has joined EPC's leadership team as VP of sales for Greater China and Southeast Asia, based in Taipei, Taiwan.

Chang has over 20 years of experience in R&D, technical sales, and marketing within the computer and semiconductor industry. His primary responsibilities at EPC are creating and implementing sales strategies to achieve sales objectives in Greater China and Southeast Asia, driving design wins and revenue growth as well as assisting customers in adopting eGaN FETs and integrated circuits for power conversion systems.

"As a customer-oriented engineer,



Roy Chang has gained solid sales, customer and distribution management experience in multi-national organizations including ramping new technology sales," comments Nick Cataldo, senior VP of global sales & marketing. "He has a proven track record of managing sales, marketing, and FAE [field application engineer] organization to increase values for customers and turn new business opportunities into results," he adds.

"I look forward to Roy's contribution to our sales growth; assisting me in expanding our customer base, maximizing new business acquisition, and capturing new markets throughout Asia Pacific," says Stephen Tsang, VP of sales, Asia-Pacific.

Chang joins EPC from GaN FET designer and manufacturer Transphorm Inc of Goleta, near Santa Barbara, CA, USA, where he was VP of sales, Taiwan. Before joining EPC, he held R&D, technical sales, as well as sales & marketing leadership positions with Acer and Texas Instruments.

"With my experience in ramping new technology sales, I look forward to contributing to EPC in creating design wins using our gallium nitride FETs and integrated circuits," says Chang.

Navitas issues 150W AC–DC GaN power IC reference design offering 21W/in³ and 95% efficiency

Navitas Semiconductor Inc has announced the availability of a 150W AC–DC reference design utilizing its gallium nitride (GaN) power ICs. With a power density of more than 21W/inches^3 and efficiency of over 95%, the NVE021A is more than 2x smaller than typical commercial designs and 40% smaller than the previous best-in-class, it is claimed.

The design can be adapted over a power range of 85–500W to enable a new class of converters to address ultra-thin LED TVs, fast-charging laptop adapters, high-density gaming systems, all-in-one PCs and any other systems seeking high-density or high-efficiency power solutions.

Navitas says that its GaN power ICs enable high-frequency switching to shrink passive components.

Soft-switching critical-conduction mode (CrCM) power factor correction (PFC) and LLC DC–DC stages operate at working frequencies up to 300kHz (600kHz during start-up, burst mode) — the fastest-possible speed provided by off-the-shelf controller ICs currently available, it is claimed.

"Navitas GaN power ICs enable breakthrough adapter performance in small size and high efficiency with simple, practical and economical designs," says Stephen Oliver, VP of sales & marketing. "Silicon-based designs are slow, bulky and heavy," he adds. "This reference design is the first in a series that will demonstrate how new GaN power ICs can increase frequencies 5x or more with efficiencies of 95%, enabling a 3–5x increase in power densities for a broad range of AC–DC applications".

The NVE021A reference design (150W, AC to 12V DC) is immediately available direct from Navitas at a price of $465 each, which includes a comprehensive user guide/test report with all schematic and layout design files, plus bill of material.

www.navitassemi.com

Navitas' CTO presents GaN Power IC developments at ISPSD 2017

At the 29th International Symposium on Power Semiconductor Devices and ICs (ISPSD 2017) in Sapporo, Japan (28 May – 1 June), Navitas' co-founder & chief technology officer/chief operating officer Dan Kinzer delivered a plenary address 'Developments in GaN Power ICs'.

The paper reviewed the beginnings of power integrated circuit techniques, leading to present implementations in advanced IC products, and forecasts future directions for the new technology. "We are also delighted by the response of the power electronics industry to our GaN power IC's innovations," says Kinzer.

"ISPSD Japan 2017 is a key opportunity for Navitas to present advances in GaN power ICs and how they are enabling new benchmarks in speed, efficiency and power density at an affordable cost," says VP of sales & marketing Stephen Oliver. "Since launching our single- and half-bridge GaN Power ICs the high customer demand is validating the huge advantages of the Navitas portfolio," he adds. Over 30 Navitas patents are granted or pending.

www.ispsd2017.com

Navitas partners with Asian distributors

Navitas Semiconductor Inc of El Segundo, CA, USA has expanded its support in Asia with two new distribution partnerships for its GaN power ICs. By partnering with Myland Technologies Inc and Allied Group (HK) Ltd, Navitas says it is providing customers in China and Taiwan with fast and easy access to samples, products and reference designs, featuring what it claims is the first GaN power IC technology.

"High-volume customers in China and Taiwan are developing remarkable, innovative products, and Navitas' monolithically integrated GaN technology enables their engineers to deliver next-generation power solutions with high performance, small size and low cost," says VP of sales & marketing Stephen Oliver. "Our partnerships with these leading distributors will ensure customers have close, dependable relationships and faster times to market."

In February, Navitas introduced what was claimed to be the first integrated half-bridge GaN power IC, enabling up to a 100x boost in switching speeds while increasing energy savings by 40% or more.

"GaN has inherent advantages to ensure the continued evolution of advanced applications," comments Myland's general manager Kevin Yu.

"There is high demand for new technology to overcome power design obstacles, across mobile, consumer and industrial markets and from 25W smartphone chargers to multi-kW server power supplies," adds Sammi Li, chief representative for the Allied Group.

www.mylandtech.com
www.szapl.com

Texas Instruments launches high-voltage, three-phase high-PWM-frequency GaN inverter reference design for 200V AC servo drives & robotics

Texas Instruments Inc (TI) has launched a three-phase, gallium nitride (GaN)-based inverter reference design that helps engineers build 200V, 2kW AC servo motor drives and next-generation industrial robotics with fast current-loop control, higher efficiency, more accurate speed, and torque control.

The three-phase high-frequency GaN inverter reference design features TI's newest LMG3410 600V, 12A GaN power module with an integrated FET, gate driver and protection (launched in April 2016). The GaN module allows the design to switch up to five times faster than silicon FETs, while achieving efficiency levels above 98% at 100kHz and above 99% at 24kHz pulse width modulation (PWM) frequency, the firm says. With GaN, designers can optimize switch performance to reduce power loss in the motor, and downsize the heatsink to save board space. Operating the inverter at 100kHz significantly helps to improve torque ripple when used with low-inductance motors.

The GaN inverter power stage interfaces with microcontrollers (MCU), including TI's TMS320F28379D drive control system-on-chip to help dynamically adjust voltage frequency and achieve ultra-fast current loop control.

TI has also introduced its new DesignDRIVE Fast Current Loop software with sub-cycle PWM update techniques that help to push current-loop performance in servo drives to less than 1μs (potentially tripling motor torque response). The Fast Current Loop software is said to outperform traditional MCU-based current-loop solutions, and is available free with controlSUITE software.

In addition to the GaN module, the reference design relies on TI's AMC1306 isolated delta-sigma modulators with current sensing to increase motor control performance. TI's ISO7831 digital isolator also provides reinforced isolation between the MCU and the design's six PWMs.

www.ti.com/tool/TIDA-00915

VisIC's board gains NXP's executive VP of business development David French

VisIC Technologies Ltd of Nes Ziona, Israel — a fabless developer of power conversion devices based on GaN metal-insulator-semiconductor high-electron-mobility transistors (MISHEMTs) — says that David D. French has joined its board.

"The power semiconductor market shows excellent growth prospects over the next decade, and GaN technology in particular shows great promise in addressing the global need for energy efficiency," says French. "Based on their technology strengths I am enthusiastic about the business potential of VisIC."

French has 40 years of semiconductor industry experience in a wide array of roles, and now serves as executive VP of business development at NXP Semiconductors. He has been with NXP since 2012, and has previously served as executive VP of R&D and as general manager of the Portable and Computing business unit, with direct involvement in product development, marketing, manufacturing, strategic planning and business management.

French was CEO of Quantenna Communications Inc in 2009–2010. Prior to that, he was president & CEO of Cirrus Logic Inc from 1999 to 2007, overseeing its transition from supplying digital components to PC applications to being a leading supplier of audio and mixed-signal components in mobile, automotive and professional applications. French was VP & general manager of Analog Devices Inc from February 1988 to June 1998, where he played a lead role in establishing ADI as a top-tier supplier of digital signal processing (DSP) components. Prior to Analog Devices, he held key management positions at Texas Instruments and Fairchild Semiconductor.

French also currently serves as vice chairman and director of Advanced Semiconductor Manufacturing Corporation Ltd, a dedicated analog semiconductor foundry based in Shanghai, China, and as a director of WeEn Semiconductors, ASEN Semiconductors, and Vango Technologies in China. He has previously held positions on the boards of directors of the Global Semiconductor Alliance, the Consumer Electronics Association, Analogix Semiconductor, Symwave Inc, and Transwitch Corp.

French received his BS in Electrical Engineering from the University of Rochester in 1977.

"Our goal is to drive rapid growth as a leading provider of GaN power devices, and to establish a long-lasting brand based on the technology we have pioneered over the past six years," says VisIC's co-founder & CEO Tamara Baksht. "French's rich experience and insight as a globally recognized executive and entrepreneur involved in many semiconductor companies is a tremendous benefit to VisIC, as well as our customers."

www.visic-tech.com

Raytheon's GaN-based AESA upgrade to Patriot radar surpasses 1000 hours of operation

Raytheon Company of Waltham, MA, USA says that, since its debut at the 2016 AUSA (Association of the United States Army) Annual Meeting & Exposition in Washington DC last October, its gallium nitride (GaN)-powered active electronically scanned array (AESA) proposed upgrade to the Patriot Air and Missile Defense radar has surpassed more than 1000 hours of operation in just over a year (half the time of a typical testing program).

"We achieved this milestone so quickly because of our successful experience developing and maturing GaN for programs like the US Navy's Air and Missile Defense Radar," says Doug Burgess, director of AESA programs at Raytheon's Integrated Defense Systems (IDS) business. "We're ready to take the next step and get this radar into the hands of our customers."

During the course of the 1000 hours, Raytheon's GaN-based AESA prototype radar routinely demonstrated 360° capability by working together with a second GaN-based

AESA antenna that was pointed in a different direction. As targets flew out of one array's field of view and into another, the two arrays seamlessly passed information back and forth, tracking the target continuously. The main array also detected and tracked tactically manoeuvering fighter jets and thousands of other aircraft.

"Raytheon's GaN technology is backed by 19 years of research and $300m in investment, while our competitors are either new to the market or primarily build GaN for commercial applications," says Ralph Acaba, VP of Integrated Air and Missile Defense at Raytheon IDS. "When national security is on the line you want highly reliable, proven technology that is certified by the US Department of Defense for use in military radars."

Raytheon's GaN-based AESA radar will work with the Integrated Air and Missile Defense Battle Command System and other open architectures. It maintains compatibility with the current Patriot Engagement Control Station and full interoperability with NATO systems.

Raytheon says that a number of current and expected future Patriot Air and Missile Defense System partner nations in Europe and Asia have expressed interest in acquiring GaN-based AESA. Poland submitted a Letter of Request for GaN-based AESA Patriot on 31 March. Raytheon's GaN-based AESA technology also meets Germany's requirements for the German Taktisches Luftverteidigungssystem (TLVS) tactical air and missile defence system.

www.raytheon.com/capabilities/products/patriot

Thales UK designs GaN MMIC/packaging for Europe's MAGNUS program using NI AWR software

As one of six firms from five European countries involved in designing products for the MAGNUS program — a European Defense Agency project aimed at developing European-sourced application technologies for gallium nitride on silicon carbide (GaN-on-SiC) used in advanced radar, communications and electronic warfare (EW) systems spanning 2–18GHz — aerospace, defense and space contractor Thales UK has designed 10W GaN monolithic microwave integrated circuit (MMIC) power amplifiers based on the 0.25µm foundry process of United Monolithic Semiconductors (UMS). In parallel with this, package design and thermal analysis tasks were also undertaken.

After the MMICs had been fabricated and packaged, they were used to design a demonstrator unit, which Thales UK then leveraged to design a 30W microwave power module (MPM). Two foundry runs were conducted.

The design targeted a frequency range of 6–18GHz, with 10dB gain, and 10W output power. It was decided to use a non-uniform distributed amplifier topology, which is suited to broadband operation because it is inherently stable. The goal was to design two distributed amplifiers on a chip between a pair of splitter/combiner networks. For the first foundry run the amplifiers were combined off chip, and for the second run the combining was done on chip.

The MMIC designs were created using NI AWR's Design Environment, specifically Microwave Office circuit design software. The passive structures were simulated in AXIEM 3D planar EM simulator, and the package was analyzed in Analyst 3D finite-element method EM simulator.

"Our design and simulation efforts showed that the UMS PDK [process design kit], as well as the Microwave Office and Analyst models, were very accurate, which led to the success of this project," comments Rashid Fazaldin, microwave design engineer at Thales UK.

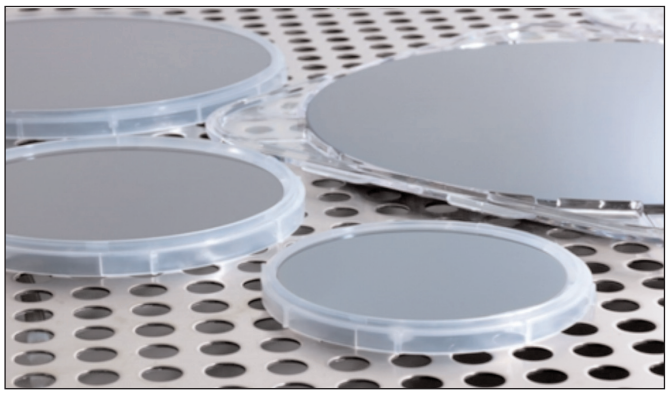
www.awrcorp.com/products

EpiGaN showcases 200mm GaN-on-Si epiwafers for 650V power switching and RF power

At the 2017 Power Conversion and Intelligent Motion (PCIM) Europe expo in Nuremberg, Germany (16–18 May) and also at the International Conference on Compound Semiconductor Manufacturing Technology (CS ManTech 2017) in Indian Wells, CA, USA (22–14 May), EpiGaN nv of Hasselt, near Antwerp, Belgium showcased the latest enhancements of its gallium nitride on silicon epiwafer family that meets industrial specifications for high-electron-mobility transistor (HEMT) devices at 650V.

EpiGaN has developed 200mm versions of its HV650V and HVRF GaN-on-Si epiwafers. The firm claims good dynamic behavior for power devices for the HV650V RF power products, and the lowest RF losses (<0.5dB/mm up to 50GHz) for the HVRF product family.

EpiGaN says that a key concept of its GaN/Si epiwafer technology is the in-situ SiN capping layer.



Pioneered by EpiGaN, this feature is said to provide superior surface passivation and device reliability, and enables contamination-free processing in existing standard Si-CMOS production infrastructures.

Also, in-situ SiN structuring allows the use of pure AlN layers as barrier materials, which results in lower conduction losses and/or allows the design of smaller-size chips of the same current rating.

"GaN technology has begun to enter many applications, either in power switching or in RF power amplification," says co-founder & CEO Dr Marianne Germain. "We are particularly proud to have developed GaN-on-Si epiwafers that show the lowest RF loss up to 100GHz," she adds. "This is a timely answer to the increasing demands in wireless communication such as the introduction of 5G and the Internet of Things."

At PCIM Europe, Germain participated in a panel discussion 'GaN — Design, EMC and Measurement' at the Fach Forum, organized by Bodo's Power Systems. Also, chief marketing officer Dr Markus Behet gave a presentation 'From Hype to Reality: GaN/Si — Where Are We Today?' at PCIM Europe's Exhibitor Forum and at the CS ManTech Exhibitor Forum.

www.epigan.com

AKHAN gains ex-Motorola veteran as sales advisor

AKHAN Semiconductor Inc of Gurnee, IL, USA, which specializes in the fabrication and application of lab-grown, electronics-grade nanocrystalline (NCD)-based materials & devices for semiconductor and electronic applications, says that Jeffrey Miller has joined it as sales advisor to the board.

Miller was most recently Motorola Mobility LLC's corporate VP & general manager of North American Sales and Operations based in Chicago, managing the firm's multi-billion dollar North American profit & loss, including oversight of business relationships with wireless operators and retailers, while handling global technical sales, and program management. He also currently serves on the board of directors for 1871, Chicago's start-up incubator.

Previously, Miller served in several general management positions and was responsible for leading Motorola's Enterprise market segment, Global Strategic Accounts Program and served as the leader of Motorola's Global eCommerce business.

Prior to these roles, Miller spent five years as executive VP of sales & marketing of Santa Barbara, CA-based start-up Somera Communications, which he took public in 1999. Before Somera, Miller worked at Motorola Inc from 1996–1999, leading sales, engineering and deployment teams within the Cellular Infrastructure Group. He also has more than 10 years of experience at AT&T, holding leadership positions in sales management, marketing and product management.

"With over 25 years of experience in the consumer hardware and telecommunications industries with Fortune 500 and start-up companies, Jeff's distinguished career and track record for meeting business growth targets through strategic partnerships will be an asset to our company, particularly as we begin the launch of our Miraj Diamond Glass products for Consumer businesses," says founder & CEO Adam Khan. "Having worked on several successful programs previously with Jeff, both myself and the other Motorola alumni on the AKHAN team look forward to continuing that success at AKHAN working alongside Jeff," adds president & chief operating officer Carl Shurboff.

www.akhansemi.com

Element Six develops new thermal grade of CVD diamond heat spreader for high frequencies and power density

Luxembourg-registered synthetic diamond materials firm Element Six (E6), a member of the De Beers Group of Companies, has developed a new thermal grade of synthetic diamond grown by chemical vapor deposition (CVD). Diafilm ETC700 is both thermally and electrically conductive and is suited to effectively managing heat in high-frequency, high-power-density devices, says the firm.

With a thermal conductivity of up to 700W/mK, Diafilm ETC700 CVD diamond heat spreaders are three times more effective in spreading heat than alternative ceramic solutions, reckons Element Six. This electrically conductive all-diamond solution does not require the metal coatings typical of other heat-management materials, resulting in reduced frequency-dependent conductive losses. Diafilm ETC700 is also claimed to outperform other commercially available metallized, non-diamond heat spreader materials or common metal solutions. A larger conduction cross-section enables better RF performance by improving the ground-plane isolation. Diafilm ETC700 maintains a high bulk thermal conductivity, while the bulk electrical conductivity reduces capacitive coupling between ground planes at low frequencies, and reduces conductive losses at higher frequencies.

Element Six claims that its range of Diafilm heat spreaders (available in a range of sizes, thicknesses and metallization) has the highest known thermal conductivity of any solid material at room temperature. With the addition of Diafilm ETC700, Element Six has expanded its portfolio to a total of six material grades spanning several levels of thermal, electrical performance and cost points, ranging from 700W/mK to 2000W/mK.

"For more than two decades, Element Six's CVD diamond has proven to be the most effective heat management material, far surpassing the performance of competing materials such as copper or ceramics," claims business development manager Thomas Obeloer. "Our team of developers is committed to continually improving upon our already industry-leading technology to meet new demands in advanced electronics and high-frequency devices."

CVD diamond is said to be a superior material for high-power-density/high-frequency devices due to a unique combination of properties including high thermal conductivity, mechanical strength, electrical insulation, low weight and chemical inertness. Diafilm ETC700 is claimed to offer better electrical device operation, lower operating temperatures and improved reliability and longer lifespans for high-frequency active semiconductors.

www.e6.com/thermal

Upgrades and enhancements to NI AWR Design Environment now available in V13.02

RF/microwave electronic design automation (EDA) software provider NI (formerly AWR Corp) of El Segundo, CA, USA has released an updated Version 13.02 of its NI AWR Design Environment that contains many upgrades and enhancements to Microwave Office and Analog Office circuit design software, Visual System Simulator (VSS) system design software and AXIEM and Analyst 3D electromagnetic (EM) simulators.

This latest release continues to address design challenges associated with highly integrated RF/microwave components (power amplifiers, filters, and more) commonly found in communications and radar systems.

V13.02 enhancements include:

- Microwave Office Load Pull: a new script improves the handling of projects with large numbers of load-pull measurements;
- AXIEM EM Technology: improved iterative solver passivity as well as improved AXIEM DC convergence of the multiple RHS solver, and improved solver speed and memory performance;
- Remote Computing: improved file transfer speed between local and remote machines; and
- User Environment: dozens of user-productivity enhancements related to NI AWR Design Environment job scheduler, user environment, measurements and interchange file format (IFF)/ printed circuit board (PCB) wizards.

www.awrcorp.com/products

Presto appoints COO and VP sales to address demand for IoT & related turnkey production & operations outsourcing

Presto Engineering Inc of San Jose, CA, USA — which provides outsourced operations to semiconductor and Internet of Things (IoT) device firms (including developing industrial solutions for RF, analog, mixed-signal and secured applications, from tape-out to delivery of finished goods) — has expanded its management team by appointing Cedric Mayor as chief operating officer (COO) and Martin Kingdon as VP sales.

"We have experienced growing demand for IoT [Internet of Things] and related turnkey production & operations outsourcing," says CEO Michel Villemain. "Our expanded management team will complement our talented employee base to help meet this market demand and advance Presto Engineering into the next phase of innovation and growth."

Mayor was previously Presto's chief technology officer. In his new role as COO, he will work with Presto's Europe- and Asia-based facilities to take customers' new product releases from prototype to high-volume production, and through wafer procurement to finished goods. He has been with the firm for more than seven years and has over a decade of experience in semiconductor design and manufacturing. As a graduate of France's Ecole Centrale Marseille, Mayor has a Master's degree in Physics and Electrical Engineering and holds several patents in chip design.

Kingdon has more than 20 years of experience in sales and marketing of semiconductor devices, IP, and test & manufacturing. Prior to joining Presto as VP sales, he was European sales director for the test and manufacturing services division of TT Electronics plc.

Kingdon graduated from the UK's University of York and holds a Master's degree in Electronic Systems Engineering.

www.presto-eng.com

IQE wins 2017 Raytheon Supplier Excellence Program EPIC Award

Epiwafer foundry and substrate maker IQE plc of Cardiff, Wales, UK says that its US operations have been selected as a 2017 Raytheon Supplier Excellence Program EPIC Award winner.

As part of the Raytheon Supplier Excellence Program, suppliers are awarded for their outstanding performance, contributions and support to programs across one or more Raytheon businesses. IQE has been selected to receive an EPIC Award for its overall Excellence in Performance, Innovation & Collaboration.

IQE's commitment to excellence "enables our joint success and solidifies a platform for 'Building our Future Together' in support of our mutual customer, the US warfighter," comments M. David Wilkins, VP for contracts & supply chain at Raytheon Company.

"It is a great honor to receive the 2017 Raytheon Supplier EPIC Award, which recognizes the integrity, quality and expertise that IQE offers its customers," says Dr Wayne Johnson, VP of IQE's Power business unit.

www.raytheon.com
www.iqep.com

StratEdge expands CMC base laminate packages to high-power GaN transistors & MMIC devices

StratEdge of San Diego, CA, USA (which designs and produces packages for microwave, millimeter-wave and high-speed digital devices) has expanded its LL family of high-power laminate copper-moly-copper (CMC) base packages to include both gallium nitride (GaN) transistor and monolithic microwave integrated circuit (MMIC) device packages and package assembly services.

The packages can now accommodate large MMICs, with die attach areas as high as 5.92mm x 12.14mm. They operate at frequencies from DC to as high as 63GHz for applications in communications, radar, automotive, aerospace, defense, and those requiring high-power millimeter-wave signals.

StratEdge also offers complete automated assembly & test services for these packages, including gold-tin solder die attach. These assembly processes routinely generate >96% void-free attachment with bond line thicknesses of <6μm when used with the new LL series of packages. This is particularly important for GaN power amplifiers, where efficient thermal transfer is critical for improved operation and reliability of the device, says StratEdge.

Laminate package for high-power GaN device.

The LL family of CMC-base packages dissipate heat from high-power compound semiconductor devices, such as gallium nitride, gallium arsenide (GaAs), and silicon carbide (SiC). Both leaded and leadless versions are available. Standard transistor packages are 0.8-inches (20.32mm) long x 0.23-inches (5.84mm) wide with two leads and a raised lid with an epoxy seal. Packages are either flangeless (with a fully hermetic seal and a flat ceramic lid) or flanged (with a bolt hole on each end so the package can be bolted to the printed circuit board). These laminate power packages are built with a base material ratio of 1:3:1 CMC, which provides a good thermal match for alumina-based materials and a GaN chip.

"StratEdge was one of the first to market with laminate power packages for GaN devices," says president Tim Going. "StratEdge has continued to develop packages to handle the requirements of new materials and devices. Our LL family additions can handle frequencies up to 63GHz and large MMIC devices, and our precision automated assembly & test services enable the chips to operate with the efficiency and electrical integrity they were designed to achieve."

StratEdge exhibited at the IEEE International Microwave Symposium (IMS 2017) in Honolulu, Hawaii (6–8 June).

www.stratedge.com

France's CORIAL seeks distributor partners

CORIAL of Bernin, France, which manufactures plasma etch and deposition processing equipment for specialty semiconductor markets, is expanding its global business reach by seeking new distributor partners to join its sales and support network.

The announcement precedes several significant introductions from CORIAL this year, according to CEO André Lechat. "We are on the brink of introducing a suite of new process control software for R&D; processes for the MEMS, power devices, and optoelectronics markets; and a new 6-inch cluster tool that will change the way our customers work with plasma etch and deposition equipment," he adds.

With CORIAL, distributors are able to offer customers high performance, reliable equipment that delivers new advances in process flexibility, system upgradability and cost of ownership, says the firm. Distributors can benefit from promoting CORIAL equipment designed specifically for numerous specialty semiconductor markets including MEMS, power devices, optoelectronics, wireless communication and advanced packaging. Spanning connected devices, lighting, sensors, electrical vehicles, or data storage, the specialty semiconductor market is booming and offers many new opportunities for distributors of plasma processing equipment.

"Partnering with CORIAL provides distributors significant advantages," says Lechat. "Our comprehensive distributor program covers co-op marketing, sales and technical training and much more".

CORIAL is seeking distributors with experienced sales and service personnel, comprehensive knowledge of local market, and a strong network. In particular, to be in close proximity to customers, the firm is seeking distributors in Europe, the Middle East and Africa.

www.corial.com

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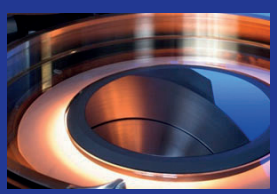

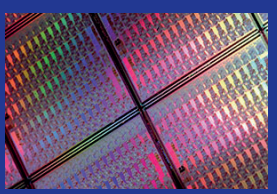

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Curious? For further information, please contact us at **NAsP.de**

Aixtron to sell ALD/CVD memory product line to US subsidiary of South Korea's Eugene Technology

Deposition equipment maker Aixtron SE of Herzogenrath, near Aachen, Germany is to sell the atomic layer deposition (ALD) and chemical vapor deposition (CVD) memory product line — based at its US subsidiary Aixtron Inc in Sunnyvale, CA, USA — to Eugene Technology Inc, a US subsidiary of South Korea's Eugene Technology Co Ltd that makes single-wafer ALD, CVD and plasma deposition and surface treatment systems.

Aixtron Inc will continue to provide sales and support for its continued businesses, and to pursue its thin-film encapsulation (TFE) activities.

The agreed purchase price of $45-55m will be paid in cash at closing. The purchase price includes inventory and other pre-paid assets. Due to ongoing business, their value will be determined at the time of closing.

The transaction is subject to regulatory approvals, including the Committee of Foreign Investments in the United States (CFIUS), and is expected to close in second-half 2017.

Aixtron expects that the transaction will not affect its full-year 2017 guidance for both order intake and revenue of €180–210m (including core business and ALD/CVD business up to the date of sale).

www.eugenetech.co.kr
www.aixtron.com

Aixtron appoints Grawert as executive board member

Schulte and Grawert to jointly lead firm

Aixtron has announced the appointment of Dr Felix Grawert as a new member of its executive board (to assume the position on 1 October or earlier).

Both Dr Schulte and Dr Grawert will jointly share the responsibilities of the executive board and will execute the corporate strategy.

Kim Schindelhauer will resume the position of chairman of the supervisory board and will closely support the firm's strategy projects.

Grawert joins Aixtron from Infineon Technologies, which he joined in 2013, heading the product segment of High Voltage Conversion. Before that, he worked for eight years at McKinsey & Company, managing industrial projects mainly from the high-tech and semiconductor areas. Grawert has a degree in Electrical Engineering from the University of Karlsruhe and a Master of Science in Electrical and Computer Engineering from the Georgia Institute of Technology. He also holds a PhD in Electrical Engineering and Computer Science from the Massachusetts Institute of Technology (MIT).

"With Dr Grawert, we have found a personality who combines technical intellect with entrepreneurial instinct," comments CEO Kim Schindelhauer. "We are convinced that Dr Grawert, together with Dr Schulte, will actively shape Aixtron's strategy to successfully develop Aixtron's portfolio of future technologies and exploit their respective revenue potential."

Veeco completes acquisition of Ultratech for $862m

Thin-film etch and deposition process equipment maker Veeco Instruments Inc of Plainview, NY, USA has completed its acquisition of Ultratech Inc of San Jose, CA, USA (which designs and makes lithography, laser-processing and inspection systems used to manufacture semiconductor devices and LEDs.

Ultratech provides lithography equipment for advanced packaging applications and for LEDs, and is a pioneer in laser spike anneal technology used for the production of microelectronic devices. In addition, it offers wafer inspection solutions leveraging its proprietary coherent gradient sensing (CGS) technology that address a wide variety of semiconductor applications.

The strategic transaction "establishes Veeco as a leading equipment supplier to the growing advanced packaging industry," says Veeco's chairman & CEO John R. Peeler. "This compelling combination increases our scale while bringing together complementary technologies and a strong talent pool," he adds. "This is the ideal platform to accelerate growth, enhance profitability and deliver significant value for our customers and shareholders."

The transaction is expected to be immediately accretive on a non-GAAP basis. Veeco is targeting $15m in annualized run-rate synergies within 24 months after closing, to be achieved through increased efficiencies and leveraging the scale of the combined businesses.

Ultratech shareholders receive $21.75 in cash and 0.2675 of a share of Veeco common stock for each Ultratech share outstanding. The total transaction is valued at about $862.3m, consisting of about 7.4 million shares of Veeco common stock and $628.4m in cash to former Ultratech shareholders and equity award holders. Ultratech Inc stock has ceased trading and is no longer listed on the NASDAQ Stock Market.

www.ultratech.com
www.veeco.com

Umicore inaugurates metal-organic precursor production facility in Germany

Precious Metals Chemistry business unit's TMGa and TEGa target semiconductor and LED markets

Umicore's business unit Precious Metals Chemistry of Hanau, Germany has inaugurated its production unit for metal-organic precursor technologies used in the semiconductor and LED markets, respectively TMGa (trimethylgallium) and TEGa (triethylgallium).

The event was attended by European and overseas customers as well as local and regional politicians. Guest of honour was Dr Barbara Hendricks, Germany's Federal Minister for the Environment, Nature Conservation, Building and Nuclear Safety.

Umicore's TMGa manufacturing process is claimed to be unique, offering a more sustainable and ecological production method by minimizing hazardous side streams and material losses and optimizing yield to nearly 100%.

"This patented innovation has now become a world-class and industrial-scale manufacturing plant," says Dr Lothar Mussmann, vice president of Umicore Precious Metals Chemistry. "It will provide benefits for our customers and the environment and underlines Umicore's position as a pioneer in sustainable technologies."

Umicore Precious Metals Chemistry claims to be the only European manufacturer of TMGa and TEGa and supplies customers worldwide from its manufacturing base in Hanau. The business unit adds that it helps to reduce cost of ownership through its innovative approach to process chemistry and its collaborative approach with customers and end users.

http://pmc.umicore.com/en/markets/ElectronicMaterials

Applied Energy Systems introduces updated heater blanket for SEMI-GAS and VERSA-GAS source systems delivering liquefied gases

Applied Energy Systems (AES) of Malvern, PA, USA (which provides high- and ultra-high-purity gas systems, services and solutions) has introduced an updated design for its heater blanket for use with SEMI-GAS and VERSA-GAS source systems supporting liquefied gas delivery. New features have been added to the standard design to improve the product's safety and performance in vaporizing liquefied gases to achieve high, sustainable flow rates, says the firm.

The updated UL-labeled heater blanket is compatible with source products from both of AES' gas delivery equipment brands, including VERSA-GAS vSource, and vBulk gas cabinets, gas panels, and rack-mount systems, and SEMI-GAS lines of Centurion gas cabinets, Decaturion wall mount systems, Megaturion bulk gas systems, and Xturion custom solutions.

The new design for a standard (9" diameter x 51" high) cylinder includes:

- A silver, silicone-coated fiberglass exterior and ¼"-thick needled fiberglass insulation for a thicker, more robust and rigid construction and increased durability.
- Wattage density of 1.16W per square inch up to 760W at $240V_{AC}$.
- A 24" heated zone at the base of the cylinder to maximize efficiency and optimize gas usage.
- A cinch drawstring and insulation zone at the top of the heater blanket to minimize heat loss.
- 8 straps and 8 quick disconnect buckles, with double straps at the heated zone, to ensure constant, secure contact with the gas cylinder.
- Six manual, resettable thermostats to monitor heat distribution. If the maximum temperature is reached, the electric current will be interrupted to allow the blanket to cool down.
- (2) K-type thermocouples for temperature monitoring and control.

"The updated heater blanket provides our customers with new value-added features to optimize high-volume flow rate performance for low vapor pressure gases, while ensuring safety," says Jim Murphy, general manager of Applied Energy Systems. "Our team of engineers added practical upgrades to evolve this product in ways that best suit our customers' real-world environments and that meet the distinct operational requirements of dealing with liquefied gases."

www.appliedenergysystems.com

Cambridge Nanotherm partners with Japan's Inabata for global sales and distribution

Cambridge Nanotherm Ltd of Haverhill, Suffolk, UK, a producer of nanoceramic thermal management technology for LEDs and electronics, has added a global sales and distribution arm by giving Japanese firm Inabata worldwide sales and distribution rights across key territories.

Cambridge Nanotherm says that its thermal management technology is already in the production stage with many of the top LED makers and now it is looking to use Inabata's global network to both consolidate existing relationships and open up new markets and new applications. The partnership provides access to a qualified sales and distribution team with great reach and reputation in the marketplace, adds Nanotherm.

Inabata has more than 60 offices in 19 countries and around 3500 staff globally. Inabata's three 'Information and Electronics' divisions provide everything from displays, imaging and clean energy solutions, to Li-ion batteries, general semiconductors, and raw semiconductor processing materials. Overall, the IT & Electronics division represents about 38% of Inabata's revenue.

"Inabata's focus on servicing the supply chain of the top electronics manufacturers, and their expertise in the information and electronics arena, make them a perfect match," believes Cambridge Nanotherm's sales director Mike Edwards. "While Inabata's ability to execute globally played a key role in our selection process, that they are headquartered in Japan aligns closely with one of our main strategic markets," he adds. "Inabata's agreement to sell Nanotherm's products is a clear vindication of the enormous market potential of Nanotherm's thermal management solutions. Both Nanotherm and its customers stand to benefit from Inabata's considerable sales and distribution network, expertise, and the access this will give Nanotherm to its key markets worldwide," Edwards concludes.

"Cambridge Nanotherm's unique products address several major shortcomings of existing thermal management solutions and can play a role in helping to shape the future of the industry," believes Inabata manager Toshihiro Matsuo.

www.camnano.com

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Plasma-Therm wins two 'RANKED 1st' awards in VLSIresearch's Customer Satisfaction Survey

For the 19th year, plasma process equipment maker Plasma-Therm LLC of St Petersburg, FL, USA has been recognized for the quality of its systems and customer support according to the annual global survey Customer Satisfaction Survey of the semiconductor industry conducted by market analyst firm VLSIresearch.

Survey participants are asked to rate their suppliers in 15 categories based on supplier performance, customer service, and product performance. Plasma-Therm earned five awards, including two 'RANKED 1st' awards, for having the highest scores of all companies in the categories 'Etch & Clean Equipment' and 'Focused Suppliers of Chip Making Equipment'.

In the combined ranking of all Fab Equipment Suppliers both large and small, Plasma-Therm scored second only to ASML, the world's largest photolithography supplier, thereby earning an additional 'THE BEST' award for the company.

In the combined ranking of all Fab Equipment Suppliers both large and small, Plasma-Therm scored second only to ASML, the world's largest photo-lithography supplier

Plasma-Therm also earned a '10 BEST' award in the category 'Focused Suppliers of Chip Making Equipment' and a 'THE BEST' award in the 'Suppliers of Wafer Fab Equipment to Specialty Chip Makers' category.

"As we continue expanding our product and application portfolio, we never lose focus on providing the best service and support in the industry to all of our customers, from small institutions and start-ups to specialty fabs and high-volume manufacturers," says Plasma-Therm's CEO Abdul Lateef.

With this year's awards, Plasma-Therm now has received a total of 37 awards over 19 years of participation in the Customer Satisfaction Survey. VLSIresearch received feedback from more than 79% of the chip market in this year's survey, conducted over two-and-a-half months and in five languages.

www.plasmatherm.com

EVG earns fifth consecutive triple win in VLSIresearch's annual Customer Satisfaction Survey

For the fifth consecutive year, EV Group of St Florian, Austria — a supplier of wafer bonding and lithography equipment for semiconductor, micro-electro-mechanical systems (MEMS) and nanotechnology applications — has earned all three awards resulting from VLSIresearch Inc's annual Customer Satisfaction Survey.

For 2017, EVG was ranked as one of the '10 BEST Focused Suppliers of Chip Making Equipment' and one of 'THE BEST Suppliers of Fab Equipment', increasing its rankings in both award segments compared to last year. EVG also again received a 'RANKED 1st award' in the 'Specialty Fab Equipment' category. In addition, EVG was recognized as one of 'THE BEST Suppliers of Fab Equipment to |Specialty Chip Makers' — a new award category introduced in this year's Customer Satisfaction Survey.

According to VLSIresearch, EVG received its highest scores in the supplier performance category, which includes trust in supplier and technical leadership. EVG also received strong marks in product performance, quality of results, and process support.

This year is the 15th consecutive year that EVG has been listed among the 'THE BEST' suppliers, as well as the fifth year claiming the number-one spot as the highest ranked wafer bonder supplier. In the '10 BEST Focused Suppliers of Chip Making Equipment'' segment, EVG moved up two positions to #6, while in 'THE BEST Suppliers of Fab Equipment' segment, it moved up three positions to #5.

"EV Group has mastered its strategy of on-going and sustained investment in technology invention, innovation and implementation. This strategy, along with a high-volume manufacturing emphasis, provides the basis for great customer satisfaction," comments VLSIresearch's CEO & chairman G. Dan Hutcheson. "Quality products, dedication to customer success, and sustainable business through a high level of expertise and technical leadership, were among the attributes cited by customers in their feedback," he adds.

"Whether investing in challenging new applications, partnering with our customers to accelerate new products and processes from early technology implementations through high-volume manufacturing, or continuously enhancing our solutions to enable higher performance and lower cost of ownership, EVG is committed to enabling our customers to achieve manufacturing success," says Hermann Waltl, executive sales and customer support director at EVG.

www.EVGroup.com
www.VLSIresearch.com

EVG expanding production & test capacity at corporate HQ

New building to also expand warehouse space

EV Group — a supplier of wafer bonding and lithography equipment for semiconductor, micro-electro-mechanical systems (MEMS) and nanotechnology applications — is expanding production capacity at its corporate headquarters in St Florian am Inn, Austria.

Representing a €20m investment, the expansion will include the construction of a new building providing additional production and test capacity for EVG equipment that meets the high cleanliness requirements of the semiconductor industry, as well as allowing for a significant expansion of warehouse space.

"With the new building adjacent to our existing manufacturing facilities, we will first and foremost create additional test rooms for the final assembly, software installation and quality assurance of our equipment and the technical source inspection by our customers," says Dr Werner Thallner, executive operations & financial director. "This enables us to act on the significant increase in demand for our solutions in both existing and new markets, and pursue our mid- and long-term growth targets at the same time."

EVG's HQ, including construction site for additional production & test capacity.

The new building is set to open by the end of 2017.

www.EVGroup.com

EVG surpasses 1100 wafer bonding chambers installed worldwide

EVG says that more than 1100 of its wafer bonding chambers have now been installed at customer facilities worldwide to date. The EVG500, EVG850, GEMINI and ComBond series of wafer bonding solutions, in particular, are seeing strong demand due to their performance and cross-platform compatibility, which allows users to more easily ramp up their R&D processes to high-volume manufacturing, says EVG.

"Our product offerings span the entire manufacturing chain from R&D and small-scale production environments to full-scale, high-volume production," says Hermann Waltl, executive sales & customer support director. "This enables us to support our customers throughout as they transform new ideas into real-world products."

For adhesive, solder and eutectic bonding, the EVG500 series of semi-automated wafer bonders and GEMINI series of fully automated wafer bonders support non-hermetic, cost-efficient encapsulation of CMOS image sensors, surface acoustic wave (SAW) filters for wireless RF chips, and other devices for mobile phones and other high-volume consumer applications. Additionally, tool configurations can be tailored to more demanding bond processes such as hermetic encapsulation for MEMS devices.

For high-vacuum encapsulation bonding, the new EVG ComBond automated high-vacuum wafer bonder provides ultra-high-vacuum encapsulation (10^{-8}mbar) needed for next-generation MEMS devices, such as gyroscopes, microbolometers, and advanced sensors used in autonomous cars, virtual reality headsets and other applications.

For fusion bonding, the EVG850LT and the GEMINI FB automated fusion bonders enable manufacturing of high-accuracy optical devices, image sensors, and engineered substrates such as silicon-on-insulator (SOI), silicon carbide (SiC) and gallium nitride (GaN) for RF, power and other high-speed/high-efficiency devices.

"EVG is continuously improving our process solutions in order to address wider market applications and more stringent industry requirements," says Waltl. "This has paid off for our customers, which in turn has enabled us to maintain our leadership position in the wafer bonding market," he adds.

www.evgroup.com/en/products/bonding/waferbonding

Brewer Science sells wafer-processing equipment unit

Cost Effective Equipment LLC formed by ex-employee

Brewer Science Inc of Rolla, MO, USA, which provides thin-wafer-handling materials, processes and equipment, has sold its Cee semiconductor processing equipment business unit. While remaining in Rolla, former employee Russ Pagel has formed the new company Cost Effective Equipment LLC to take over ownership and operate the business.

The strategic decision to sell the equipment unit was made to allow Brewer Science to focus more on developing materials and processes for the microelectronics and semiconductor industry. "Selling the equipment unit is part of the company's long-term plan to concentrate its expertise in materials science and advanced manufacturing technologies," says Kim Arnold, executive director, Advanced Packaging business unit. In addition to lithography products, protective coatings and wafer-level packaging materials, Brewer Science is developing sensors and flexible hybrid manufacturing.

The Cee equipment product line was founded in 1987 when Dr Terry Brewer recognized the need for high-performance laboratory-scale wafer processing tools. At the time, commercially available tools were inadequate to meet the needs of leading-edge materials and process development, says the firm.

The strategic decision to sell... was made to allow Brewer Science to focus more on developing materials

Thousands of Cee tools are now used worldwide for research, testing and small-volume manufacturing of semiconductor devices.

As a Brewer Science employee for 35 years as well as a founding member and later director of the equipment business group, Pagel will take the majority of Cee business unit employees with him to the new firm, involving expertise in technology development, design, engineering, applications, sales, support and operations. The new firm will offer all existing Cee products as well as service and support.

Cost Effective Equipment LLC will also continue to honor product warranties and provide ongoing support to past and current Brewer Science equipment customers.

www.costeffectiveequipment.com
www.brewerscience.com

BluGlass to install BLG-300 RPCVD system upgrade

BluGlass Ltd of Silverwater, Australia — which was spun off from the III-nitride department of Macquarie University in 2005 — says that it is making progress on key projects critical to commercializing its remote-plasma chemical vapor deposition (RPCVD) technology for LED and power electronics markets.

Scaling project and BLG-300 upgrade — enabling uniform RPCVD over larger areas

As reported in February, the upgraded chamber of the smaller RPCVD system (the BLG-180) has brought deposition uniformity to a suitable level that meets industry demonstration requirements. BluGlass says that this is a step towards the scalability milestones required for commercializing RPCVD. This RPCVD chamber design has been applied to the design and manufacture of the upgraded BLG-300 chamber, which is on site and will be installed in the coming weeks. The BLG-300 upgrade had been paused to allow progress on the collaborations with LED maker Lumileds of San Jose, CA, USA and epiwafer foundry & substrate maker IQE plc of Cardiff, Wales, UK.

"The scaling project milestones are critical to the commercialization of RPCVD," says managing director Giles Bourne. "Despite progress on our industry collaborations, BluGlass will now move forward immediately with the scaling project, and implement the new BLG-300 chamber. During this time, the BLG-180 will become the main workhorse to continue development," he adds. "Completion of the BLG-300 upgrade is required to support the positive completion of our numerous industry evaluations, and enable us to further discussions on the competitive advantages of RPCVD with other potential customers and collaborators. Therefore, this has become a priority for the company."

Industry collaborations — delivering industry acceptance of RPCVD

BluGlass says that progress is being made on both the Lumileds Phase II milestones and the IQE deliverables. The firm is working with Lumileds to develop a new implementation of LEDs and with IQE to develop specific enabling technology for high-quality nitride films on silicon and rare earth oxide (cREO) on silicon substrates. Both collaborations aim to capitalize on the benefits of low-temperature RPCVD.

Technology team expanded

To better enable its growing commercialization activity, BluGlass has expanded its technology team by adding two process engineers. Joining the engineering staff, they will assist in the further design and optimization of RPCVD, device design and characterization, and deliver custom epitaxy services.

www.bluglass.com.au

Seren's GaN template process transferred to BluGlass platform

BluGlass has completed Phase 1 of transferring the template process of semi-polar GaN product developer Seren Photonics Ltd of Cardiff, Wales, UK to the BluGlass metal-organic chemical vapor deposition (MOCVD) epitaxial platform.

BluGlass has been working with Seren since November 2016, with the objective of transferring the process from laboratory-scale equipment onto a production-relevant MOCVD platform.

Semi-polar GaN is an alternative GaN template for LED manufacturing that overcomes many of the problems associated with the green gap (inability to make efficient green LEDs using MOCVD) and has the potential to also address LED efficiency droop, where the LEDs become gradually less efficient at high power. Previously, semi-polar GaN was only available in small pieces, cut from a bulk GaN crystal. The Seren technology creates high-quality semi-polar GaN on industry-standard 2", 4" and 6" sapphire wafers. BluGlass and Seren are working together to demonstrate commercially viable semi-polar devices including reviewing the potential to use BluGlass' proprietary RPCVD technology to further improve the performance of green LEDs.

"We've always had a vision that Seren's technology can help transform the LED industry, especially for green LEDs," says Seren's chairman Dr Godfrey Ainsworth. "This successful first phase transfer is another major milestone in our development as a supplier of semipolar GaN products".

"It's pleasing to see another BluGlass custom epitaxy customer achieve a successful technology demonstration," says BluGlass managing director Giles Bourne. "We look forward to continuing to assist Seren deliver the successful completion of the next stage of development," he adds. "BluGlass selects its customers based on the potential benefits to the nitrides industry, as we seek to work with the next generation of technology developers."

BluGlass will continue to work with its customer Seren, with future development now focusing on refining the manufacturing process with an emphasis on improving uniformity and yield, whilst parallel development will continue to focus on further reduction in defect density.

Phase 2 of the collaboration will focus on refining the manufacturing process with an emphasis on improving uniformity and yield, whilst parallel development will continue to focus on further reduction in defect density.

www.serenphotonics.co.uk

RayVio demonstrates UV-C dosing for water sterilization

Health and hygiene company RayVio Corp of Haywood, CA, USA, which is commercializing deep-ultraviolet (UV) LEDs and consumer disinfection solutions, has published its latest application note, which details its UV dosing experiments proving the water sterilization capability of the firm's UV-C LEDs. Water safety is of particular concern in consumer appliances and applications where water may stand for a period of time, be exposed to contaminants, or be turned into vapor and distributed through the air, as is the case with humidifiers.

"3mW of UV-C light from a RayVio XE Series LED applied hourly for 5 minutes can keep stored water 'clean' indefinitely," says Dr Doug Collins, chief technology officer & VP of engineering.

The first experiment — which was a side-by-side test of two clean water samples — showed that intermittent treatment (dosing) with RayVio's UV-C light will keep clean water clean while water that is not dosed will have significant growth of bacteria.

The second experiment — with two heavily contaminated water samples — demonstrated that contaminated water exposed to periodic doses of UV-C light from RayVio's UV LED can be decontaminated with a few doses of UV light over the span of several hours.

"Water safety is on everyone's mind because of its potential as a breeding ground for bacteria and viruses and the ease with which infections can be spread at homes and in offices," says Collins. "Our XE Series UV-C LEDs can keep clean water from becoming contaminated with germs and clean already contaminated water," he adds.

Lifetime for UV-C LEDs approaching 10,000 hours

The operational lifetime of UV-C LEDs is critical to most applications, particularly those that affect people's health and hygiene, says RayVio. Lifetime performance of the firm's XE and XP Series UV-C LEDs continue to lead the industry, it is claimed. With lifetimes approaching 10,000 hours, the value and longevity of many consumer applications continues to increase as well.

Boost in UV-C LED performance

Disinfecting flowing water and sterilizing medical instruments requires the highest possible levels of UV-C LED performance. RayVio is now in volume production of what it claims is the industry's highest-performing UV-C LED (the XP Series, with 70mW of output). The firm remains on-track to deliver 100mW from a single device in the near future.

www.rayvio.com

Crystal IS supplements Klaran disinfection product line with UVC LEDs for healthcare industry

Crystal IS Inc of Green Island, NY, USA, an Asahi Kasei company that makes proprietary ultraviolet light-emitting diodes (UVC LEDs), has added to its Klaran disinfection product line by launching three new UVC LED products targeting the healthcare industry.

The new devices deliver up to three times greater germicidal performance at 260–270nm than similar devices, it is reckoned, enabling medical equipment manufacturers to integrate quantifiable disinfection capabilities into their products. Emitting UV energy at the peak absorption range of bacterial D/RNA ensures a highly effective and consistent germicidal effect across a range of potentially lethal pathogens linked to healthcare acquired infections (HAIs).

The new UVC LEDs enable the development of portable equipment and handheld devices, which can enhance existing aseptic protocols by automating traditional manual tasks with a measured dose of disinfection. Using these devices, infection control departments and epidemiologists can also track and establish associations between aseptic protocols and reductions in the incidence of HAIs to improve compliance reporting and quality of care.

Crystal IS says that for healthcare equipment manufacturers, the new Klaran UVC LEDs:

- provide effective and consistent disinfection power across a range of pathogens and microbes;
- offer targeted disinfection with minimal stray energy loss compared with other technologies;
- offer flexible design, and low-energy means to innovate portable or hand-held devices; and
- feature instant-on capability for ease of use and increased productivity.

"We are committed to ensuring our products meet the specific needs of the healthcare industry," says CEO Larry Felton. "These new Klaran devices and our support teams help our healthcare customers advance their proof-of-concept designs from early-stage development through to commercial launch."

The new Klaran UVC LEDs are produced on the company's lattice-matched aluminum nitride (AlN) substrates, which enable high germicidal output at deep UVC wavelengths. The new healthcare additions to the Klaran product line include a high-powered version for handheld medical devices and two long-lifetime products for portable equipment.

Crystal IS exhibited the new products at 34th annual MD&M East conference in New York City on (13–15 June).

www.mdmeast.mddionline.com

Nitride Semiconductor files patent infringement lawsuit against Rayvio's UV-LED products

On 23 May, Nitride Semiconductor Co Ltd of Tokushima, Japan filed a patent infringement lawsuit with the US District Court, Northern District of California, against ultraviolet (UV) LED maker Rayvio Corp of Haywood, CA, USA.

In the complaint, Nitride is seeking injunction, damages and accounting, asserting that Rayvio infringes its US patent 6,861,270 ('Method for Manufacturing Gallium Nitride Compound Semiconductor and Light Emitting Element') by manufacturing its products. The patented invention is said to significantly contribute to improving the light-emitting efficacy of LEDs.

Nitride Semiconductor says that, with professor Shiro Sakai of Tokushima University, it succeeded in developing the first highly efficient UV-LEDs in 2000, and has since continued to manufacture and sell UV-LEDs, including making a huge investment in R&D. The firm says that it will take resolute action against infringers in any country where appropriate and necessary to protect its patents and other intellectual property rights.

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

UNIQUE project to develop mass-market UV-C LEDs for industrial disinfection applications

Five Bavarian concerns span supply chain from AlN material to system integration

Funded by the Bavarian Ministry for Economic Affairs, Media, Energy and Technology and sponsored by VDI/VDE/IT, the UNIQUE project (which runs from July 2016 to June 2019) aims to develop high-power UV-C LEDs (with wavelengths of 260-280nm) as mercury-free light sources for industrial disinfection processes. Potential applications span domestic water purification to industrial disinfection of food packaging.

With the LEDs based on aluminum gallium nitride (AlGaN), meeting this objective requires fundamental material, technology and system developments along the entire value-added chain. The project hence involves five Bavarian companies and research institutions, coordinated by Osram Opto Semiconductors GmbH of Regensburg, Germany.

aprotec GmbH is responsible for the design of a special installation for producing aluminum nitride (AlN) volume crystals by evaporating AlN powder at over 2000°C. The Fraunhofer Institute for Integrated Systems and Device Technology (IISB) in Erlangen, Germany is in charge of developing and optimizing a process chain for producing AlN substrates, which includes everything from the synthesis of high-purity AlN powder and the production of AlN crystals to the manufacture of AlN substrates from the AlN crystals. Osram Opto is developing the UV-C LED chip, using the associated epitaxy and processing on the basis of the AlN substrate.

An aluminum nitride crystal.

Osram Opto is already active in the near-UV range. UNIQUE will extend our portfolio into the deep UV range

UV LED chips need the protection of a gas-tight package that offers a constant vacuum and hence a stable atmosphere for the chip. Developing a permanently vacuum-tight package from inorganic UV-stable materials and evaluating the structure and connections are the tasks of SCHOTT AG of Landshut, Germany. Finally, Dr Hönle AG is responsible for integrating the UV-C modules into a new disinfection system and conducting the appropriate system tests.

By developing a small, cost-effective, energy-efficient, mercury-free, long-life UV diode the project partners aim to gain a strong position in the growing market for UV LEDs and to use the results of the project to strengthen Bavaria as a location for business. "Our many years of experience in the development of mass-market opto semiconductor components will help make the UNIQUE project a success and contribute to bringing the prototype to market at a later date in volume production," says Dr Hans-Jürgen Lugauer, head of UV development at Osram Opto. "Osram Opto is already active in the near-UV range. UNIQUE will extend our portfolio into the deep UV range, specifically for disinfection applications."

www.osram.com

Seoul Semi files German patent lawsuit against Mouser

Seoul Semiconductor Europe GmbH of Munich (a subsidiary of South Korea's Seoul Semiconductor Co Ltd) has filed a patent infringement claim in Germany at the District Court of Düsseldorf against global electronic component distributor Mouser Electronic Inc, accusing it of selling LED products made by Taiwan-based Everlight Electronics Co Ltd.

Seoul asserts that Everlight's mid-power LED products infringe its patents, seeking a permanent injunction, damages, and recall and destruction of the products.

The patent boosts light extraction from LEDs by enhancing internal-reflection efficiency (widely used in mid-power and high-power LEDs).

The litigation is the second patent infringement litigation by Seoul or its affiliate affecting Everlight's LED products. In March, Seoul Semiconductor Co Ltd filed a patent infringement claim in Germany, accusing high-power LED products manufactured by Everlight as well as other LED makers. It says these patent litigations underscore its commitment to protecting its intellectual property rights against infringement, including products consisting of mid-power and high-power LEDs.

Everlight has been implicated in other patent infringement lawsuits, says Seoul Semiconductor. "Several LED companies have grown rapidly in a short period of time despite a lack of valuable patent portfolios," says Nam Ki-bum, vice president of the Research Center at Seoul Semi. "Seoul, however, has been investing 10% of its revenue in research and development for many years to develop innovative technology and strengthen our patent portfolio," he adds. "To support a fair market that respects intellectual property rights, Seoul will continuously monitor and take action against alleged infringers in any countries where infringement occurs."

www.everlight.com
www.SeoulSemicon.com

Seoul Semiconductor settles LED filament bulb lawsuit against Kmart

On 8 June, Seoul Semiconductor and its affiliate Seoul Viosys Co Ltd have resolved patent litigation filed in US Federal District Court on behalf of Seoul and The Regents of the University of California against retailer Kmart Corp, asserting infringement of eight patents based on Kmart's sales of Kodak/Spotlite branded filament LED bulbs.

Kmart will stop selling Kodak/Spotlite-branded filament LED bulbs. The patents relate to essential structures of filament LED products, including high color rendering index (CRI) enhancement with phosphor combinations, epi growth, chip fabrication, multi-chip mounting technology, omnidirectional lamp technology, and Acrich MJT technology.

In addition, Seoul has sent warnings to manufacturers of LED filament bulbs as well as other LED lighting products to cease any infringement of Seoul's patents.

Currently, filament LED end-products are manufactured by many lighting manufacturers, such as Super Trend Lighting, Longstar Lighting, Topstar Lighting, and Yankon Lighting. Seoul has already put manufacturers of various LED lighting products on notice of its patents and requested that sales of any infringing products must be immediately ceased.

"Various LED lighting products currently on the market infringe Seoul's patents," says Nam Ki-bum, executive VP of the Research Center at Seoul. "Now that we have resolved one litigation in this area, we will devote more resources to actively protecting our valuable intellectual property rights relating to LED products. Distributors should also take active precautionary measures not to sell infringing products. As long as such measures have not been taken, we will continuously take legal action against manufacturers and distributors relating to suspected infringing products in any countries where infringement occurs."

Luminus selects Artec Lantec as Israel rep

Luminus Inc of Billerica, MA, USA, which makes LEDs and solid-state light sources, has selected Tel Aviv-based Artec Lantec, a boutique representative and stocking distributor of components and systems for Israel's electronics industry, to represent it exclusively in Israel.

Luminus says its LED technology is suitable for projection display and illumination applications requiring high brightness, high efficacy and the efficient harnessing of light from a small point source.

"The only way to advance successfully in today's global business arena is by forging mutually beneficial partnerships with the right partners," says Artec's CEO Yoram Sror. "We have all the right connections to integrate Luminus into important projects on an ongoing basis."

According to the report 'LED lighting Market for Residential, Architectural and Outdoor Applications: Global Industry Perspective, Comprehensive Analysis, and Forecast, 2016 – 2022' from Zion Market Research, the global LED lighting market is rising at a compound annual growth rate (CAGR) of about 13% from $26.09bn in 2016 to $54.28bn by 2022. This is especially relevant for Israel, where many emerging technologies and solutions are created for the global market.

www.arteclantec.com
www.luminus.com

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www.evatecnet.com

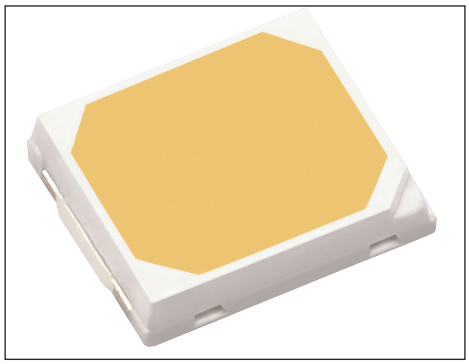
Lumileds adds 3V version to LUXEON 2835E mid-power LED range, raising efficacy to 170lm/W

LED maker Lumileds of San Jose, CA, USA has added the LUXEON 2835E 3V to its LUXEON 2835 Line.

The standard 2.8mm x 3.5mm package footprint first gained traction in television backlighting, but it is now proving convenient in general lighting applications including downlights, indoor area lighting such as TLEDs and troffers and lamps like B12 and A19 bulbs.

Lumileds claims that the LUXEON 2835E 3V raises the standard for this class of product in efficacy and reliability — with luminous efficacy up to 170lm/W — while meeting the DesignLights Consortium (DLC) Premium requirements.

"Because of the cost sensitivity of this market, other manufacturers have turned to lower-cost materials and practices that frankly have impacted long-term reliability," reckons product line director Yan Chai. "Lumileds has maintained its commitment to the highest-quality materials including proprietary phosphors, all-gold wire bonding, and the tightest process control to deliver the best performance and lumen maintenance," he adds. The LEDs are also DLC Premium V4.1 qualified, giving access to maximum energy savings, the highest utility rebates and EnergyStar certification.



Lumileds' new LUXEON 2835E LED.

Because of the cost sensitivity of this market, other manufacturers have turned to lower-cost materials and practices that frankly have impacted long-term reliability

The LUXEON 2835 Line consists of LUXEON 2835C for higher-output and LUXEON 2835E for lower-output ranges. LUXEON 2835E is available in a wide range of color temperatures of 2700–6500K with a minimum color rendering index (CRI) of 80. At the nominal drive current of 60mA, the LUXEON 2835E can achieve very high efficacy of 170lm/W and produces 30lm at 4000K and 80 CRI at 60mA. Alternatively, it can be driven at up to 150mA to produce > 60lm (4000K and 80 CRI).

In addition to this new 3V version, the LUXEON 2835E is also offered in 6V and 9V versions for entry-level A19 bulbs. Like other products in Lumileds mid-power family, the 6V and 9V LUXEON 2835E LEDs are hot-color targeted to ensure accurate color representation at application conditions.

Steve Barlow rejoins Lumileds as senior VP of Illumination

LED maker Lumileds of San Jose, CA, USA (a subsidiary of Royal Philips) has appointed Steve Barlow as senior vice president of its Illumination Business. He rejoins Lumileds from LED maker Cree Inc of Durham, NC, USA, where he served as senior VP of sales & business development, responsible for the lighting division products, channels and revenue growth.

Barlow has over 25 years of sales, marketing and business development experience in the semiconductor and LED lighting industry. He first joined Lumileds in 2003, helping to build its LED lighting business. He then served as chief commercial officer at Intematix Corp, responsible for all commercial functions including global sales, marketing, application engineering, customer service, business development and distribution.

Steve Barlow.

"He has an outstanding track record in the lighting industry, where he has demonstrated strong leadership, technology vision and customer relationship building skills," comments Lumileds' CEO Mark Adams.

The company's intellectual property, comprehensive product portfolio and deep customer relationships will be the cornerstone of our continued success

Philips announced on 12 December 2016 that it had signed an agreement to sell a majority stake in Lumileds to certain funds managed by affiliates of Apollo Global Management LLC. The transaction is expected to be completed in first-half 2017, subject to customary closing conditions. As required by the agreement, Apollo has been briefed on the appointment of Steve Barlow as SVP of Illumination.

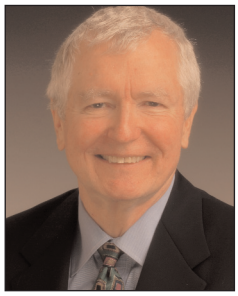
"Lumileds has created a unique position in the marketplace by offering differentiated lighting solutions," comments Barlow. "The company's intellectual property, comprehensive product portfolio and deep customer relationships will be the cornerstone of our continued success."

www.lumileds.com

Lumileds Solid State Lighting Fellow George Craford awarded IEEE Edison Medal

LED maker Lumileds of San Jose, CA, USA says that, at the IEEE Honors Ceremony in San Francisco on 25 May during the IEEE Vision, Innovations, and Challenges (IEEE VIC) Summit, George Craford (the Lumileds Solid State Lighting Fellow) will be presented with the IEEE Edison Medal for "a lifetime of pioneering contributions to the development and commercialization of visible LED materials and devices".

Craford's career spans from the early days when LEDs were first developed to the delivery of high-brightness LEDs suitable for commercial use in applications including LED bulbs. He is best known for his invention of the yellow LED in 1972. Craford then led the development of increasingly brighter red, orange and amber LEDs. In 1979, he began work at Hewlett-Packard, where his team pioneered the development of aluminium indium gallium phosphide (AlInGaP) LEDs using metal-organic chemical vapor deposition (MOCVD), which was then a relatively expensive lower-volume process and had not been utilized for the high-volume commercial production of LEDs.



George Craford.

AlInGaP LEDs increased the performance of red and yellow LEDs by more than 10 times. Craford's team continued to achieve technology breakthroughs in AlInGaP LEDs, reaching 100lm/W.

"Not only was George responsible for substantial breakthroughs in technology but, with his team, ensured that the technology could be reliably and cost effectively manufactured," comments Mark Karol, chair of the 2017 IEEE Awards Board.

Craford's later work focused on making white LED light cost effective for retail, office, architectural, outdoor and industrial lighting markets. In the early 2000s, his team's work enabled the commercialization of the first high-power LEDs in the 10–20lm range. Such LEDs contributed to the creation of the first LED bulbs to meet the high-efficiency and long-lifecycle requirements to win the US Department of Energy's 'L Prize' for a 60W-equivalent LED bulb.

"George has terrific instinct for what will work, but at the same time he's got that practical engineering side that drives a solution until it produces the best results," comments Lumileds' chief technology officer Jy Bhardwaj.

Craford is an IEEE Life Fellow and a member of the National Academy of Engineering. Previous awards include the 2002 National Medal of Technology and the 2015 US National Academy of Engineering Charles Stark Draper Prize. He has also been awarded the International SSL Alliance Global Solid State Lighting Development Award, the Strategies in Light LED Pioneer Award, the University of Illinois Alumni Distinguished Service Award, the IEEE Morris N. Liebmann Award, the IEEE Third Millennium Medal, the Optical Society of America Nick Holonyak Jr Award, the International Symposium on Compound Semiconductors (ISCS) Welker Award, the Materials Research Society MRS medal, the Electrochemical Society Electronic Division Award, and the Economist Innovation Award.

www.lumileds.com

Lumileds adds Advanced Technologies to Matrix Platform

Lumileds has announced Advanced Technologies, key components of its Matrix Platform, which streamline the development of integrated, fully assembled LED light engines. Combined with the firm's LUXEON LEDs, Matrix Platform Advanced Technologies pave the way for design and manufacturing developments:

- Oberon Intelligent Assembly is claimed to be the industry's only pick-and-place system that eliminates bins, instead selecting LEDs based on specific test data such as flux or V_f;
- Integrated Light Guides are ultra-thin and enable an enhanced light control;
- Integrated Drivers, designed to seamlessly incorporate all the necessary electronic components in a way that dramatically simplifies fixture design and reduces space requirements;
- Dimming Electronics involve patented circuitry technology to achieve the coveted dim to warm effect;
- Connectivity and Controls allows lighting manufacturers to design luminaires that can be controlled remotely, via apps or other devices.

Lumileds is working with Matrix Platform customers to meet their requirements. Lighting solutions can be developed by configuring LUXEON LEDs with exclusive Advanced Technologies on rigid or flexible substrates. "Customers find that, not only does the Matrix Platform approach enable award- and market-winning solutions, it also shaves weeks if not months off the traditional assembly approach and ensures a product reliability that only Lumileds can guarantee," claims Matrix Platform product manager Viral Hazari. Matrix Platform hence offers lighting manufacturers faster time to market, greater supply chain efficiency and reduced inventory, the firm adds.

www.lumileds.com/matrix-platform

Osram launches first multi-chip LED with lens integrated into single module, targeting camera flash applications

Osram Opto Semiconductors GmbH of Regensburg, Germany says that, for the first time, it has integrated two LED chips and a lens into a single module. The compact Oslux S 2.1 multi-chip LED gathers the firm's technical expertise into a new LED product for camera flash applications. With its brightness of 125 lux, the Oslux S 2.1 provides uniform illumination of photos and video recordings from mobile devices such as smartphones.

Osram Opto's new Oslux S 2.1 for camera flash applications combines two chips of different color temperatures — a cold-white chip of 6000K and a warm-white chip of 2250K (Dual-CCT) — providing both a multi-chip LED and a lens for the first time. This not only makes manufacturing easier by saving a step, but also produces excellent results, says the firm. With a maximum deviation of 300K, the Oslux offers high color fidelity and color uniformity across the target scene, it is claimed.

Osram Opto's Oslux S 2.1 multi-chip LED.

The integration of two LED chips and a silicone lens in one module offers benefits in video lights and camera flash applications. Now, no separate step is necessary for optimum positioning of the lens, which saves time and optimizes the use of the generated light. While dimensions of 5.0mm x 5.0mm x 1.15mm make the Oslux S 2.1 with its lens slightly taller than previous models, it requires less space on the board and has a smaller exposed aperture than two single LEDs, making it more compact overall. The silicone lens also allows the module to be reflow solderable, allowing the module to be easily integrated into standard manufacturing flows.

"With the new Oslux S 2.1 we were able to achieve very high quality," says product marketing manager Russell Willner. "We have subjected it to both electrical and optically demanding testing and are very happy with the results."

The Oslux S 2.1 is available now, and in early 2018 Osram Opto is planning to release an additional version (Oslux S 2.2) with an epoxy lens (rather than a silicone lens). Due to this extremely hard material, the Oslux S 2.2 can be installed in mobile devices without a separate protective window, providing additional industrial design options. Also, a spectrum-optimized converter will provide the Oslux S 2.2 with better photos.

www.osram-os.com

Osram showcases Oslon Square Hyper Red high-power LED with larger chip and improved radiant flux for horticulture lighting

At the LightFair International 2017 trade show in Philadelphia (9–11 May), Osram Opto Semiconductors GmbH of Regensburg, Germany has showcased the Oslon Square Hyper Red LED prototype for promoting healthy plant growth. This third-generation 2W LED features improved emission characteristics, higher optical output and corrosion resistance, so plant lighting systems based on it can be made particularly economical, says the firm.

By using LEDs with different wavelengths, commercial growers are now able to control each individual stage of plant growth. With a wavelength of 660nm the prototype of the Oslon Square Hyper Red, for example, can control the growth of blossom. Together with the deep blue (450nm) and far red (730nm) versions, Osram Opto's Oslon family spans the entire spectrum of plant growth.

The prototype of the high-power LED has an integrated 2mm x 2mm chip that provides improved performance. By using the latest technologies, developers have been able to achieve a typical radiant power of 905mW with radiant efficacy of 60%, at a drive current of 700mA and an operating temperature of 25°C. This represents an improvement of 13% in terms of radiant power and 25% better radiant efficacy compared with the existing Oslon SSL LED. The beam angle of the Oslon Square Hyper Red is 120°.

"Thanks to its high corrosion resistance and long life, the new Oslon Square Hyper Red is extremely reliable," says Kok Peng Lim, product manager SSL. "Our new flagship product therefore also meets the usual high quality standards of the entire Oslon family."

The Oslon Square Hyper Red has the same footprint as the existing Oslon SSL versions, so it can be easily used as a replacement. Switching to the new product makes economic sense for users in two respects, reckons Osram Opto: (1) the new high-power LED is more powerful than its predecessor, and (2) one Oslon Square Hyper Red can replace two Oslon SSL LEDs.

Volume production of the new LEDs is scheduled for the end of 2017.

www.osram.com

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FerroTec

Cree's chairman & CEO Chuck Swoboda to step down upon appointment of successor

Swoboda to remain as consultant during transition period

LED chip, lamp and lighting fixture maker Cree Inc of Durham, NC, USA says that chairman, president & CEO Chuck Swoboda will step down from his executive positions and as a member of the board of directors once a successor is appointed, after which he will remain available as a consultant during a transition period. The board will retain a leading executive search firm to identify a successor. Both internal and external candidates will be considered.

Since joining Cree in 1993, Swoboda has held numerous executive positions, leading the firm from a near start-up to now employing about 6400 staff worldwide. He has served as a member of the board since 2000, CEO since 2001, and chairman since 2005. In 2010, he was named Ernst & Young's Entrepreneur of the Year for the Carolinas, and in 2013 he was named The Edison Report's Lighting Industry Person of the Year. Cree was recognized as one of MIT Technology Review's 50 Smartest Companies for 2014, and as one of Fast Company's World's 50 Most Innovative Companies in 2015.

"My decision to change my work-life balance follows a recent medical issue, which was resolved, and which caused me to reevaluate my priorities," states Swoboda. "This is a good transition time for Cree as we have three core businesses poised to enter another phase of accelerated growth," he believes. "I look forward to working with the Cree board to find the right leader and to ensure a smooth handoff to my successor."

"The board extends its deep appreciation to Chuck for his outstanding leadership over the past 16 years as CEO, and for his 24 years of service to Cree," comments lead independent director Robert A. Ingram. "During that time, his passion for the business and focus on innovation has helped transform industries and has enabled the Company to achieve an eight-fold increase in revenue," he notes. "He and the rest of the board agree that now is the right time to accelerate the process to identify a new CEO to lead Cree and further grow our three businesses."

Cree has also reaffirmed its business outlook (announced on 25 April) for fiscal fourth-quarter 2017 (ending 25 June) of revenue of $340–360m, with net income rising to $2–7m ($0.02–0.07 per diluted share).

www.cree.com

Osram launches its smallest sidelooking IR LED for eye-tracking systems in VR/AR headsets

Osram Opto Semiconductors GmbH of Regensburg, Germany is launching its smallest ever sidelooking infrared LED. Based on the proven Firefly platform (used widely for LEDs in the visible spectrum), the 850nm-wavelength SFH 4055 is targeted primarily at eye-tracking systems in augmented and virtual reality headsets.

Eye-tracking systems use multiple infrared LEDs to illuminate users' eyes and capture the light reflected back with camera sensors, allowing them to compute the position of the user's pupil and work out what direction they are looking in. Incorporating this technology into virtual reality (VR) or augmented reality (AR) headsets requires infrared LEDs that are small enough to fit into glasses around eyepieces. The the new Firefly sidelooking LED has a footprint of just 1.0mm x 0.55mm, and a low height of just 0.325mm.

Intuitive interaction, less computing power

Eye tracking supports entirely new, highly intuitive forms of interaction in VR and AR applications and enables users to control software programs by directing their gaze. For example, AR glasses can display information that relates specifically to an object that a user has selected.

There is an added benefit for VR systems: they can exploit eye tracking to reduce the amount of computing power they require (a useful capability, given the need to render images extremely quickly so as to offer users a realistic experience). Image rendering requires computers that can deliver a lot of processing and graphics power. With eye tracking, these systems can focus on rendering images at a high resolution in the line of sight and maintain a lower resolution in the periphery.

Benefits for optical touchscreens too

Infrared transmitters, lasers and photodetectors from Osram are already in use in VR and AR solutions, and the first infrared Firefly will enable it to support new applications in this fast-growing market.

The SFH 4055 is generally aimed at applications that require exceptionally compact infrared transmitters. For example, optical touchscreens rely on very low-profile, side-emitting infrared LEDs to create a grid of infrared light used for detecting finger positions.

www.osram.com

Osram acquiring California-based LED Engin

Purchase to boost Osram's specialty lighting business

Lighting manufacturer Osram GmbH of Munich, Germany has agreed to acquire LED Engin Inc of San Jose, CA, USA (which develops and makes LED emitters, optics components and light source modules in a high-lumen-density, multi-die package for solid-state lighting applications). The firm has about 30 employees and annual sales of around $10m.

LED Engin specializes in ultra-bright, ultra-compact solid-state lighting solutions for specialty markets including entertainment lighting, ultraviolet, horticulture, tunable white and medical lighting applications. Its products mainly incorporate LED chips from Osram Opto Semiconductors GmbH of Regensburg, Germany.

"LED Engin opens up new opportunities for us to offer our customers tailored specialty lighting solutions," says Hans-Joachim Schwabe, CEO of Osram's Specialty Lighting (SP) business unit. "LED Engin products are suitable for a variety of specialty applications, making them an ideal addition to our portfolio," he adds.

LED Engin will be integrated into the professional and industrial applications section of the SP business unit. LED Engin products are used in applications where powerful, compact LED light sources or special customized LEDs are required, for example to light restaurants, shops, museums, and galleries. The firm also supplies lighting products for horticulture markets and powerful UV LEDs for industrial applications, such as the printing, curing and dental markets. In the entertainment sector, LED Engin should enhance Osram's value chain, together with ClayPaky and ADB (the specialists for concert, event, theater, stage, and TV studio lighting).

"We look forward to expanding our product portfolio and customer reach while continuing to serve our existing valued customers with additional resources," comments LED Engin's chief executive officer David Tahmassebi.

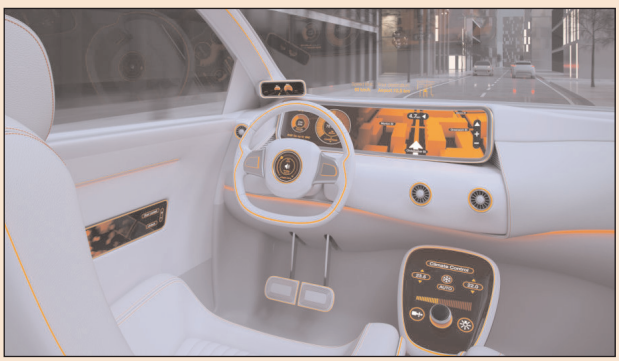
www.ledengin.com
www.osram.com

Osram's latest-generation Topled E1608 low-power LED shrinks package 20-fold while boosting brightness by 3.6x

After its Topled became the first surface-mountable LED more than 25 years ago, Osram Opto Semiconductors GmbH of Regensburg, Germany has now launched the latest generation, the Topled E1608, with a package smaller than its predecessor models by a factor of 20. Despite this miniaturization, the low-power LED is bright, reliable and robust, says the firm, offering greater options and design flexibility, particularly for car interior applications.

The new Topled E1608 LEDs are based on the latest chip technologies such as ThinGaN as well as thin film and sapphire. In combination with the latest high-efficiency converters, the new low-power LEDs are 3.6 times brighter than preceding Topled models (at a normal operating current of 20mA). For example, the converted pure-green version achieves what is claimed to be an unprecedented 780mcd at 10mA.

For the package, Osram uses tried and tested pre-mold technology, but reduced in size to 1.6mm x 0.8mm for the E1608, compared with the standard 3.2mm x 2.8mm Topled. At 0.6mm, the E1608's height is also considerably less than the previous 1.9mm. Due to the new package dimensions, the E1608 can now be used for more compact customer systems.



LED illumination of car dashboard.

"The new Topled E1608 LEDs are some of the smallest LEDs in their class, offering reliability, a wide selection of colors and impressive performance values," claims Michael Godwin, Osram Opto's director of World Wide Interior Automotive Products. "In addition, they are suitable for all customer requirements — whether the application is toward the top or bottom of the brightness range," he adds. "We anticipate they will become firmly established in the market and may eventually define a new industry standard. These robust LEDs are suitable particularly for the automotive sector for applications such as displays, ambient lighting and backlighting of switches and instruments."

Osram's next-generation Topled will be available in numerous colors — from yellow and orange to super red, white, pure green and true green. The current market launch of six Topled E1608 products is the start of a whole series of new versions in this product family. In the course of 2017 more new versions will be successively launched.

Leti demos first WVGA 10µm-pitch GaN microdisplays for augmented reality video

Extending its expertise in high-brightness microdisplay technology for augmented-reality and other applications, micro/nanotechnology R&D center CEA-Leti of Grenoble, France demonstrated what it claims is the first wide video graphic array (WVGA) gallium nitride microdisplay with a 10µm pixel pitch at Display Week in Los Angeles (21–26 May).

The 10µm pixel-pitch technology will help to address the growing demand for augmented-reality glasses for consumer and professional users, head-up displays for vehicle drivers, and for pico projectors and other compact projectors, says Leti.

Based on a self-emissive GaN-based technology, the prototype microdisplay is said to exhibit the highest resolution with the smallest pixel pitch (10µm) ever presented. This was achieve by patterning high-density microLED arrays and hybridizing them on a CMOS circuit, using Leti's micro-tube technology. The demonstrator featured a monochrome (blue or green) active-matrix prototype with a WVGA resolution of 873 x 500 pixels.

"We will continue to work towards a 5µm pixel pitch and, beyond that, on a new technology that will take GaN LED microdisplays to less than a 5µm pixel pitch," says project manager François Templier.

At Display Week, Leti presented the new technology in the invited talk 'A Novel Process for Fabricating High-Resolution and Very Small Pixel-pitch GaN LED Microdisplays', demonstrating the feasibility of LED arrays with pixel pitch as small as 3µm (a world record).

The results were obtained under a collaborative work program with III-V Lab (the joint Alcatel-Lucent, Thales and CEA-Leti industrial research laboratory).

www.leti.fr
www.3-5lab.fr

SoraaLaser demonstrates new dynamic laser light source technology for specialty lighting

At LightFair International in Philadelphia (9–11 May), SoraaLaser of Goleta, CA, USA (a spin-off from LED lighting firm Soraa Inc that is commercializing visible laser light sources) demonstrated its new dynamic laser light source technology

The solid-state light sources feature fiber-delivered illumination that can be dynamically tuned from a narrow beam spotlight to a broad floodlight using a smartphone app control.

SoraaLaser claims that its solid-state laser light source technology provides advantages over LED, OLED and legacy sources in specialty lighting by enabling digital design freedom for specifiers and luminaire manufacturers in architectural, outdoor, hospitality, retail, security and entertainment lighting. In the past, dynamic beam shaping could only be accomplished by motors, manual change-out of optics, or the switching on and off of many dozens of LEDs within a large matrix, says the firm.

SoraaLaser's visible laser light sources utilize its patented semi-polar gallium nitride (GaN) laser diodes, combined with advanced phosphor technology, packaged into lighting-friendly assemblies. Compared with other light sources, they are said to provide novel properties by combining the benefits of solid-state illumination (such as minimal power consumption and long lifetime) with the highly directional output that has been possible only with legacy technology. Because the laser diodes are focused to a small spot on the phosphor and converted to white light, the SoraaLaser light sources are said to deliver high luminance and enable safe, highly collimated white light output, superior optical control with miniature optics and reflectors, along with high-efficiency fiber-optic transport and waveguide delivery.

www.soraalaser.com

Soraa Sky wins LightFair International Innovation Award

The consumer-focused Soraa Sky bulb won an Innovation Award at LightFair International.

Formerly named Helia, it dynamically adjusts color and spectral content to promote positive effects on the body's natural circadian rhythm. By starting with a full-spectrum LED source, it precisely tunes in and out the blue-light content throughout the day — just like the sun — while always providing white light.

Using BlueFree LED technology, Soraa Sky's lighting system recognizes that blue light is helpful in the morning, just like the sunrise. During the day, it emits museum-quality light with moderate blue light. In the evening, Sky bulbs have the unique ability to completely remove blue emissions, but still provide soft white light (violet replaces blue light), aiding subsequent sleep.

www.soraa.com
www.lightfair.com

CST leading Quantum Ring Single Photon LED project

Mass production of low-cost, single-photon LEDs targets next-generation network security

III-V optoelectronic foundry Compound Semiconductor Technologies Global Ltd (CST Global, a subsidiary of Sweden-based Sivers IMA Holding AB) of Hamilton International Technology Park, Blantyre, near Glasgow, Scotland, UK is leading the gallium antimonide/gallium arsenide (GaSb/GaAs) Quantum Ring Single Photon LED (QR_SPLED) project, which runs from March 2017 until February 2018 and seeks to mass produce low-cost, single-photon LEDs (SPLEDs); a critical technology step in the development of commercially viable, next-generation, intrinsic network security.

The academic partner on the project is Dr Manus Hayne of the Department of Physics at Lancaster University, who is said to be a recognized authority on GaSb/GaAs quantum rings and their use in devices such as telecoms-wavelength vertical-cavity surface-emitting lasers (VCSELs).

"To successfully produce next-generation, secure networks we must first mass produce low-cost, single-photon LED sources," says project lead Thomas Slight, a research engineer at CST Global. "They provide two enabling security elements. The first being that the single-photon LED can transmit unique 'key exchange' encryption and decryption data within each data packet, making it impossible to hack. The second being that any attempt to measure or 'eavesdrop' on communications is immediately detected and the communication terminated."

The QR-SPLED project (EP/P034233/1) is funded by UK government through the agency Innovate UK and the Engineering and Physical Sciences Research Council (EPSRC), in the framework of the UK National Quantum Technologies Programme, with additional funding expected for developing a packaged SPLED solution later. UK funding of £252,649 is targeted at retaining the critical knowledge and expertise generated by the project in the UK and allowing CST Global, and other commercial partners, to be at the forefront of emerging, next-generation quantum-telecoms-driven network security.

www.CSTGlobal.uk
http://siversima.com

FBH showcases diode laser and UV LED developments

At the Laser World of Photonics 2017 trade show in Munich, Germany (26–29 June), Berlin-based Ferdinand-Braun-Institut, Leibniz-Institut für Höchstfrequenztechnik (FBH) — which offers the full value chain in-house (from design through chips to modules), and increasingly develops these devices for use as operational systems — presented its latest developments in diode lasers and ultraviolet (UV) light-emitting diodes (LEDs).

Specifically, FBH showcased a unique, computer-controlled picosecond light source delivering high-precision pulses in the pico- and nanosecond ranges, a 6kW fiber-coupled pump module for solid-state laser systems, and a demonstrator module equipped with UV-C LEDs for water disinfection purposes. The LEDs have been developed within the Advanced UV for Life consortium managed by FBH.

Flexible all-in-one pulse light source

With its PLS series, FBH offers laser sources that deliver high-precision pulses in the pico- and nanosecond range with nanojoule energies. Pulse energy, width, and spacing as well as repetition frequencies can be flexibly adjusted. The laser system offers freely selectable repetition rates from the hertz to the megahertz range and peak pulse powers of up to 50W. It uses tailored diode lasers for impulse generation combined with optimized RF components as electronic drivers (both are core competencies of FBH).

The computer-controlled all-in-one system can be switched into different pulse modes and thus be integrated into various laser systems with little effort. The system is equipped with 1030nm diode lasers, but can easily be adapted to other wavelengths. It is therefore suitable for applications such as material processing, bio-medical examinations, and mobile LIDAR systems. The PLS 1030 was constructed jointly by laser and RF circuit experts with engineers from the in-house Prototype Engineering Lab, an FBH team that develops industry-ready and user-friendly prototypes. Companies hence get direct access to the latest research results.

Efficient diode lasers for applications with kilowatt-class output

FBH develops high-brilliance diode lasers in a large variety of designs in the wavelength range 630–1180nm. All activities aim to steadily increase efficiency, reliability and output power of diode lasers and bars. In recent work, laser bars with a 6mm-long resonator and 10mm aperture have reached output powers of 1kW while maintaining a conversion efficiency of 63%. Detailed results for these bars were presented at the CLEO Europe conference in Munich, which takes place on 25–29 June (in parallel with Laser World of Photonics).

Bars with long cavities of this kind provide ultra-low thermal and electrical resistances. They are therefore expected to be highly beneficial for kW-level continuous-wave (CW) operation and thus particularly attractive for industrial and scientific high-power applications. For example, such diode laser bars are used as pump sources for solid-state and fiber lasers or employed directly in material processing.

The high-intensity output of the single emitters in the stacks is optically combined into a beam and then coupled with low losses into a fiber. A pump laser system is hence available for the first time that simultaneously offers high power, good efficiency, and a long duty cycle. Novel high-energy-class solid-state lasers can therefore be efficiently pumped

FBH says that innovations regarding chip design and technology along with mounting and module design have simultaneously enabled advances in pumping of solid-state systems. Novel chips with a very broad aperture of 1.2mm were integrated into innovative side-cooled stacks that are particularly suitable for pulsed operation with a larger duty cycle of 20%. The high-intensity output of the single emitters in the stacks is optically combined into a beam and then coupled with low losses into a fiber. A pump laser system is hence available for the first time that simultaneously offers high power, good efficiency, and a long duty cycle. Novel high-energy-class solid-state lasers can therefore be efficiently pumped with these systems. In its booth, FBH presented an example pump laser module with 6kW peak power and an electro-optical efficiency of 50%.

High-brilliance tapered lasers with further increased output power

Tapered lasers deliver high optical output powers in a narrow spectral line with equally good beam quality. FBH recently further enhanced its output power in the spectral range 980–1120nm. The newly developed 1030nm tapered diode lasers yield up to 10.3W diffraction-limited output power, much increased on the previous record of 8W. This corresponds to 76% of the emitted light output. This improvement was due to further optimization of the lateral spatial mode filtering and the internal wavelength-selective gratings. The latter ensure laser emission within 22pm spectral width over the full operating range. The diode lasers are hence also suitable for challenging applications like non-linear frequency conversion.

www.world-of-photonics.com
www.fbh-berlin.com
/en/news-

Synopsys releases RSoft Photonic Component Design Suite version 2017.03 for opto device analysis

Updated interface with Sentaurus TCAD products and new high-speed optical absorption calculation now available

Synopsys Inc of Mountain View, CA, USA — which provides electronic design automation (EDA) software, semiconductor IP and services for chip and electronic system design — has announced the latest release of its RSoft Photonic Component Design Suite for photonic devices and components used in optical communications, optoelectronics and semiconductor manufacturing.

Version 2017.03 accelerates optoelectronic device analysis with an updated interface to Synopsys' Sentaurus TCAD (technology computer-aided design) products and new general monitor objects in the RSoft BeamPROP tool that can speed simulations of waveguide photodetectors by as much as 100x compared with finite-difference-time-domain (FDTD) methods.

The release also builds on the RSoft tools' capabilities for modeling nanoscale optical structures with an improved bi-directional scattering distribution function (BSDF) calculation for mixed-level LED/OLED simulations.

Sentaurus TCAD interface: enhanced usability and faster waveguide photodetector simulations

The Sentaurus TCAD interface provides seamless integration of the RSoft optical tools in Sentaurus Workbench for in-depth, multi-disciplinary simulations of optoelectronic devices. Usability improvements include support for systems with dispersive materials and dynamic updates of materials and the common simulation area. Native bi-directional data interchange between the RSoft tools and Sentaurus Workbench has been expanded to include the BeamPROP tool for waveguide detector simulation, giving designers what is claimed to be a substantial speed advantage. Specifically, BeamPROP's new general monitor objects perform highly efficient optical power absorption calculations to speed photodetector simulations by up to 100x compared with FDTD-based methods. This enables faster device characterization and optimization and also reduces time-to-market and development costs, says Synopsys.

"Designers can use the RSoft-Sentaurus TCAD interface for accurate, high-speed simulations of complex optoelectronics that benefit from both photonic and electronic simulations," says George Bayz, VP & general manager of Synopsys' Optical Solutions Group. "For example, the new version offers significantly faster simulations of waveguide detectors used in photonic integrated circuits."

Improved BSDF scattering calculation

The new release improves Synopsys' LightTools and RSoft mixed-level co-simulation method, which combines ray- and wave-based techniques to incorporate polarized diffraction effects in LightTools' ray-tracing simulator with accuracy and efficiency. The co-simulation method uses the RSoft BSDF capability, which now performs more robust scattering calculations of polarization-dependent effects in nanoscale optical structures. This can be useful for designing LEDs and OLEDs used in high-efficiency backlights, projection display lighting and sensors, says Synopsys.

https://optics.synopsys.com/rsoft/rsoft-component-design.html

Sofradir develops 2048x2048 15µm-pitch SWIR detector for space observation

Collaboration with CEA-Leti and CEA-IRFU under ESA's Near Infrared Large Format Sensor Array program targets fully characterized low-flux, low-noise ALFA prototype in Q1/2019

Sofradir of Palaiseau near Paris, France — a subsidiary of Safran and Thales that makes cooled infrared (IR) detectors for military, space, scientific and industrial applications — is developing its first very-large-format (2048x2048) 15µm-pixel-pitch infrared detector. The supersize IR detector is designed for future scientific space observation equipment and Extremely Large Telescopes (ELT) for ground observation aimed at tackling major scientific challenges.

The ALFA 2Kx2K (Astronomy Large Focal Array) 15µm-pitch short-wave infrared detector is intended to provide the highest levels of performance in quantum efficiency (QE), dark current and noise in order to optimize IR observations for astrophysicists.

Sofradir is collaborating with the French research centers CEA-Leti in Grenoble and CEA-IRFU in Paris to develop the ALFA near-infrared detector through a European Space Agency (ESA) initiative. Sofradir plans to deliver a fully characterized low-flux, low-noise ALFA prototype in first-quarter 2019.

"ALFA 2Kx2K will enable OEMs to build new instruments, opening up new opportunities for us in astronomy and other sciences, where every single infrared application needs very low flux and low noise compatibility," says space activities manager Philippe Chorier.

Large-format infrared detectors (greater than 1024x1024) are highly complex devices that only a handful of manufacturers in the world can produce to space-grade standards, says Sofradir. This new low-flux, low-noise near-infrared (NIR) 2Kx2K detector for space astrophysics is the result of developments that the ESA initiated several years ago under its Near Infrared Large Format Sensor Array (NIRLFA) program (on which Sofradir, CEA-Leti and CEA-IRFU have been working since 2009).

The NIR detector is based on mercury cadmium telluride (HgCdTe) as the absorbing material, and includes a read-out circuit (ROIC) with a source follower per detector (SFD) at the input stage.

Sofradir says that the detector's development will benefit from its experience as a leading manufacturer of IR detectors deployed in space (totaling more than 82 flight models to date). Space programs include: Sentinel 2 and Sentinel 5 (Copernicus), and MTG (Meteosat Third Generation) and Exomars.

"Thanks to ALFA detector, Sofradir will be able to offer a new up-to-date solution for applications in space, science and astronomy," says Chorier.

Sofradir and its subsidiaries ULIS and Sofradir-EC exhibited a selection of IR detectors and large-format models for airborne, naval, ground vehicle and space applications at the Paris Air Show (19–25 June).

www.sofradir.com

ProPhotonix delivers 100,000th laser module for robotic guidance application

ProPhotonix Ltd of Salem, NH, USA, a designer and manufacturer 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) with operations in Ireland and the UK, says that it has now delivered more than 100,000 custom laser diode modules designed specifically for obstacle detection in robotic guidance applications.

Robotic guidance applications (i.e. autonomous mobile robots employing vision systems to direct and redirect a robot) require laser modules to be both compact and robust. Long lifetimes are also important, as replacing laser modules can be costly. Critical to this application is the ability to meet a number of demanding requirements of the laser beam to ensure successful obstacle detection.

ProPhotonix reckons that, as a supplier of laser diodes as well as a laser module manufacturer, it is well positioned to identify the most suitable laser diode to meet the user's optical requirements. Its ability to design an optimal optical system and to manufacture laser module parts in house ensures that the tight tolerances required are reliably and consistently achieved, the firm claims.

"This is an excellent example of how ProPhotonix works with OEMs to understand the key requirements for their application and then utilizes its strengths and experience to design a cost-effective custom solution to consistently deliver on those requirements," says Jeremy Lane, managing director of ProPhotonix Ltd UK. "The volume of sales in this instance is a good indicator of the suitability and reliability of the laser module."

www.prophotonix.com

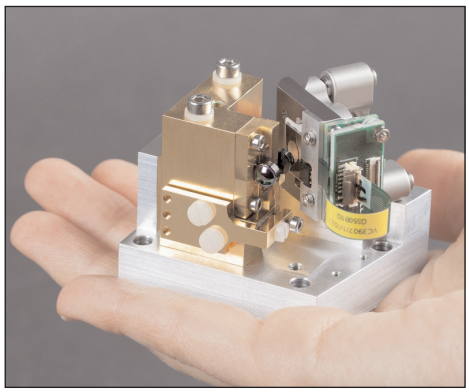
MIRPHAB to provide tailor-made spectroscopy solutions

EU-funded project to fabricate mid-IR sensor devices for early adopters

Every chemical substance absorbs a very individual fraction of infrared light. This absorption can be used with optical methods for identifying substances. Such methods are used in the chemical industry, for example, but also in the healthcare sector and in criminal investigation. If a company plans a new project, it often needs individually tailored sensor solutions. In the search for a suitable system, they are now supported by the EU-funded pilot line MIRPHAB (Mid InfraRed PHotonics devices fABrication for chemical sensing and spectroscopic applications) for the development of sensor technology and measurement technology in the mid-infrared. Three of Germany's Fraunhofer institutes are participating in the project.

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

If a company is looking for a sensor solution, such as to identify a certain substance in the production process, it often has very individual requirements. This starts with the substances to be accounted for to the number of required sensors up to the speed of the production process. In most cases, a 'one-size-fits-all' solution is not sufficient, and several suppliers are needed in order to develop the optimal individual solution. In the MIRPHAB pilot line, leading European research institutes and companies from the MIR industry have joined forces to provide tailor-made devices from a single source. Interested parties can address a central contact person, who then compiles the best possible solution from the component portfolio of MIRPHAB members according to the modular principle.



Demonstrator of the miniaturized laser source consisting of a quantum cascade laser chip and a MOEMS grating scanner.

To strengthen the European industry in the long term and expand its position in chemical analysis and sensor technology, the development of individual MIR sensor solutions within the framework of MIRPHAB is supported by EU funding. This significantly reduces the investment costs and hence the entry threshold for companies in the MIR sector. In combination with the virtual infrastructure developed in the course of MIRPHAB, high-quality MIR sensors are therefore also of interest to companies for whom the costs and development effort have previously been seen as being too high. In addition, MIRPHAB gives firms access to the latest technologies, enabling them to gain an edge over the competition as an early adopter.

Customized MIR laser source

A central component of MIRPHAB sensor solutions is provided by the Fraunhofer Institute for Applied Solid State Physics IAF in Freiburg in cooperation with the Fraunhofer Institute for Photonic Microsystems IPMS in Dresden. Fraunhofer IAF is introducing the technology of quantum cascade lasers (QCLs), which emit light in the MIR range. In this type of laser, the wavelength range of emitted light is spectrally very broad and can be customized during manufacturing. To select a specific wavelength within the wide spectral range, it has to be chosen via an optical diffraction grating and coupled back into the laser chip. By rotating the grating, the wavelength can be tuned continuously. The grating is produced at the Fraunhofer IPMS in miniaturized form using micro-electro-mechanical system (MEMS) technology. This makes it possible to oscillate the grating at a frequency of up to 1kHz and to hence tune the wavelength of the laser source up to 1000 times per second over a very wide spectral range.

The Fraunhofer Institute for Production Technology IPT in Aachen is also involved in MIRPHAB in order to make the production of lasers and gratings more efficient and to optimize them for pilot series production. With its expertise, it transforms the production of the rapidly tunable MIR laser into industrially applicable production processes.

Process analysis in real time

At present, many applications in spectroscopy are still in the visible or near-infrared range and use relatively weak light sources. MIRPHAB offers solutions based on infrared semiconductor lasers. These have a significantly higher light intensity, enabling completely new applications. As a result, up to 1000 spectra per second can be recorded with the MIR laser source, which, for example, enables the automated monitoring and control of chemical reactions and biotechnological processes in real time. MIRPHAB says that it is therefore making a key contribution to the factory of the future and Industrie 4.0.

www.mirphab.eu

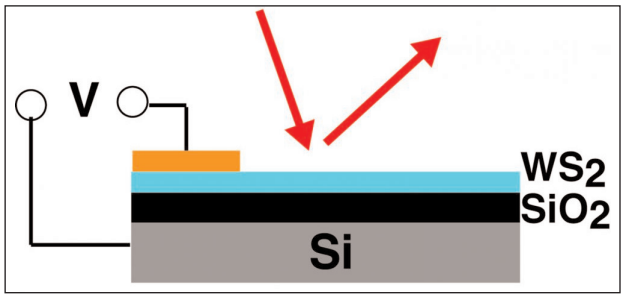
Method developed for electrically tuning refractive index in metal dichalcogenide monolayers by 60%

2D materials promise development of field-effect photonics for controlling optical functionality using CMOS circuits

North Carolina State University (NCSU) — in collaboration with researchers at Philadelphia's Temple University and China's Wuhan Institute of Technology — have discovered a technique for controlling light with electric fields (Yiling Yu et al, 'Giant Gating Tunability of Optical Refractive Index in Transition Metal Dichalcogenide Monolayers', Nano Letters; DOI: 10.1021/acs.nanolett.7b00768).

"Light may be controlled to be strong or weak, spread or focused, pointing one direction or others by an electric field," says Linyou Cao, assistant professor of materials science and engineering. "Just as computers have changed our way of thinking, this new technique will likely change our way of watching. For instance, it may shape a light into arbitrary patterns, which may find applications in goggle-free virtual reality lenses and projectors, the animation movie industry or camouflage."

"Light may be controlled by tuning the refractive index of materials. The more one can control a material's refractive index, the more control you have over the light that interacts with that material," Cao says. "Unfortunately, it is very difficult to tune refractive index with electric fields," he adds. "Previous techniques could only change the index for visible light by between 0.1 and 1% at the maximum."



Technique for electrically manipulating light through interaction with an atomically thin semiconductor.

Cao and his collaborators have developed a technique that allows them to change the refractive index for visible light in some semiconductor materials by 60% – two orders of magnitude better than previous results. The researchers worked with a class of atomically thin transition metal dichalcogenide (TMDC) monolayers, specifically molybdenum sulfide (MoS_2), tungsten sulfide (WS_2) and tungsten selenide (WSe_2).

"We changed the refractive index by applying charge to two-dimensional semiconductor materials in the same way one would apply charge to transistors in a computer chip," Cao says. "Using this technique, we achieved significant, tunable changes in the index within the red range of the visible spectrum."

Currently, the new technique allows researchers to tune the refractive index by any amount up to 60% — the greater the voltage applied to the material, the greater the degree of change in the index. And, because the researchers are using the same techniques found in existing computational transistor technologies, these changes are dynamic and can be made billions of times per second.

"This technique may provide capabilities to control the amplitude and phase of light pixel by pixel in a way as fast as modern computers," says Yiling Yu, a recent graduate of NCSU and lead author of the paper.

"We can optimize the technique to achieve even larger changes in the refractive index," believes Cao. "We also plan to explore whether this could work at other wavelengths in the visual spectrum."

Cao and his team are also looking for industry partners to develop new applications for the discovery.

The work was undertaken with support from the US National Science Foundation (NSF) under grant ECCS-1508856, and from the Center for the Computational Design of Functional Layered Materials at Temple University, which is funded by the Department of Energy under grant DESC0012575.

http://pubs.acs.org/doi/abs/10.1021/acs.nanolett.7b00768
www.mse.ncsu.edu

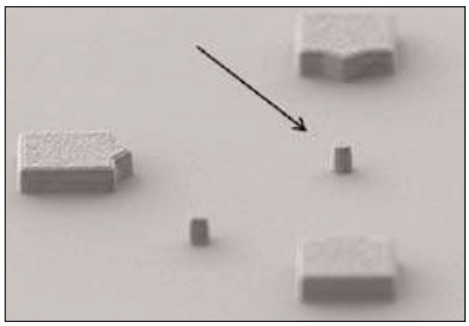
A*STAR develops manufacturing of hybrid silicon lasers for mass-produced photonic devices

New heterocore configuration and integrated fabrication process combines low-temperature SiO_2 interlayer bonding with dual hard-mask, single lithography patterning

Producing semiconductor lasers on a silicon wafer is a long-held goal for industry, but their fabrication has proved challenging. Now, researchers at the Data Storage Institute (DSI) of Singapore's Agency for Science, Technology and Research (A*STAR) say that they have developed a way to manufacture them that is cheap, simple and scalable (Chee-Wei Lee et al, 'Fabrication and Demonstration of III–V/Si Heterocore Microcavity Lasers via Ultrathin Interlayer Bonding and Dual Hard Mask Techniques', ACS Photonics (2016) 3 (11), p2191).

Hybrid silicon lasers combine the light-emitting properties of group III–V semiconductors like gallium arsenide and indium phosphide with the maturity of silicon manufacturing techniques. Such lasers are attracting attention as they promise inexpensive, mass-producible optical devices that can integrate with photonic and microelectronic elements on a single silicon chip. They have potential in a wide range of applications, from short-distance data communication to high-speed, long-distance optical transmission.

In existing production processes, lasers are fabricated on separate III–V wafers before being individually aligned to each silicon device — a time-consuming, costly process that limits the number of lasers that can be placed on a chip.



Oblique angle scanning electron microscopy image of a 500nm-diameter microdisk.

To overcome these limitations, Doris Keh-Ting Ng and her colleagues at the A*STAR Data Storage Institute have developed a method for producing a hybrid III–V semiconductor and silicon-on-insulator (SOI) optical microcavity, greatly reducing the complexity of the fabrication process and resulting in a more compact device.

"It is very challenging to etch the entire cavity," says Ng. "Currently, there is no single etch recipe and mask that allows the whole microcavity to be etched, and so we decided to develop a new approach."

By first attaching a thin film of III–V semiconductor to a silicon oxide (SiO_2) wafer using a SOI interlayer thermal bonding process, they produced a strong bond that also removes the need for strong oxidizing agents, such as Piranha solution or hydrofluoric acid.

Also, by using a dual hard-mask technique to etch the microcavity that confined etching to the intended layer, they eliminated the requirement to use multiple overlay lithography and etching cycles — a challenging procedure.

"Our approach cuts down the number of fabrication steps, reduces the use of hazardous chemicals, and requires only one lithography step to complete the process," says Ng.

The work is said to present, for the first time, a new heterocore configuration and integrated fabrication process that combines low-temperature SiO_2 interlayer bonding with dual hard-mask, single lithography patterning.

"The process not only makes it possible to produce heterocore devices, it also greatly reduces the challenges of fabricating them, and could serve as an alternative hybrid microcavity for use by the research community," reckons Ng.

http://pubs.acs.org/doi/abs/10.1021/acsphotonics.6b00794
www.a-star.edu.sg/dsi

II-VI Inc ramps production of 18W pump laser diodes

Production capacity to be doubled by end-2017

Engineered materials and optoelectronic component maker II-VI Inc of Saxonburg, PA, USA (which provides solutions for next-generation optical networks) is ramping up production of 18W pump laser diodes for fiber lasers.

Kilowatt-class fiber lasers used for cutting, welding and brazing rely on component innovations to scale their performance. II-VI's new high-brightness laser diodes feature a 190µm-wide output facet designed to achieve optimum coupling efficiency into widely used 200µm-core fibers. The increased output power per emitter enables fiber-laser manufacturers to generate higher power levels with a reduced number of emitters.

"As a result of the strong demand for our new laser diodes, we will double our production capacity by the end of this year," says Karlheinz Gulden, general manager, II-VI Laser Enterprise. "Customers continue to rely on II-VI's high-power semiconductor laser technology innovations that enable their fiber lasers to be competitive in terms of power, reliability and cost," he adds.

The 18W pump laser diodes are available at 915, 940 and 976nm. They feature II-VI's proprietary E2 front mirror passivation, preventing catastrophic optical damage (COD) to the laser diode facet even at extremely high output powers. The pump laser diodes are offered as bare dies, chips on ceramic submount or in fiber-coupled single- and multi-emitter modules.

II-VI's broad portfolio of components for fiber lasers includes seed lasers, acousto-optic modulators, pump and fiber laser combiners, as well as micro-optics for high-power isolators and 10kW IBS-coated laser optics. II-VI also offers multi-kW laser heads and laser light cables.

At Laser World of Photonics 2017 in Munich, Germany (26–29 June), II-VI exhibited its portfolio of merchant products for laser technology platforms employed in high-power or precision materials processing. From ultraviolet to far-infrared, II-VI's laser optics were on display along with new products for fiber lasers and as well as laser heads and beam delivery solutions. In the life sciences area, II-VI's display consisted of spectroscopy optics, flow cells and precision temperature controlled modules to support advances such as in DNA sequencing. The firm also exhibited products from epitaxial wafers to semiconductor lasers that can enable new features such as 3D sensing in the next generation of consumer electronics.

II-VI Inc launches 600W direct-diode laser engine

II-VI Inc says its DirectProcess 900 direct-diode laser engine is now available with 600W continuous output, in a smaller form factor and with new network interfaces.

Direct-diode laser technology has emerged to improve productivity for a growing number of materials processing applications, including aluminium processes in automotive and consumer products. II-VI says that, in particular, its direct-diode laser engines enable greater energy efficiencies and improved quality of workmanship in aluminium cutting and welding operations.

"600 Watt output power in a square beam and at aluminium's peak absorption wavelength is very attractive for a broad range of aluminium and aluminium-copper processing applications," says Wolfgang Gries, general manager, II-VI DirectPhotonics. "Using GaAs emitters and high-power laser optics manufactured in-house, II-VI achieves an unmatched level of vertical integration in its network-ready laser engines aimed at Industry 4.0 smart factories," he adds.

600W output power in a square beam and at aluminium's peak absorption wavelength is very attractive for a broad range of aluminium and aluminium-copper processing applications

Due to their small size and light weight, II-VI's direct-diode laser engines can be mounted on robotic arms such that the power of the wavelength-optimized laser diodes are directly transferred to the work piece, achieving very high energy efficiency. Featuring square beams with high power uniformity, the direct-diode laser engines enable aluminium cuts with sufficiently smooth edges to reduce or eliminate post-process steps, says the firm.

The DirectProcess 900 can be managed and programmed remotely to perform precisely timed processes through its new TCP/IP and EtherCAT interfaces. II-VI's direct-diode laser engines can be deployed along with the firm's multi-kW laser heads or laser light cables. II-VI says that it can also design and manufacture custom beam-delivery solutions by leveraging its broad portfolio of high-power laser optics.

www.world-of-photonics.com
www.ii-vi-photonics.com

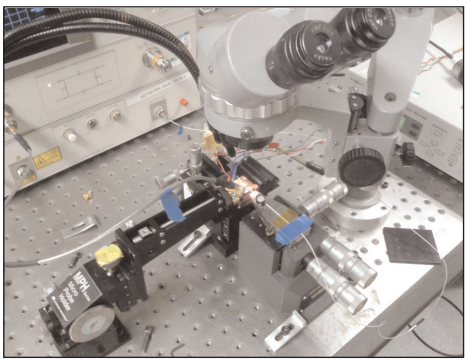
CST Global presents 'detuned' DFB lasers for increased modulation efficiency in fiber-optic transmission

Interim summary for project iBROW; 1310nm lasers show greater modulation efficiency than 1550nm

III-V optoelectronic foundry Compound Semiconductor Technologies Global Ltd of Hamilton International Technology Park, Blantyre, near Glasgow, Scotland, UK says that, at the III International Conference on Applications in Optics and Photonics (AOP 2017) in Faro, Portugal (8–12 May), research engineer Horacio Cantu presented his recently published white paper 'Performance characteristics of 1550nm and 1310nm detuned, ridge waveguide, distributed feedback, laser diodes' (AO100-194), co-authored by director of engineering Andrew McKee.

The paper acts as an interim summary by CST Global for the project iBROW (Innovative ultra-Broadband Ubiquitous Wireless Communications Through Tera-hertz Transceivers). Led by the University of Glasgow, iBROW is a funded, research project looking at the development of new technology platforms for ultra-broadband communication networks of multiple Gigabits/second — massively outperforming current platforms.

"We can modulate light with radio-data, for transmission over fiber-optic networks, without analog-to-digital conversion," says Cantu. "The available bandwidth is huge; there is almost no latency; and the data can remain in its original format, for transmission via passive networks."



Test rig for laser modulation efficiency measurement.

The white paper is concerned with the performance of in-plane, ridge-waveguide distributed feedback (DFB) laser diodes for data transmission, centred on 1550nm and 1310nm wavelengths. "We successfully showed that 'detuning' DFB lasers from their peak optical gain increases modulation efficiency; a bias power to frequency characteristic proportional to data carrying capacity or bandwidth," says Cantu. "We also showed that, as the temperature increases from 25°C to 85°C, modulation efficiency can also be increased," he adds.

Both carrier wavelengths enable an ultra-broadband solution. "We found 1310nm lasers had greater modulation efficiency than 1550nm lasers. However, because 1550nm has a much larger transmission range, more research is required to establish if it is the best, practical, ultra-broadband solution in the long-term," Cantu notes.

"We are a long way from a commercial, ultra-broadband solution that is low cost, energy efficient, compact, operates at room temperature, and integrates consumer portable devices and fiber-optic networks." However, the white paper concludes that detuning DFB laser transmitters increases bandwidth capacity in optical fiber networks.

www.gla.ac.uk/schools/engineering
http://ec.europa.eu/programmes/horizon2020

CST Global presents paper on high-speed 850nm VCSELs

A the VCSEL Day 2017 conference in Cardiff, Wales (8–9 June) CST Global project engineer Iain Eddie presented a white paper on high-speed 850nm vertical-cavity surface-emitting lasers (VCSELs), demonstrating how data transmission rates of 50Gb/s can be achieved.

Recognized as an essential building block of modern optical communication systems, VCSELs offer a high-bandwidth, power-saving and low-cost solution for the active optical cable (AOC) links used in next-generation, data centers and high-performance computing.

"The VCSELs and GaAs PIN photodiodes used in AOCs must deliver 50Gb/s or more, to meet anticipated demand," says Eddie. "We have designed and fabricated new 850nm VCSELs and photo-detectors with low capacitance for high-speed operation. We have then successfully demonstrated how VCSEL aperture size can enable modulation bandwidths of up to 27GHz with data transmission rates of up to 50Gb/s."

The white paper gave a summary report for the project ADDAPT (Adaptive Data and Power Aware Transceivers for Optical Communications), a Seventh Framework Programme (FP7) funded by the European Commission running for 42 months from November 2013, which seeks to combine the complementary competences of two universities (project coordinator TU Dresden and Politechnika Warszawska) as well as five commercial organizations (IBM Research GmbH in Switzerland, Primetel plc in Cyprus, Argotech AS in Czech Republic, VI Systems GmbH in Germany, and TE Connectivity Nederland BV in The Netherlands, plus device manufacture by the UK's CST Global).

www.CSTGlobal.uk

NeoPhotonics' Q1 revenue down 28% year-on-year to $71.7m after sale of Low-Speed Transceiver product line

Growth expected in second-half 2017 after China inventory correction continues into Q2

For first-quarter 2017, NeoPhotonics Corp of San Jose, CA, USA (a vertically integrated designer and manufacturer of hybrid photonic integrated optoelectronic modules and subsystems for high-speed communications networks) has reported revenue of $71.7m, down 28% on $99.1m a year ago and 35% on $109.8m last quarter

"The first quarter of 2017 marked a milestone with our transition to a purely High-Speed company with our focus on 100G and above as networks move to 400G and 600G," says chairman & CEO Tim Jenks. "We completed the sale of our Low-Speed Transceiver product assets [in January] and we tightened our focus on continuing the growth of our global high-speed component and modules businesses."

Sales of high-speed products were $58.7m (82% of revenue) and networking products were $13m (18% of revenue). Excluding $1.5m from two weeks of low-speed product shipments (prior to sale of the product line), revenue was $70.2m (84% high-speed products; 16% networking products).

Geographically, of total revenue, 54% came from China (down from 65% last quarter), 17% from the Americas (down slightly from 18%), 5% from Japan (up from 4%), and 24% from the rest of the world (up from 13%). Revenue from China fell significantly due to the sale of the Low-Speed Transceiver product line. Excluding low-speed products, shipments to the China region were down about 40%, compared with business outside China growing by nearly 10%.

There were two 10%-or-greater customers. US-based Ciena comprised about 14% of revenue (level with last quarter). However, China's Huawei Technologies and its affiliate Hi-Silicon Technologies collectively comprised 41% of revenue (down from 53% last quarter, or 50% excluding low-speed products).

"Demand was very strong in China, with overly optimistic forecasts entering 2017," notes Tim Jenks. "A leading customer there accumulated significant inventory as a result. But demand dropped precipitously as they moved to rapidly adjust their outsized inventory to align with their production, given that expected China tenders had not materialized. Coupled with these demand dynamics, our revenue performance in Q1 additionally reflects the seasonal impact from pricing, Chinese New Year and other factors," he adds.

"Some products with elevated levels of inventory are also among our higher-margin products, such that during the period of burning off this inventory our margins are being adversely affected," explains Jenks. On a non-GAAP basis, gross margin has fallen further, from 32.8% a year ago and down from 29.9% last quarter to 26.3% (below the forecasted 28–31%). Of this drop, about a quarter is due to a mix shift from the China customer inventory, about half is due to unfavourable direct material procurement costs from a major contract manufacturing partner, and a quarter is due to under-utilization as a result of the lower volumes in NeoPhotonics' own plants.

Operating expenses have risen from $23m a year ago and $26.6m last quarter to $30.2m, reflecting some periodic costs and higher annual audit costs in the first quarter.

Net loss was $10.7m ($0.25 per diluted share), compared with net income of $6.3m ($0.13 per diluted share) last quarter and $7m ($0.15 per diluted share) a year ago. Adjusted EBITDA was a loss of $5.2m (compared with a gain of $12.5m last quarter and $12.3m a year ago).

In addition to the cash loss of $5m, working capital changed by about $14m (principally from build-up in inventory). So, cash outflow from operations was –$19m. Capital expenditure (CapEx) was $17.6m (down from $21.7m). So, free cash flow was about –$36m in cash burn. However, during the quarter, NeoPhotonics received about $22m in cash from the sale of the Low-Speed Transceiver business. So, cash and cash equivalents, short-term investments and restricted cash fell overall by $14.1m, from $105.6m to $91.5m.

"The inventory overhang and customer actions to reduce it reduced our Q1 outlook and will similarly impact our Q2," says Jenks. For second-quarter 2017, NeoPhotonics expects revenue of $68–74m (up only modestly after excluding low-speed product revenue). Gross margin should fall to 23–26%, due mainly to the temporary adverse mix impacts (with low volumes on higher-margin products, largely the result of China's inventory overhang). Operating expenses are expected to fall to $26–27m. Net loss per share should be $0.19–0.26, with cash loss cut to $3m. However, the change in working capital is expected to rise to about $16m. CapEx should fall to $16m.

"We saw both the build of inventory and the coming China market softness in early March," notes Jenks. "We now anticipate continuing China softness through Q2 as they consume inventory, followed by a stronger China market in the second half of the year as new provincial tenders are awarded and our Chinese customers increase their pulls on both our production and are higher than normal in order of finished goods inventory. This will lead to a normalized product mix and gross margin," he adds.

Overall, demand is expected to grow late in Q2.

Due to both the sale of its Low-Speed Transceiver product assets and the continued slowness seen in first-half 2017 in the China market, NeoPhotonics is implementing several cost-saving measures, including thinning R&D in legacy areas and restructuring actions to reduce sales, general & administrative (SG&A) expenses (rationalizing the number of product lines, reducing its real-estate footprint, and making certain staffing reductions). This should yield $6-9m in annualized operating cost savings. The firm is also looking further for areas to increase savings as the year progresses. The full quarterly impact of cost-reduction actions should be realized by third-quarter 2017. The firm will record a pre-tax charge of $0.7–1m for severance costs in Q2. However, it is seeking to continue (with limited critical hiring) to ensure that key R&D developments progress and that it maintains production capabilities to respond to any upside.

"We are very well along in our previously announced capacity expansion plan [about 80% of the way through the CapEx program] and, to this end with both progress to date and with China overhang, we anticipate returning to our normalized CapEx of 6-8% of revenue in the second half," says chief financial officer Ray Wallin. "Demand for 100G-and-beyond products will be stronger in the second half of 2017 than in the first half. The market dynamics driving growth in the optics market remains very robust," adds Jenks.

"The China market is a timing issue related to the transition from national backbone deployments to provincial backbone and metro deployments and related to the accumulated inventory overhang," he adds. "Worldwide metro and data-center interconnect 100G coherent deployments continue to grow and now exceed long-haul levels by ports. 100G is now standard, and all line-side and client-side applications and networks are moving rapidly to 200G and 400G, with 600G on the horizon for data-center interconnect fat pipe applications," continues Jenks. "We are well positioned to serve these growing markets with both our high-capacity production and our new solutions focused on 400G-and-above coherent and data-center products," he believes.

www.neophotonics.com

Lumentum showcases new technologies and products

At Laser World of Photonics 2017 in Munich, Germany (26–29 June), optical and photonic optical component and subsystem maker Lumentum Holdings Inc of Milpitas, CA, USA showcased its latest products addressing the industrial diode laser, commercial laser, and 3D sensing markets.

On hand is the new-generation CORELIGHT Series of kilowatt-class fiber-laser engines as well as the ST2 200W fiber-coupled diode pump laser module, the PicoBlade 2 ultrafast laser, the Q-Series diode-pumped UV lasers, and 3D sensing and industrial diode laser displays.

Pump lasers

Launched in early February at SPIE Photonics West 2017 in San Francisco, the ST2 is now in full production. Fiber-coupled pump laser modules are a main component in applications such as pump sources for rod, fiber and disk lasers. The ST2 is part of the ultra-compact and high-brightness ST series, which enables a 'build-your-own' kilowatt (kW) laser. The ST series leverages a history of using fiber-coupled device packages such as the L4, incorporating a highly reliable design in a scalable commercial product. The ST series undergoes testing for endurance and power stability to withstand prolonged use in manufacturing settings.

CORELIGHT Series of kW-class fiber-laser engines

Highlighted at SPIE Photonics West 2017 and now available in production volumes, the next-generation CORELIGHT YLE fiber-laser engines are cost-effective and highly configurable fiber-laser systems offered in single-module 2kW and 3kW systems and multi-module 4kW, 6kW and 9kW systems. At Laser World of Photonics Munich, Lumentum showcased a CORELIGHT YLE 9kW laser system.

The CORELIGHT YLE series fiber-laser systems is said to enable flexibility and peak performance in challenging cutting, welding and material deposition deployments. Users now have additional configuration options to differentiate their latest machine tools. CORELIGHT's beam characteristics are said to enable high-quality and high-speed cutting performance of steel, copper, brass, aluminum, etc. CORELIGHT products also meet high-reliability standards critical for high-volume macro-machining industrial environments.

3D Sensing

Lumentum has a wide range of 3D sensing products to enable next-generation capabilities for diverse consumer electronics and automotive applications. Products include a high-power diode-laser portfolio spanning edge-emitters, fiber-coupled devices and vertical-cavity surface-emitting lasers (VCSELs). At Laser World of Photonics, a VCSEL wafer and a light detection and ranging (Lidar) display showcase 3D sensing capabilities.

Presentation

In the forum on Lasers and Optics on 26 June, Erik Zucker, senior director, Lasers Product & Technology Strategy is presenting on 'Efficient, robust, reliable — high-power, fiber-coupled laser diode pump source, and application'.

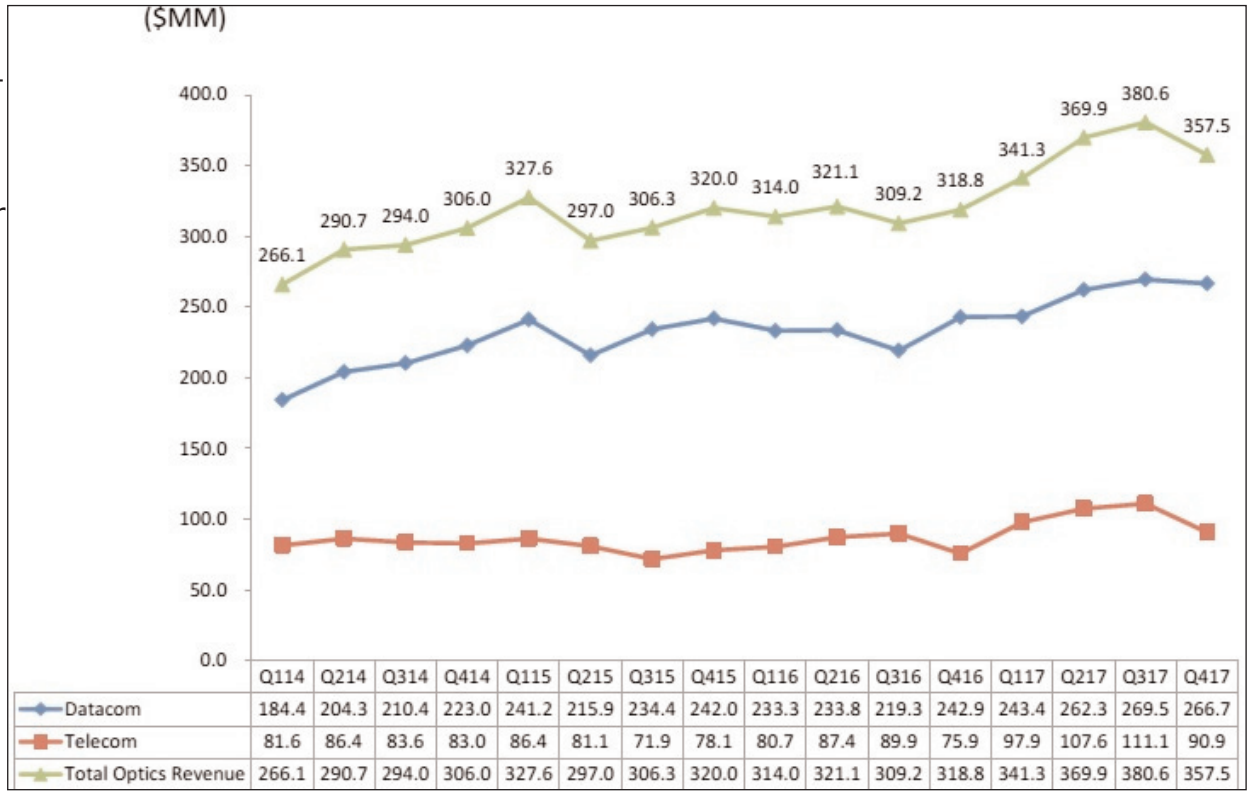
www.ii-vi-photonics.com
www.lumentum.com

Finisar reports record full-year revenue, but a 6% drop quarter-to-quarter driven by Chinese telecom OEMs

Growth to resume in October quarter, driven by 100G QSFP28 transceivers for hyper-scale data centers and VCSEL arrays for 3D sensing

For full-year fiscal 2017 (to end-April), fiber-optic communications component and subsystem maker Finisar Corp of Sunnyvale, CA, USA has reported record revenue of $1449.3m, up 14.7% on fiscal 2016's $1263.2m.

However, for fiscal fourth-quarter 2017 revenue was $357.5m, up 12% on $318.8m a year ago but down 6.1% on $380.6m last quarter (and lower than even the reduced guidance of $360–380m).



	Q114	Q214	Q314	Q414	Q115	Q215	Q315	Q415	Q116	Q216	Q316	Q416	Q117	Q217	Q317	Q417
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
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
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

Telecom product sales were $90.9m, up 19.8% on $75.9m a year ago but down 18.2% from $111.1m last quarter (exceeding the expected drop of just $15m), due mainly to a decline in revenue from Chinese OEM customers (historically about 20% of total revenue, but currently in the low teens) plus the impact of the full three months of the annual telecom price erosion.

Datacom product sales were $266.7m, up 9.8% on $242.9m a year ago but down 1.1% on $269.5m last quarter (contrary to the expected growth of $5m). Sales of 100G QSFP28 transceivers for datacom applications continued to rise strongly (by over 30%), but this was more than offset by lower demand for other datacom products, primarily 10G-and-below shortwave transceivers (which comprise about 20% of datacom revenue, and are expected to continue to decline).

There was just one 10%-or-greater customer (rather than two last quarter). The top 10 customers comprised 58.9% of total revenue (up from 57.4%).

On a non-GAAP basis, full-year gross margin has risen from 30.3% in 2016 to 35.9% in 2017. However, although up on 30.6% a year ago, fiscal Q4 gross margin was 36.2%, down from 37% last quarter (due mainly to the impact of the full three months of the annual telecom price erosion).

Operating expenses have risen further, from $66.2m a year ago and $70.5m last quarter to $71m (exceeding the expected $70m). Full-year operating expenses hence grew from $269.9m in 2016 to $280.3m in 2017 (although falling from 21.4% of revenue to 19.3% of revenue).

Full-year operating income has more than doubled from $112.3m (operating margin of 8.9% of revenue) in 2016 to $240.6m (16.6% margin) in 2017. However, up on $31.2m (9.8% margin) a year ago, fiscal Q4 operating income was $58.4m (16.3% margin, rather than the expected 17%), down from $70.4m (18.5% margin) last quarter.

Full-year net income has similarly more than doubled from $109.8m ($1.01 per fully diluted share) in 2016 to $231.7m ($2.03 per fully diluted share) in 2017. However, up on $31.8m ($0.29 per fully diluted share) a year ago, fiscal Q4 net income was $57.5m ($0.50 per fully diluted share, at the bottom of the guidance range of $0.50–0.56), down from $67.2m ($0.59 per fully diluted share) last quarter, due to mainly the lower revenue.

Capital expenditure (CapEx) was $47.8m. Finisar recently started construction of a third building on

its Wuxi site (to be completed in calendar second-half 2018), primarily for manufacturing.

Cash, cash equivalents and short-term investments have risen by $22.6m during the quarter and by $674.3m over the full fiscal year to $1.237bn (up from $562.5m), due mainly to the issuance in December of $575m of 0.5% convertible notes due in December 2036, which yielded net proceeds of $569.3m. Excluding those net proceeds, cash would have risen by $105m over the year.

For fiscal first-quarter 2018 (to end-July 2017), Finisar expects revenue to fall to $330–350m, due mostly to lower telecom revenue at Chinese OEM customers. "Datacom will be relatively flat as revenue growth for 400G QSFP28 transceivers is offset by lower sales of 10G and 100G CFP2 Ethernet transceivers," says chairman & CEO Jerry Rawls. Due mainly to lower revenue, gross margin should fall to 35%. OpEx should be relatively flat at about $71m. Operating margin is expected to fall to 14%. Earnings per fully diluted share is expected to fall to $0.37–0.43. CapEx is projected to be about $45m (then in the same range in fiscal Q2, before starting to trend down by about $5m per quarter).

"Despite a challenging outlook in the near-term with lower demand for our Chinese OEM customers, we are optimistic about the outlook for Finisar's fiscal 2018," says Rawls. Revenue growth is expected to resume in fiscal Q2 (to end-October), driven by sales growth in 100G QSFP28 transceivers for hyperscale data centers and sales of vertical-cavity surface-emitting laser (VCSEL) arrays for 3D sensing. "We have made really good progress on our high-powered VCSEL array program," notes Rawls. "We have received production purchase orders and expect to soon receive customer approval to ship meaningful volumes [tens of millions] in our second fiscal quarter." In addition, the 100G & 200G coherent CFP2 ACO transceivers and reconfigurable optical add-drop multiplexer (ROADM) line-card should be fully qualified by a key OEM customer that is supplying to the Verizon Metro upgrade. "We are currently qualified at multiple other customers for our CFP2 ACO and are in the qualification process with a number of additional new customers," notes Rawls.

www.finisar.com

Tyndall's Peter O'Brien receives Horizon 2020 Ireland's Champions of EU Research award for PIXAPP

Dr Peter O'Brien, head of Photonics Packaging Research at Ireland's Tyndall National Institute (based at University College Cork) and deputy director of the Irish Photonic Integration Centre (IPIC), has been honoured with a Horizon 2020 outstanding achievement award for his leadership of the PIXAPP Photonic Integrated Circuits Assembly and Packaging Pilot Line project.

O'Brien is one of 16 individuals who received Horizon 2020 achievement awards at the 'Ireland's Champions of EU Research' event (held in Dublin) for projects that exhibited outstanding leadership in their respective program areas of Horizon 2020.

John Halligan TD (Minister of State for Training, Skills, Innovation, Research and Development), together with Enterprise Ireland's CEO Julie Sinnamon, presented the outstanding achievement awards to academic researchers, companies and research organizations that have reached the pinnacle of European research. The awards recognize the contribution of the award winners and all project leaders from Ireland to the country's national success in the €75bn Horizon 2020 EU Framework Programme for research and innovation.

Led by Tyndall at UCC, the PIXAPP consortium brings together 18 partners in Ireland, the UK, Germany, France, Belgium, The Netherlands, Finland, Italy and the Czech Republic to establish what is reckoned to be the world's first open-access photonic integrated circuit (PIC) assembly & packaging pilot line. It combines a highly interdisciplinary team of leading industrial and research organizations and provides Europe's small & medium enterprises (SMEs) with a unique one-stop-shop, enabling them to exploit the advantages of PIC technologies. The €15.5m initiative is intended to help to drive EU growth and competitiveness in the global photonics industry.

At the ceremony, Horizon 2020 Champion awards were also presented to Tyndall researchers recognized as having successfully coordinated a Horizon 2020 project. Those award recipients are:

- Brian Corbett for TOP-HIT, a European consortium led by Tyndall, developing novel technology to address the challenge of integrating components of different materials in large volumes at the semiconductor scale. Funded under the Horizon 2020 program for Smart System Integration, TOP-HIT runs from 2015 to 2018 and is worth over €5m.
- Kafil M. Razeeb for TIPS, a Tyndall-led consortium of European researchers to develop intelligent circuits that can make photonic devices up to five times more efficient, resulting in faster data transmission at a lower cost. Also funded under Horizon 2020's call for Smart Integration Systems, the 'Thermally Integrated Smart Photonics Systems' (TIPS) project involves industry and research partners from Ireland, Germany, The Netherlands and France.

www.pixapp.eu
www.tyndall.ie

Emcore launching OBI-mitigated RF-over-glass optical networking unit transceiver at ANGACOM

At the ANGACOM 2017 Exhibition & Congress for Broadband, Cable and Satellite in Cologne, Germany (30 May — 1 June), 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 — launched its new radio-frequency-over-glass (RFoG) optical networking unit (ONU) transceiver, an OBI (optical beat interference)-mitigated design using the firm's linear externally modulated laser (L-EML).

RFoG technology enables cable operators to offer a fiber-to-the-premise (FTTP)-type architecture without changes to standard equipment in the head-end or central office. The RFoG ONU resides at the customer's location and provides the interface between the optical network and the subscriber coaxial network.

Emcore's RFoG ONU transceiver is designed to support standard CATV downstream and upstream transmission bands for triple-play voice, video and data signals in single-family and multiple-dwelling unit applications. Downstream it receives a 1550nm forward-path optical signal carrying an RF cable television spectrum up to 1.2GHz, making it compatible with the cable industry's DOCSIS 3.1 standard. For return-path, it supports digital upstream transmission using an L-EML transmitter operating at 1610nm that supports a 5–85MHz spectrum. The RFoG ONU is compliant with the SCTE (Society of Cable Telecommunications Engineers) RF-over-glass specification.

The new product introduction will "significantly improve RFoG network performance in high-density customer environments by virtually eliminating the effects of OBI," says president & CEO Jeffrey Rittichier. "Units will begin to ship soon to select cable MSOs, with production expected to ramp-up over the coming months," he adds.

Emcore's RFoG achieves OBI mitigation through proprietary upstream laser wavelength management. It features 6kV surge withstand on all coax ports, less than 1.0μs upstream laser activation/deactivation time with low idle state power usage, and is UL, EMC and FCC part 15B compliant.

www.emcore.com

Emcore presents on linear fiber optics in hybrid fiber-coax networks

Emcore exhibited at the ANGACOM Exhibition & Congress for Broadband, Cable and Satellite for the 10th consecutive year. In addition, senior product line director Grant Olecko presented a talk 'Seeing the True Benefits of Linear Fiber Optics in HFC' on 31 May at the ANGACOM Speakers Corner.

Together with its partner EQ Photonics GmbH at the Cologne Congress Center, Germany (30 May – 1 June), Emcore showcased its latest advances in DOCSIS 3.1, 1550nm CATV transmitters utilizing linear externally modulated laser (L-EML) technology.

Introduced at ANGACOM 2016, L-EML-based transmitters have achieved qualification with major cable multi-service operators (MSOs) and are in volume production to meet rapidly growing demand. The new Medallion 8100 DOCSIS 3.1 L-EML 1550nm CATV transmitter will be on display along with Emcore's full system-level portfolio for CATV broadband transmission including the Medallion 6100 DOCSIS 3.1 1550nm CATV transmitter, Medallion 7200 high-power CATV fiber amplifier and Medallion 2100 optical A/B switch.

In addition, Emcore introduced a compact 1.2GHz, 1550nm L-EML — based mini-transmitter card subassembly designed for CATV applications. The new 'mini-Tx' subassembly will support links of 0–100km and provides all the core elements required for designers to quickly integrate the L-EML device technology into a variety of CATV transmitter platforms.

"The acceptance of our L-EML-based CATV transmitters has been tremendous since we introduced the series last year at ANGACOM and customers have asked us to expand on the form-factor options to allow them greater flexibility on how they integrate the technology into their platforms," says senior product line director Grant Olecko. "In my presentation 'Seeing the True Benefits of Linear Fiber Optics in HFC', I'll discuss some of the giant strides Emcore has made to remove arguments of advantages of baseband digital links being evangelized by some in the industry, compared with linear fiber optics to the node," he adds.

Customers have asked us to expand on the form-factor options to allow them greater flexibility on how they integrate the technology into their platforms

At ANGACOM, Emcore also previewed the latest in high-density laser package technology with the forthcoming Emcore XMD, which incorporates the firm's proven 1550nm QAM laser technology into the ultra-compact XMD form-factor, which is about a third the size of Emcore's classic 14-pin butterfly laser modules.

www.angacom.de
www.emcore.com

POET grows revenue in Q1 after shipping backlog for DenseLight photonic sensors

Gross margin boosted by streamlining and realignment of consolidated business

For first-quarter 2017, POET Technologies Inc of San Jose, CA, USA — which has developed the proprietary planar optoelectronic technology (POET) platform for monolithic fabrication of integrated III-V-based electronic and optical devices on a single semiconductor wafer — has reported revenue of US$712,600. This is up 65% on US$423,500 last quarter, due mainly to backlog from last quarter being shipped in Q1/2017 as well as non-recurring engineering (NRE) revenue of US$80,000. Revenue in both first-quarter 2017 and last quarter reflected the sale of photonic sensors (primarily for test & measurement applications) from Singapore-based subsidiary DenseLight Semiconductor Pte Ltd (acquired in May).

Gross margin improved to 41%, compared with a negative 10% last quarter, as higher sales and NRE revenue allowed for better absorption of factory costs.

Net loss was US$3.5m ($0.01 per share), up from US$3m ($0.01 per share) a year ago. The loss included non-cash stock-based compensation of $894,813 and depreciation & amortization of $540,393, compared to $1,259,051 and $87,844, respectively a year ago.

During the quarter, cash and short-term investments fell from US$14.9m to US$11.7m.

"Results reflect our recent streamlining and realignment of the consolidated business, which was a meaningful contributor to the sequential improvement in our top-line results and gross margin," says CEO Dr Suresh Venkatesan. "Since announcing our successful demonstration of a functional vertical-cavity surface-emitting laser (VCSEL) for our integrated gallium arsenide (GaAs) optoelectronic platform in early April, we have continued to make progress on performance optimization as part of our development effort to create a single-chip transceiver optical engine for the short-reach active optical cable (AOC) market. The current market size for GaAs-based AOCs is $339m, growing to $779m by 2021, according to a recent report from LightCounting. The expected growth is the result of major cloud-based data-center operators committing to AOCs because of the higher cost associated with the power consumption of copper-based cables," Venkatesan adds.

"Additionally, we are enthusiastic about the development of our hybrid integration platform, which utilizes a combination of indium phosphide (InP) technology and dielectric waveguide devices in a single package," continues Venkatesan. "By leveraging this approach, we are able to target additional high-growth markets within data communications. This Dielectric Photonics approach eliminates the need for active alignment and other expensive packaging elements and enables significantly lower-cost solutions for medium-reach applications." Industry reports, including those from LightCounting and Oculi LLC, estimate that the 100–400G optical transceiver market is growing from about $2.5bn in 2016 to over $7.5bn by 2021, notes POET. "In addition to addressing this substantially larger market opportunity with our integrated optical engine, we believe our product roadmap also provides the flexibility to sell active and passive discrete components across the broader data communications market," says Venkatesan. "Looking forward, product development and commercialization based on this new hybrid approach as well as further advancement of our monolithic integration technology will continue to be the company's highest priority for 2017 and beyond."

www.poet-technologies.com
www.denselight.com

Alta Devices and PowerOasis to develop power system reference design for small UAVs

Lightweight GaAs PVs to be combined with Li-ion batteries in hybrid power systems

Alta Devices of Sunnyvale, CA, USA (a Hanergy company) and PowerOasis of Swindon, UK are partnering to develop the first reference design for integrated solar and lithium-ion (Li-ion) battery power systems for small unmanned aerial vehicles (UAVs). By combining Alta Devices' gallium arsenide (GaAs) solar technology with PowerOasis' expertise in hybrid power systems, small UAV developers can focus on leveraging their core expertise in aircraft design and performance, it is said.

"In the past, a UAV manufacturer had to work with multiple companies to obtain the solar technology, downstream electronics, and power management software to create a solar/Li-ion hybrid powered system. Then, they had to design the system themselves," says Alta's chief marketing officer Rich Kapusta. "By working together and providing a complete architecture for a well-crafted power system, PowerOasis and Alta Devices are streamlining the UAV development process," he adds. "We are providing a complete system for electric aircraft and UAVs, eliminating the distraction and time required to focus on the intricacies of power design."

An aircraft designer can leverage this reference design to manage the complete energy generation, storage and power management system for a UAV, without having to bring this capability in-house, saving time and resources than can be better allocated to payload design and aircraft aerodynamics, Alta Devices says.

Many aircraft companies are turning to solar to provide added endurance to UAVs. A typical battery-powered UAV can normally stay aloft for only a few hours. With solar added to the wings, the same aircraft could fly all day. By combining the certainty of Li-ion battery power with the range and power extension of Alta Devices' thin, flexible solar cells, UAVs can accomplish tasks that have not previously been possible, it is claimed. These include: infrastructure inspection over long distances, long-range search & rescue operations, precision agriculture on industrial farms, and communications infrastructure provisioning to under-served locations.

By combining the certainty of Li-ion battery power with the range and power extension of Alta Devices' thin, flexible solar cells, UAVs can accomplish tasks that have not previously been possible: infrastructure inspection over long distances, long-range search & rescue operations, precision agriculture etc

"Up until now, it's been nearly impossible to develop a hybrid solar/Li-ion UAV architecture for small aircraft because the solar technology compromised the design too severely," comments PowerOasis' chief technology officer Pete Bishop. "That is no longer true with Alta Devices' solar technology," he adds.

The reference architecture will target 2–4m (6.5–13 feet)-span UAVs, using 5s–7s Li-ion batteries. Features include:

- high-efficiency, lightweight modular power systems;
- management of battery packs using a cell-vendor-agnostic, flexible battery management system (BMS);
- communication to ground control and on-board auto pilot with continuous real-time power and energy data; and
- conditioned power outputs for critical power and payload systems.

The targeted release-date for the design is late 2017, and it will be available initially through Alta Devices and PowerOasis.

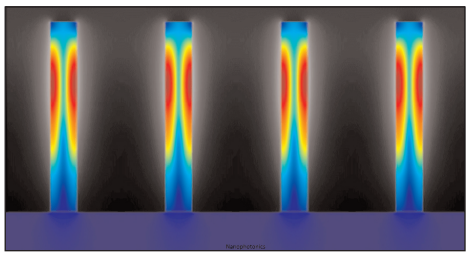
www.altadevices.com
www.poweroasis.com

Sol Voltaics completes manufacture of PV nanowires using Aerotaxy process

Step towards commercializing efficiency-boosting GaAs-based SolFilm

Sol Voltaics AB of Lund, Sweden, which is developing nanomaterials technology for enhancing solar cell efficiency, says that it has taken a significant step towards commercializing its efficiency-boosting solar technology by completing the manufacture of photovoltaic (PV) nanowires using its proprietary Aerotaxy process. This paves the way for the firm to bring its SolFilm PV solutions to market, delivering solar module power boosts of up to 50% at very low cost, it is claimed.

"Producing solar nanowires through Aerotaxy is the key to manufacturing our SolFilm," says CEO Erik Smith. The nanowires are grown such that the top and bottom of the wire have opposite doping profiles. This makes each nanowire a fully functional solar cell, with a pn junction along the length of the wire. "Whether used by module manufacturers as a single-junction, high-efficiency, low-cost solution or as a boosting technology [in a tandem cell atop another material], we believe SolFilm will usher in a new age of solar power efficiencies," he adds.



Increasing solar efficiencies at economies of scale has dramatically slowed in recent years, with conventional modules seeing an average annual efficiency increase of just 0.2-0.3%, notes Sol Voltaics. With many emerging efficiency-boosting technologies continuing to be prohibitively expensive, unstable or lacking reliability, SolFilm offers solar panel makers an economically viable bridge with a proven material to generate previously unreachable solar efficiencies, the firm reckons.

SolFilm is a lightweight photonic film consisting of billions of gallium arsenide (GaAs) nanowires oriented facing the sun. Each nanowire is a complete solar cell, converting high-energy sunlight directly into power. Previously used mostly in space and concentrated photovoltaic (CPV) solar projects, GaAs has long held great potential for the mainstream solar industry but its high fabrication costs have prevented economical fabrication of large solar panels, says Sol Voltaics. Manufacturing nanowires with Aerotaxy dramatically reduces the required amount of GaAs and removes the need for a crystalline support wafer, significantly lowering material costs, claims the firm. Sol Voltaics reckons that, with the recent results, it has taken a step towards delivering an increase in power for conventional solar modules while reducing the price of solar energy.

Sol Voltaics, which last year became the first company to successfully align nanowires in a thin film, was recently recognised as 'Company of the Year' at the Rapidus Awards, which recognises excellence in innovation as well as companies that have the greatest potential for future success. Last May, the firm also completed a $17m investment in new equity, including $4.5m in funding from the Swedish Energy Agency and the European Union's Horizon 2020 research and innovation program.

www.solvoltaics.com

LayTec's in-line process inspection system chosen by CTF Solar for CdS/CdTe PV fab in China

In-situ metrology system maker LayTec AG of Berlin, Germany says that its in-line process inspection system has been chosen by Germany-based CTF Solar — which is owned by CTIEC (part of China National Building Materials Group Corp (CNBM) — for its new 80MW per annum cadmium sulfide (CdS)/cadmium telluride (CdTe) thin-film solar cell production line in China. All key layers of the solar cell structure are monitored regarding production quality and yield.

LayTec delivers a multi-station in-line inspection system. The system inspects the incoming transparent conductive oxide (TCO)-coated float glass and generates valuable statistical process control (SPC) data of the CdS/CdTe solar cell structure through highly precise measurement of relevant film characteristics. The multi-station system is fully integrated into the production line and continuously delivers comprehensive analytical data to the local manufacturing execution system (MES) host.

"CNBM has the highest demands on quality and yield for our new CdS/CdTe fab in Chengdu," says CTF Solar's chief executive officer Dr Michael Harr. "The best process knowledge and deviation awareness at the earliest stage is a fundamental keystone for sustainable PV cell production," he adds. "LayTec's market-leading technology for inline inspection is essential for our high demands on quality and yield."

www.laytec.de

www.ctf-solar.de

First Solar secures loan from Mizuho Bank for utility-scale solar projects in Japan

First Solar Inc of Tempe, AZ, USA — which manufactures thin-film photovoltaic modules based on cadmium telluride (CdTe) as well as providing engineering, procurement & construction (EPC) services — has signed a syndicated development loan facility agreement for about ¥7bn ($64m) with Tokyo-based Mizuho Bank Ltd for its utility-scale solar project pipeline in Japan using First Solar modules.

The financing represents the first syndicated solar project development loan facility arranged and participated in by Mizuho Bank, and it is the third loan facility that First Solar has secured with Mizuho Bank.

The financing arrangement will facilitate utility-scale solar projects that will utilize First Solar's next-generation Series 6 technology.

First Solar provides energy solutions that support Japan's renewable energy target of 7% solar by 2030.

First Solar says that the agreement demonstrates its project development capabilities and track record in financing and delivering projects that support Japan's goal to be powered by reliable and affordable solar electricity.

www.firstsolar.com

First Solar appoints Molly Joseph to board

First Solar has appointed Molly Joseph to its board of directors. She will also sit on the board's Audit and Project Development committees.

Joseph is CEO of UnitedHealthcare Global and executive VP, global, UnitedHealth Group. She assumed these roles in May 2014 and March 2017, respectively, and leads overall strategic direction and operational management of business outside the USA. She serves on UnitedHealthcare's Executive Council and

UnitedHealth Group's Executive Leadership Team. From 2009 to 2014, Joseph was senior VP, global for UnitedHealth Group, leading the Global Markets division, as well as the strategic development of the global business, which grew from a start-up to a $7bn revenue business over that period of time. Prior to her global role with UnitedHealth Group, she led acquisitions and other strategic transactions across the enterprise.

Prior to joining UnitedHealth Group, Joseph was an investment banker focused on mergers and acquisitions. She began her career as a corporate lawyer, also focused on business transactions.

Joseph graduated from Santa Clara University with a Bachelor of Science degree, and received a Juris Doctorate from Georgetown Law Center.

Siva Power completes $25m funding round

CIGS PV firm to build out pilot line and develop solar module business

Copper indium gallium diselenide (CIGS) thin-film solar module developer Siva Power of San Clara, CA, USA has completed a $25m funding round focused on building out its pilot line and developing its solar module business. Jim Simons and Mark Heising led the investment with help from Jonathan Sheets.

Siva Power says that it continues to make steady progress developing its high-performance, low-cost module technology at its development facility in Santa Clara, CA.

"We are very pleased by the confidence that our investors have placed in our technical team and business model," comments CEO Bruce Sohn.

www.sivapower.com

CIGS PV firm Midsummer doubles annual revenue

Midsummer AB of Järfälla, near Stockholm, Sweden — a provider of turnkey production lines for manufacturing flexible, lightweight copper indium gallium diselenide (CIGS) thin-film photovoltaic (PV) solar cells — has reported record financial results for full-year 2016.

Revenue nearly doubled on 2015 to SEK60m and annual profit rose to SEK10m, due to several new orders for DUO thin-film solar cell manufacturing systems.

"The market acceptance for our solar energy technology solutions increased," says CEO Sven Lindström. "The DUO system is now the most widely spread manufacturing tool for flexible CIGS solar cells in the world," he reckons. To meet the increased market demand, Midsummer hired 15 new staff during the last year.

www.midsummer.se

Manz receives initial €64.3m downpayment as part of €263m CIGS PV orders from Chinese partners

Manz's sites in Germany, Slovakia and Asia working on orders

Equipment maker Manz AG of Reutlingen, Germany (which has three Solar, Electronics and Energy Storage strategic business units, and supplies integrated production lines for solar cells and modules) has received the first downpayment of €64.3m in connection with CIGS orders totaling €263m placed at the start of 2017 within the firm's strategic cooperation with its Chinese partners Shanghai Electric Group and Shenhua Group. These orders include a 44MW CIGS R&D line and a 306MW CIGS turnkey production line (CIGSfab) for series production of CIGS thin-film solar modules.

The aim of the cooperation is to speed the development of Manz's CIGS technology, and to boost its marketing also in China. Two joint enterprises were founded for this purpose: NICE PV Research Ltd focuses on R&D activities, while Suzhou Manz New Energy Equipment Co Ltd is now solely responsible for marketing activities in China, and will provide engineering services for future projects as well as provide support in their start-up phases. Both companies started operation in April.

Manz had already made all the necessary preparations over recent months in anticipation of the agreed downpayment, so implementation of the orders can begin immediately. Manz's sites in Germany, Slovakia and Asia are involved in work on the orders.

Two joint enterprises were founded: NICE PV Research Ltd focuses on R&D activities, while Suzhou Manz New Energy Equipment Co Ltd is now solely responsible for marketing activities in China, and will provide engineering services for future projects

"The receipt of the payment gives us the green light for executing the first major projects and for generating the corresponding revenues thanks to our unique cooperation with our Chinese partners," says CEO & founder Dieter Manz. "We are now setting to work, and we think there are good prospects of further attractive follow-on orders resulting from our cooperation in future."

Due to further downpayment agreements for the CIGS R&D line and the CIGSfab throughout the course of the project, these orders will be realized cash flow positive. The orders will contribute to revenue and profits as from second-quarter 2017.

www.manz.com

Flisom unveils light, rollable and customizable flexible CIGS PV module technology

At the Intersolar Europe 2017 exhibition in Munich, Germany (20–22 June), Flisom AG of Zurich, Switzerland — in which Tata Industries of the $103bn Tata group is a strategic investor and the Swiss Federal Laboratories for Materials Science and Technology (Empa) is a technology partner — unveiled its new product range, including eMetal, eFlex and eRoll products.

Flisom has spent over a decade developing high-efficiency copper indium gallium selenide (CIGS) thin-film solar modules using proprietary roll-to-roll manufacturing technologies.

Flisom's products are based on the technology developed by its research partner Empa, which has achieved record conversion efficiency of 20.4% in a flexible CIGS solar cell.

Flisom's solar module.

Flisom modules are less than 2mm thick, are ultra-light (under 500g/m^2 for some versions) with a power-to-weight ratio of up to 20 times more than conventional silicon panels, and are strong, safe and rollable.

Flisom says that, unlike competitors, it offers not only its standard portfolio of modules but also its technology as a business-enabling platform (which is customizable for end-users' applications) and the modules are designed and manufactured in house.

Gearing up for full commercialization of its product range this year, Flisom says that it is focused on enabling solar technology for applications including buildings, mobility and transport, as well as specialist customized applications, across Europe and the USA.

www.intersolar.de
www.flisom.ch
www.empa.ch
www.tata.com

Direct growth of III-V laser structures on silicon substrates

From infrared to ultraviolet wavelengths, researchers are enabling lower-cost production of silicon photonics. Mike Cooke reports.

The components of a silicon photonics platform integrating optical communications and silicon electronics are coming together. Among the aims of various research groups are the future development of co-integrated CMOS-compatible optical data links and data processing electronics. End applications include biological sensing, cloud-based applications, 'big-data' services and enterprise data centers.

The most difficult part of the equation is creating suitable light sources: efficient laser diodes (LDs) and other light-emitting devices are challenging on silicon photonics platforms since they require direct-bandgap semiconductors, in contrast to the indirect bandgap of silicon.

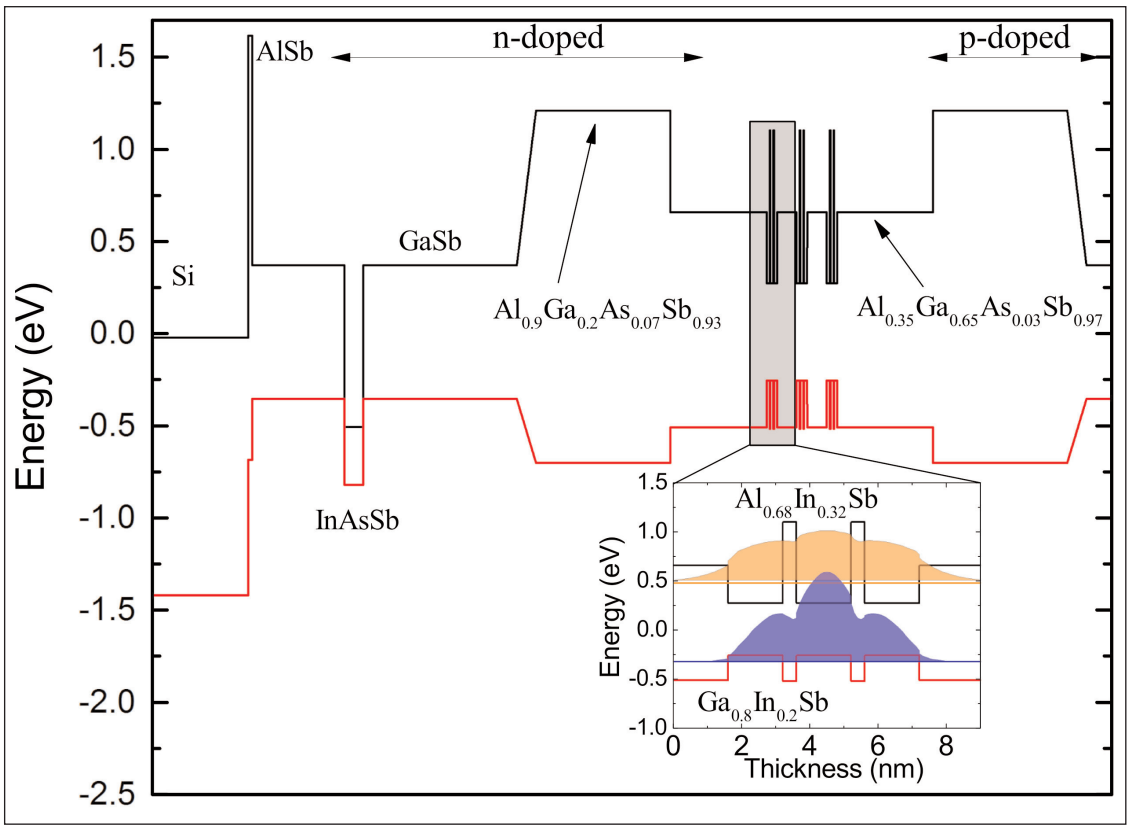


Figure 1. Simulated bandstructure of whole GaSb-on-Si laser heterostructure. Inset: GaInSb/AlInSb composite quantum well details with confined electron and hole levels and wavefunctions.

Growing advanced light-emitting III-V semiconductors on silicon suffers from challenges arising from lattice mismatches, thermal mismatches and charge polarity mismatches, generation of antiphase boundaries, etc. There are techniques to mitigate many of these problems, such as off-axis substrates to combat anti-phase boundaries, but they come at the cost of reduced compatibility with silicon microelectronics fabrication/integration and increased production expense.

Instead, such integration is often achieved using wafer bonding of separate III-V and silicon structures. However, monolithic growth would be preferred since it is expected to result in low-cost, high-yield and large-scale integration of complex optoelectronic circuits. Here we look at recent progress in monolithic direct growth of III-V semiconductors on silicon.

Fiber-optic gallium antimonide

Université de Montpellier and III-V Lab in France have developed monolithic quaternary aluminium gallium arsenide antimonide (AlGaAsSb) growth on silicon, producing laser diodes emitting at close to the 1.55μm optimum wavelength for fiber-optic telecommunications [A. Castellano et al, APL Photonics, vol2, p061301, 2017]. Normally, GaSb-based laser diodes operate best in the mid-infrared range (longer than 3μm).

While there has been progress with devices emitting at

wavelengths away from 1.55μm, previous work of the researchers struggled to create laser diodes at 1.55μm — "these lasers suffered from high threshold current densities, resulting in poor performances limited to pulsed operation," the team writes.

The latest laser material was produced using molecular beam epitaxy (MBE) on quarters of 2-inch (001) silicon wafers that were offcut 6º in the [110] direction. The offcut angle was designed to restrict formation of anti-phase domains arising from charge polarity differences in the chemical bonds between the substrate and III-V compound semiconductors.

The growth was nucleated with 4 monolayers of 450ºC AlSb. The researchers then grew 1μm of GaSb while ramping up to 500ºC, 150nm of lattice-matched indium arsenide antimonide ($InAs_{0.92}Sb_{0.08}$) etch stop/n-contact, and 800nm of 470ºC n-GaSb.

The rest of the structure was grown at 470ºC and consisted of 1.5μm of doped $Al_{0.9}Ga_{0.1}As_{0.07}Sb_{0.93}$ cladding and 230nm of undoped $Al_{0.35}Ga_{0.65}As_{0.03}Sb_{0.97}$ waveguide layers above and below the active light-emitting quantum wells. Graded AlGaAsSb layers were used to smooth the band profiles between the buffer and n-cladding, and between the p-cladding and p-GaSb contact layer (Figure 1). Beryllium and tellurium were used for the p- and n-type doping, respectively.

The active region consisted of three $Ga_{0.80}In_{0.20}Sb/Al_{0.68}In_{0.32}Sb$ quantum wells separated by 20nm of $Al_{0.35}Ga_{0.65}As_{0.03}Sb_{0.97}$ barriers. The composite well contained 6nm of GaInSb with two insertions of 0.45nm AlInSb. The strain is estimated at 1.35% relative to the GaSb lattice. The wells have a 'type-I' structure where electron and hole wavefunctions overlap by 96.2%, according to simulations. High overlap should lead to better recombination into photons.

The researchers comment: "The confined electron and hole levels are located 180meV and 190meV below the barrier level, respectively (Figure 1). Although sufficient for the holes, this confinement energy is not high enough to totally suppress thermal escape of electrons out of the QWs at room temperature and above."

The laser diodes were fabricated in a ridge format with gold-germanium-nickel alloy n-contacts on either side of the ridge and titanium-gold p-contact on top of the ridge. Electrical insulation was provided by photoresist material. The n-contact with the InAsSb layer avoids current flow through the highly defective GaSb buffer region near the silicon substrate, improving performance.

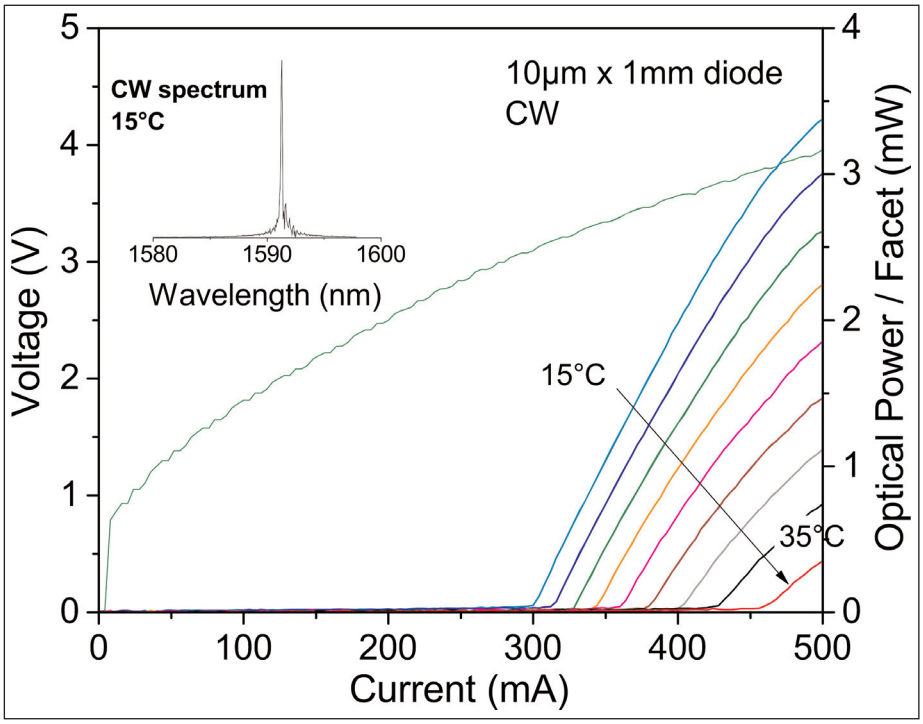


Figure 2. Light output power and voltage versus current curves from 10μm x 1mm narrow-ridge laser diode under cw operation between 15ºC and 35ºC. Inset: laser emission spectrum at 15ºC.

Mirror facets for the laser cavity were obtained by simple cleaving with no optical treatment to increase reflectivity. The devices were mounted epi-side up on copper heat-sinks.

Room-temperature pulsed operation of 100μm x 1mm broad-ridge laser diodes gave a threshold current density of 1kA/cm^2 — a value comparable with devices produced on GaSb substrate, according to the researchers. The series resistance was 3Ω and the turn-on voltage was 0.8V, close to the value expected from the bandgap.

Continuous wave (cw) current injection in 10μm x 1mm narrow-ridge laser diodes result in threshold currents of 300mA at 15ºC and 450mA at 35ºC, corresponding to a T_0 characteristic temperature of 50K (Figure 2). The researchers claim that this is comparable to what is seen in 2μm-wavelength GaSb lasers on silicon and to initial InP-based quantum well devices grown on indium phosphide (InP) emitting near 1.55μm with comparable carrier confinement. At 500mA injection, the narrow-ridge laser diodes output 3.5mW at 15ºC and 3mW at 35ºC. Higher power could be achieved by increasing current injection towards thermal roll-over. Treating the facets to improve the laser cavity could also boost performance.

At a temperature of 15ºC, the laser wavelength was 1.59μm, which corresponds to the C/L bands (1530–1565nm/1565–1625nm) for high-performance optical telecoms. [The C-band corresponds to the lowest-attenuation fiber for dense wavelength-division multiplexing (DWDM). L-band also has low attenuation and allows the use of DWDM.]

The variation in performance was represented by a threshold current density that ranges between 1kA/cm^2 and 1.5kA/cm^2 for the broad-ridge devices at room temperature. The narrow-ridge laser diodes had thresholds between 300mA and 500mA. The researchers comment: "At this stage, we ascribe these variations to different facet qualities of the laser diodes. Indeed, silicon does not spontaneously cleave along the [110] crystal direction as the III-V semiconductors do to form natural facets."

1.55μm quantum dot lasers

Hong Kong University of Science and Technology (HKUST) and Harvard University in the USA have reported progress on direct epitaxy of III-V quantum dot (QD) materials on silicon, producing 1.55μm-wavelength microdisk lasers (MDLs) [Bei Shi et al, Appl. Phys. Lett., vol110, p121109, 2017]. Normally, 1.55μm III-V devices are grown on InP. Electrically driven III-V quantum dot laser materials on silicon have recently been realized for shorter, non-optimal 1.3μm optical fiber wavelengths. The HKUST/Harvard team sees their work as "a promising path towards large-scale integration of cost-effective and energy-efficient silicon-based long-wavelength lasers."

Quantum dots are seen as a way to lower laser thresholds, to improve thermal stability, and to increase robustness against the effects of defects.

The III-V material was all grown on (001) silicon using metal-organic chemical vapor deposition (MOCVD). A number of strategies were deployed to reduce threading dislocations, anti-phase boundaries, and other common defects arising from the 8% mismatch between the InP and silicon crystal lattices (Figure 3):

1. A 1.7μm-thick GaAs intermediate buffer to accommodate the InP/Si mismatch. The GaAs buffer incorporated an AlGaAs/GaAs strained-layer superlattice (SLS) to reduce dislocation densities and give a smooth surface.
2. The InP buffer layer was grown in stages, starting with a 70nm low-temperature nucleation and continuing with 1.4μm of InP buffer grown in multiple temperature

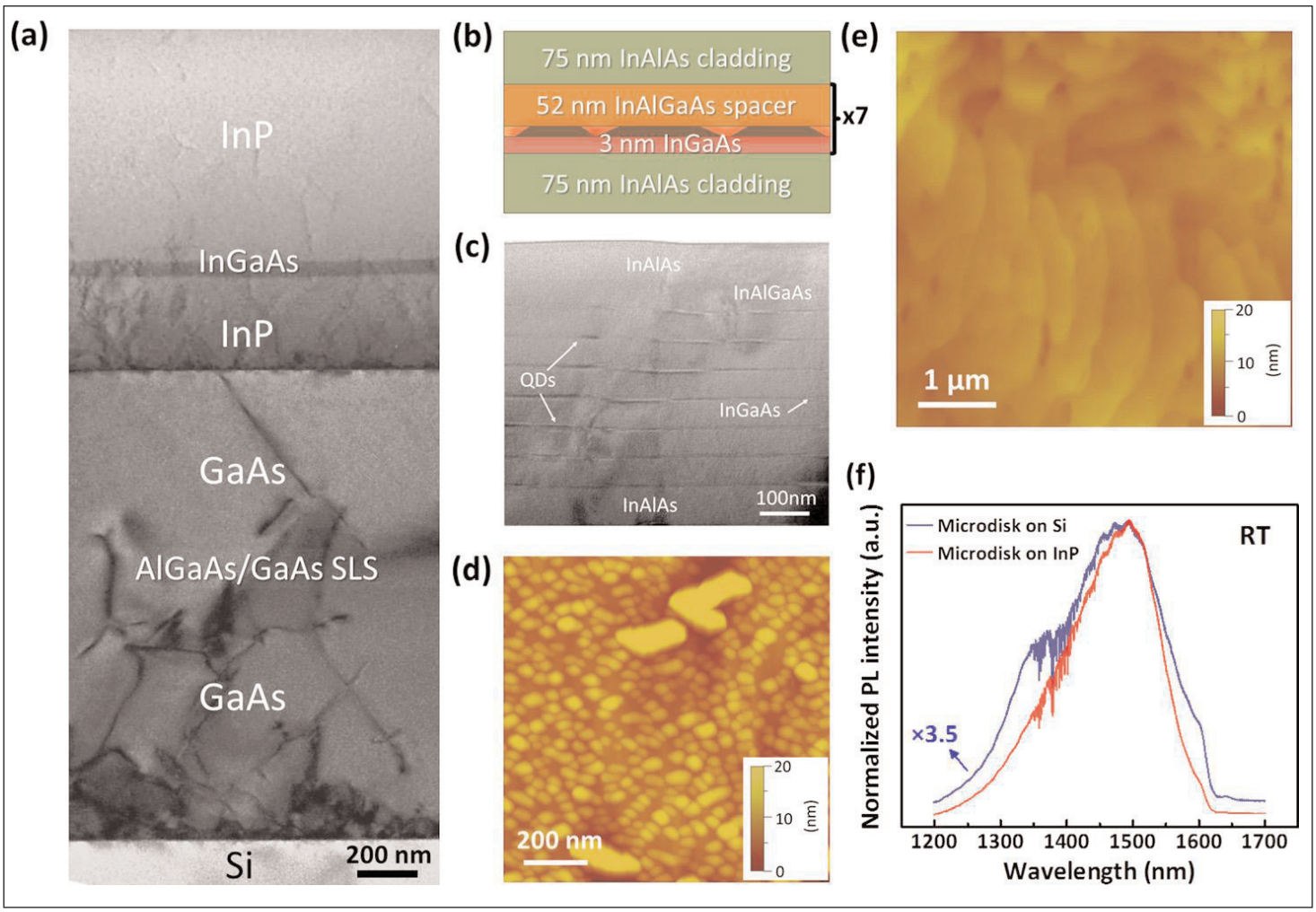


Figure 3. (a) Cross-sectional transmission electron microscope (TEM) image of InP/Si template; (b) schematic of microdisk laser structure; (c) close-up TEM of the microdisk laser on silicon, highlighting InAs/InGaAs/InAlGaAs DWELLs; (d) representative surface morphology of uncapped InAs QDs on top of InP/Si substrate; (e) typical 5μm x 5μm atomic force microscope image of InP thin-film surface grown on Si; (f) room-temperature photoluminescence of as-grown microdisk laser material on Si and InP substrates, respectively.

steps. The InP buffer included a 60nm $In_{0.6}Ga_{0.4}As$ strained-interlayer designed to filter dislocations from the GaAs/InP interface.

The resulting InP/Si template surface had 1.6nm root-mean-square roughness, according to 5μm x 5μm atomic force microscopy.

The microdisk laser structure consisted of a 7-period quantum dot in well (DWELL) structure sandwiched between 75nm InAlAs cladding layers. The InAs quantum dots had a typical diameter of 45nm with $4x10^{10}/cm^2$ density. The 3nm-thick InGaAs served as a wetting layer. The InAlGaAs was applied in two steps: 1.5nm low-temperature material to avoid desorption of the underlying dots, and a 52nm high-temperature spacer layer. The high temperature also annealed the dots to prevent dot-height dispersion and to tune the emission wavelength.

Comparing the photoluminescence (PL) with material grown on InP substrates showed a factor of 3.5 lower emission from the structure grown on the InP/Si template. The emission line was broader and a shoulder was present in the latter material. The researchers suggest that this could be due to dot-size fluctuation. They add: "The broad spectra however favor the interaction between resonant modes in small cavities and the material gain."

Lasers consisted of 1.5μm-diameter microdisks formed by colloidal lithography and dry etching down to the InP buffer. A selective wet etch then formed an InP pillar.

The laser was pumped using a 532nm Q-switched neodymium-doped yttrium aluminium garnet (Nd:YAG) pulsed laser source (20ns pulse width, 3000Hz repetition rate). Stimulated emission with a 1563nm wavelength was achieved with a high background suppression ratio of 21.7dB. There was some increase in line-width above threshold, attributed to wavelength chirping from changes in refractive index caused by transient changes of carrier density in the QDs.

The threshold pumping power was 2.73±0.23mW. The researchers say this is an upper bound, since no account was taken of multiple reflection/absorptions inside the disk and coupling efficiency of the pump beam.

Statistical studies with various 1.5μm and 4μm disk diameters demonstrated thresholds for devices on InP/Si templates about twice that of lasers produced on pure InP substrates (Figure 4). The team comments: "The larger thresholds on silicon are mainly associated with three factors. First, the material gain in the QD active region on silicon is somewhat lower due to non-radiative recombination processes introduced by crystalline defects. Second, the injection efficiency is reduced because the pump-laser-generated carriers can be partially trapped by the deep energy level traps related with dislocations in the disk region. Moreover, the broader PL emission spectrum of the MDL on silicon is more favorable for multi-mode lasers."

Varying the temperature up to 60ºC, the researchers extracted a high threshold characteristic (T_0) of 123K

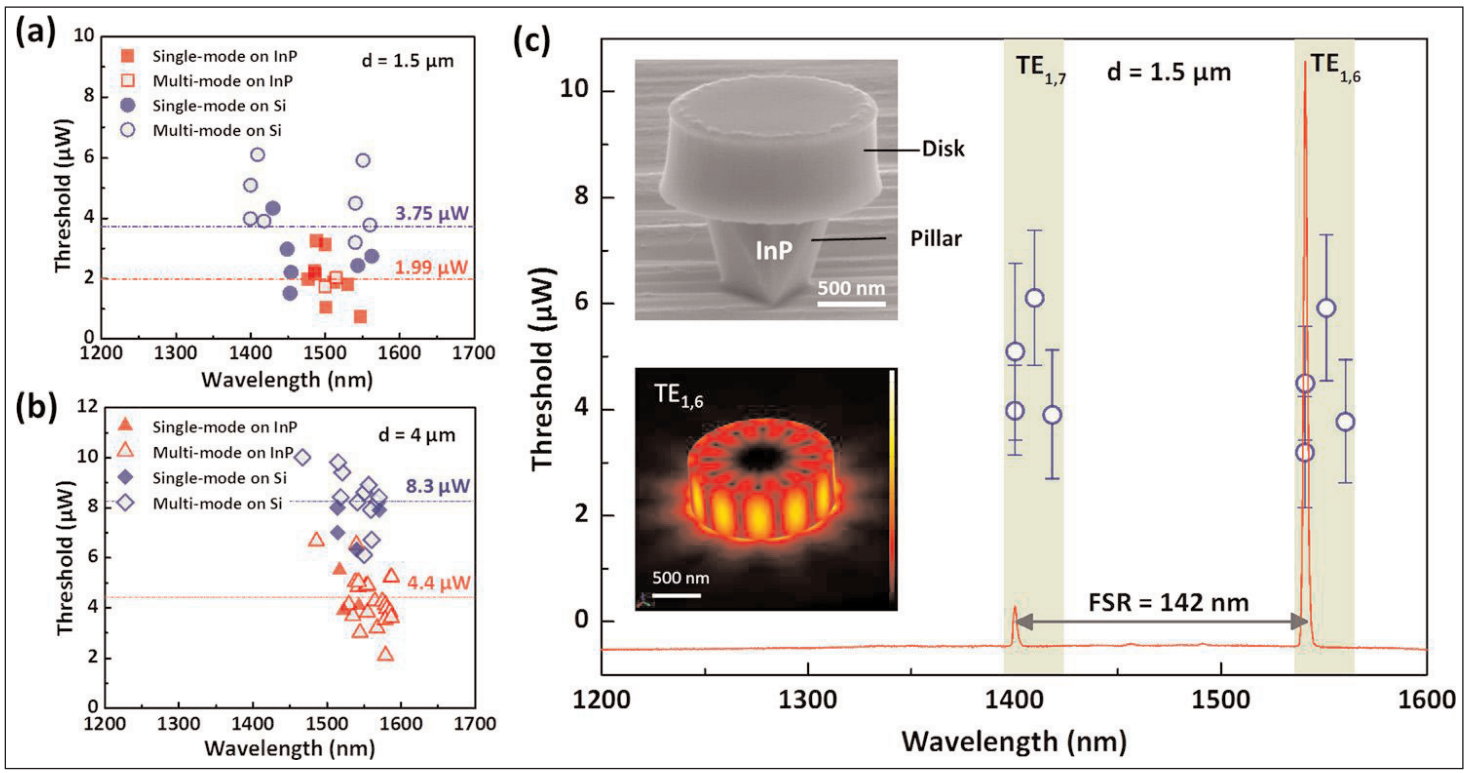


Figure 4. Single-mode (solid symbols) and multi-mode (open symbols) lasing threshold dispersion of (a) 1.5μm and (b) 4μm microdisks on InP and Si as function of wavelength. (c) Overlay of threshold powers in multi-mode 1.5μm disks with representative lasing spectrum. Top inset: scanning electron microscope image; bottom inset: three-dimensional electric field distribution of simulated $TE_{1,6}$ mode.

for one mode ($TE_{1,6}$, 1546.9nm). They describe this value as "among the best reported T_0 for QD MDLs on III-V substrates." The other mode studied ($TE_{1,7}$, 1406.2nm) had a lower T_0 of 90K. The team comments: "the larger T_0 of the $TE_{1,6}$ mode can be attributed to a better overlap with the gain spectrum at higher temperatures and a superior carrier capture efficiency in larger QDs, which prevent carrier evaporation into barriers."

Electrical pumping of InAs QDs

University College London in the UK and Univ. Grenoble Alpes in France have claimed the first electrically pumped cw InAs in GaAs quantum dot (QD) lasers directly grown on industry-compatible nominal silicon (001) substrates without any intermediate buffers [Siming Chen et al, Optics Express, vol25, p4632, 2017]. The team used a combination of MOCVD and MBE on microelectronics standard on-axis Si (001) 300mm diameter wafers. The MOCVD stage involved an Applied Materials tool.

The silicon surface was prepared by cleaning and annealing at 900ºC in hydrogen to reconstruct the surface structure to promote GaAs quality. After the anneal, the temperature was reduced to 700ºC in 30 seconds to 'freeze' in the surface reconstruction.

A two-step MOCVD was carried out to give a 40nm 400–500ºC GaAs layer and a 360nm 600–700ºC GaAs layer. The researchers say that the 400nm GaAs layer on silicon was antiphase-boundary free.

The MBE for the QD laser structure (Figure 5) was carried out in a 3-inch Veeco tool, so the virtual GaAs/Si substrate material had to be diced down to fit into the reaction chamber. The epitaxial design included n-InGaAs/GaAs strained-layer superlattices (SLSs) aiming at blocking threading dislocations from entering the active region. The cladding layers were $Al_{0.4}Ga_{0.6}As$, while the 30nm waveguide regions above and below the active region were $Al_{0.12}Ga_{0.88}As$.

The 'dot-in-well' (DWELL) active region consisted of five sequences of InAs/InGaAs/GaAs dot regions separated by 50nm GaAs spacers. The dot density of uncapped layers was around $3.5x10^{10}/cm^2$, according to atomic force microscopy. This compares with $3x10^{10}/cm^2$ for dots grown on GaAs substrates.

The material was used to fabricate broad-area lasers. Mesa structures were wet etched down to about 100nm above the active region. Further etching reached down to the n-GaAs buffer layer. Titanium/platinum/gold and nickel/germanium/gold/nickel/gold were used for the p- and n-electrodes, respectively. The silicon substrate was thinned to 120mm before cleaving into laser bars.

Testing was carried out on 3mm-long 25μm-wide devices mounted on copper heat-sinks. Gold wire-bonding was used for electrical connections. The facets were uncoated.

While the series resistance of devices on GaAs/Si and pure GaAs were similar, the QD laser performance was degraded for GaAs/Si compared with pure GaAs substrates. In particular, the threshold current density increased from $210A/cm^2$ to $425A/cm^2$ (Figure 6). Also, the slope efficiency of the laser on GaAs/Si was reduced to 0.068W/A, compared with 0.12W/A for pure GaAs-based devices. The external quantum differential efficiencies were 7.2% and 12.7% for GaAs/Si and pure GaAs, respectively.

The researchers comment: "Compared with the laser device grown on native GaAs substrate, the degraded device performances for QD laser grown on the Si (001) substrate is related to the defects propagating into the QD active layers."

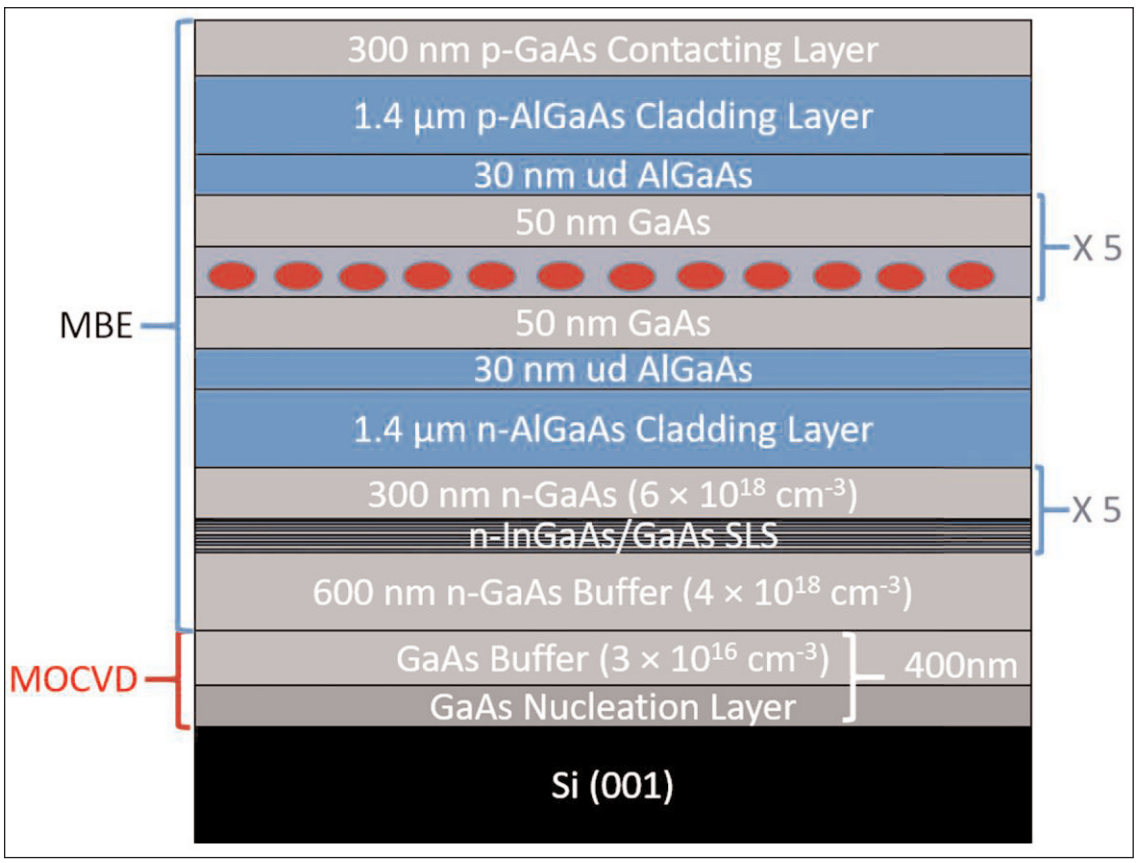


Figure 5. Schematic of QD laser structure grown on on-axis Si (001) substrate.

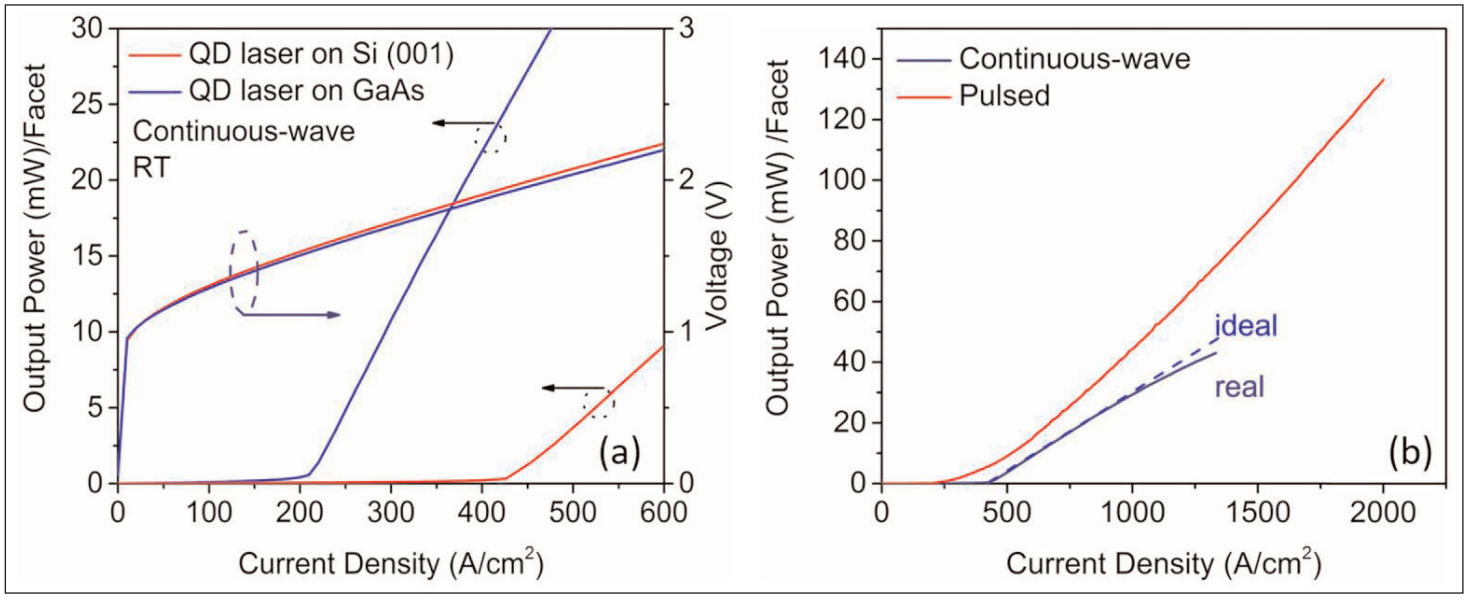


Figure 6. (a) Power-current-voltage (LIV) characteristics comparison of InAs/GaAs QD laser grown on GaAs/Si (001) to reference QD laser grown on native GaAs substrate at room temperature under cw operation. (b) LI comparison of InAs/GaAs QD laser grown on GaAs/Si (001) substrate under cw and pulsed operation conditions at room temperature.

The maximum single-facet output power of the QD laser on GaAs/Si was 43mW at 1332A/cm^2 cw injection. Pulsed operation increased the maximum to 134mW at 2kA/cm^2 injection.

The cw spectrum of the QD laser on GaAs/Si had a peak at 1292nm (1.3μm) with 49nm full-width half-maximum (FWHM) at a subthreshold current density of 267A/cm^2. Above threshold the FWHM narrowed to around 2.2nm. At higher current, the spectral output showed multiple peaks (i.e. multi-mode behavior).

Temperature-dependent pulse-mode operation saw lasing operation up to 102ºC. "To the best of knowledge, this is the first demonstration of QD lasers monolithically grown on exact silicon (001) substrate that lase over to 100ºC," the team writes. The maximum temperature for cw lasing was 36ºC.

The team points out that the performance is also down on QD lasers grown on off-cut silicon wafers. Further optimization should be possible. The researchers comment: "Nevertheless, good cw performance has been achieved, and the threshold current density reported in the present work has been reduced by more than a factor of two, compared with the very recent achievement of an InAs/GaAs QD laser on on-axis Si (001) substrate with an intermediate GaP buffer layer."

Visible and ultraviolet III-nitride

Researchers in France have created a range of optically pumped III-nitride microdisk lasers on silicon covering a wide range of wavelengths, from 280nm deep ultra-violet to 500nm blue-green/cyan [J. Sellés, Appl. Phys. Lett., vol109, p231101, 2016]. Two types of multiple quantum well structure were produced: gallium nitride (GaN) wells with aluminium nitride (AlN) barriers (deep UV), and indium gallium nitride (InGaN) with gallium nitride barriers (violet and blue-green).

The non-alloyed GaN/AlN structures avoid spectral broadening from alloy disorder, compared with more usual AlGaN-based samples. Further, "low interface roughness limits the impact of monolayer fluctuations on the QW transition energy," according to the team.

The team from Laboratoire Charles Coulomb, Centre de Nanosciences et de Nanotechnologies, Centre de Recherche pour l'Hétéro-Epitaxie et ses Applications, Université Grenoble Alpes, and Institut Nanosciences et Cryogénie (INAC), see their work as complementary to the development of infrared integrated photonics for telecommunications. In the case of visible-UV devices, potential applications include bio-chemical analysis and on-chip optical interconnects.

The researchers add: "The broad tunability paves the way to the development of a UV-visible integrated photonic platform embedding microlasers, possibly addressing multiple wavelengths. A further step will deal with the electrical injection, following the recent progresses in electrically injected InGaN lasers on Si-substrates."

Ammonia MBE was used on (111)-oriented silicon to produce a range of GaN/AlN and InGaN/GaN structures (Table 1). All the structures were grown on an AlN buffer. The InGaN/GaN structures also included a GaN buffer on top of the AlN. In the InGaN-2 sample, the GaN buffer was silicon-doped to encourage electron injection into the multiple quantum well active region.

Microdisks were patterned and dry etched before selective under-etch of the substrate to create microdisks (3μm to 12μm diameter) on silicon pedestals (Figure 7). The output was derived from

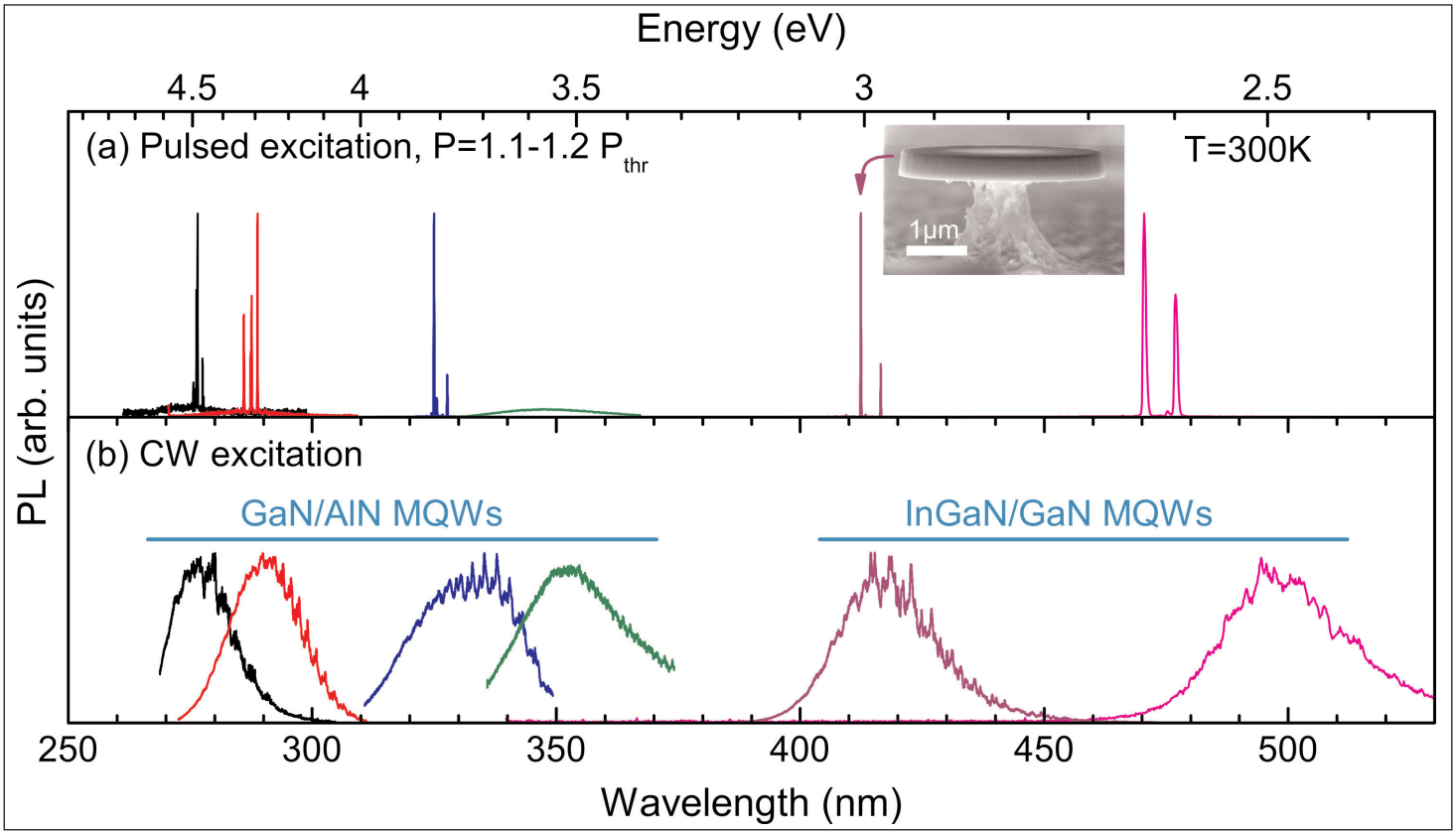


Figure 7. Photoluminescence spectra of 6 microdisk samples (from left to right, GaN-1 to GaN-4, InGaN-1, InGaN-2); (a) microlaser spectrum above threshold, under pulsed optical pumping; (b) microdisk spectrum in linear regime, under cw excitation. Inset electron micrograph of 4μm microdisk from InGaN-1 series.

Table 1. Sample active layers.

Sample	Well/barrier materials	Well thickness (nm)	Number	cw wavelength (nm)
GaN-1	GaN/AlN	0.7	20	280
GaN-2	GaN/AlN	0.7	10	290
GaN-3	GaN/AlN	1.2	10	330
GaN-4	GaN/AlN	1.8	10	350
InGaN-1	$In_{0.12}Ga_{0.88}N$/GaN	2.2	10	417
InGaN-2	$In_{0.2}Ga_{0.8}N$/GaN	2.2	10	500

Table 2. Microdisk geometries and microlaser characteristics.

	Resonator			Laser	
Sample	Diameter (μm)	Thickness (nm)	Q	Threshold (mJ-cm²/pulse)	Wavelength (nm)
GaN-1	3	220	4000	15	275
GaN-2	6	160	2000	27	290
GaN-3	6	160	2000	35	330
GaN-4	6	160	>1000		
InGaN-1	4	515	2500	3	412
InGaN-2	5	1300	2500	3	47

optical pumping with 266nm-wavelength laser light with cw or pulsed (400ps, 4kHz) operation. The longest-wavelength GaN-4 device was unable to achieve lasing — the researchers attribute this to the quantum-confined Stark effect, where electric fields from charge polarization of the III-nitride bonds inhibit electron–hole recombination into photons. GaN-4 contains the thickest wells, compared to the other devices.

The laser threshold was an order of magnitude smaller for the InGaN/GaN devices, compared with GaN/AlN microdisks (Table 2). "This can be interpreted as the difference between resonant and non-resonant excitation," the researchers write. "Indeed, the laser energy is below the AlN bandgap and above the GaN bandgap. The 266nm laser pumps the excited states of the GaN/AlN QW, and the 10 QWs can only absorb part of it. On the contrary, the entire pulse energy is absorbed by the GaN barrier in the case of InGaN QWs, leading to a larger carrier density per QW if we assume that all carriers are transferred from the barrier to the well." ■

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Alcohol-based digital etch on arsenide and antimonide III-V semiconductors

Technique enables first demonstration on antimonides, according to researchers.

Massachusetts Institute of Technology (MIT) in the USA and IMEC in Belgium have developed digital etch (DE) techniques using alcohol solutions for III-V arsenide and antimonide semiconductors structures [Wenjie Lu et al, IEEE Electron Device Letters, published online 3 April 2017].

The researchers claim that their work represents the first demonstration of digital etch on the antimonide material system. Unfortunately, normal digital etch techniques are not suitable for antimonides since water constitutes an etchant in this material system, destroying the tight control needed for devices with small feature sizes.

Finally, gate-all-around nanowire metal-oxide-semiconductor field-effect transistors (MOSFETs) were produced using the alcohol-based digital etch. The work was supported by Samsung Electronics, the US Defense Threat Reduction Agency, the US NSF Center for Energy Efficient Electronics Science, Lam Research, and Korea Institute of Science and Technology.

Digital etch is seen as similar to atomic layer deposition (ALD), but in reverse. The technique consists of two self-limiting steps, giving fine control: 1, oxidation; and, 2. oxide removal. The oxidation step used by MIT was achieved through self-limiting oxygen plasma exposure in a barrel asher for 3 minutes. Removal was carried out by one of three wet techniques: 1. sulfuric acid in deionized (DI) water; 2. sulfuric acid (H_2SO_4) in methanol; or, 3. hydrochloric acid (HCl) in isopropanol (IPA). For antimonide semiconductors only the HCl:IPA removal solution could be used.

Samples consisting of indium gallium arsenide ($In_{0.47}Ga_{0.53}As$) and indium aluminium arsenide ($In_{0.52}Al_{0.48}As$) layers were grown by molecular beam epitaxy (MBE) on indium phosphide (InP) substrate. An antimonide (Sb) structure was also grown on GaAs substrate with 20nm of $In_{0.28}Ga_{0.72}Sb$ on 200nm $Al_{0.65}Ga_{0.35}Sb$ buffer.

The samples were prepared for digital etch by native oxide removal and the application of a 100nm hydrogen silsesquioxane (HSQ) mask on a 2nm silicon nitride adhesion layer. The HSQ was patterned using electron-beam lithography. Dry inductively coupled plasma etch gave fins or vertical nanowires (VNWs) of 230nm height.

The samples were prepared for digital etch by native oxide removal. For the arsenide sample, this was achieved by buffered oxide etch, which also removed the HSQ. Native oxide was removed from the antimonide layers by HCl:IPA solution, leaving the HSQ in place.

The effect of digital etch was analyzed by scanning electron microscopy (SEM). The radial etch rate for arsenide VNWs was 1.0nm/cycle for HCl:IPA solution and 1.2nm/cycle for H_2SO_4:methanol. The rate for H_2SO_4:DI water was 1.0nm/cycle.

An antimonide VNW was reduced from 100nm to 92nm diameter by exposure to DI water, showing its etching effect. The resulting surface was rough in the AlGaSb region. A similar effect was seen in antimonide fin structures. "Therefore, water-based DE is not viable for antimonides," the researchers conclude.

The HCl:IPA digital etch on antimonide structures resulted in smoother sidewalls without excessive etching or surface damage. MIT estimates the etch rate of antimonide NWs to be 1.0nm/cycle.

The researchers also assessed mechanical yields. Surface tension in water-based processes are particularly damaging to thin VNW structures

Table 1. Mechanical yield of various diameter (D) InGaAs VNWs after 7 cycles of digital etch.

D_{intial} (nm)	D_{final} (nm)	DE:HCl/H_2O Rinse:H_2O	DE:HCl/IPA Rinse:IPA	DE:H_2SO_4/methanol Rinse:IPA	DE:HCl/H_2O Rinse:IPA
28	14	100%	100%	100%	100%
26	12	31%	100%	100%	100%
24	10	5%	100%	100%	0%
22	8	0%	97%	95%	0%
20	6	0%	5%	90%	0%

(Table 1). The team found 97% mechanical yield for 8nm arsenide VNWs thinned from 22nm diameter by 7-cycle HCl:IPA digital etch. By contrast, water-based processes gave 0% yield.

H_2SO_4:methanol digital etch allowed NWs of 6nm diameter to be reached with 90% yield, while HCl:IPA gave only 5%. According to the researchers: "This is likely due to the smaller viscosity of methanol (0.54cP) than that of IPA (2.0cP). These results indicate that NW breakage happens during the oxide etch process as well as while rinsing."

The team adds: "It should be noted that 7 DE cycles is a harsh process that is typically unnecessary in actual device fabrication. In a shortened process, higher mechanical yields at smaller diameters should be possible."

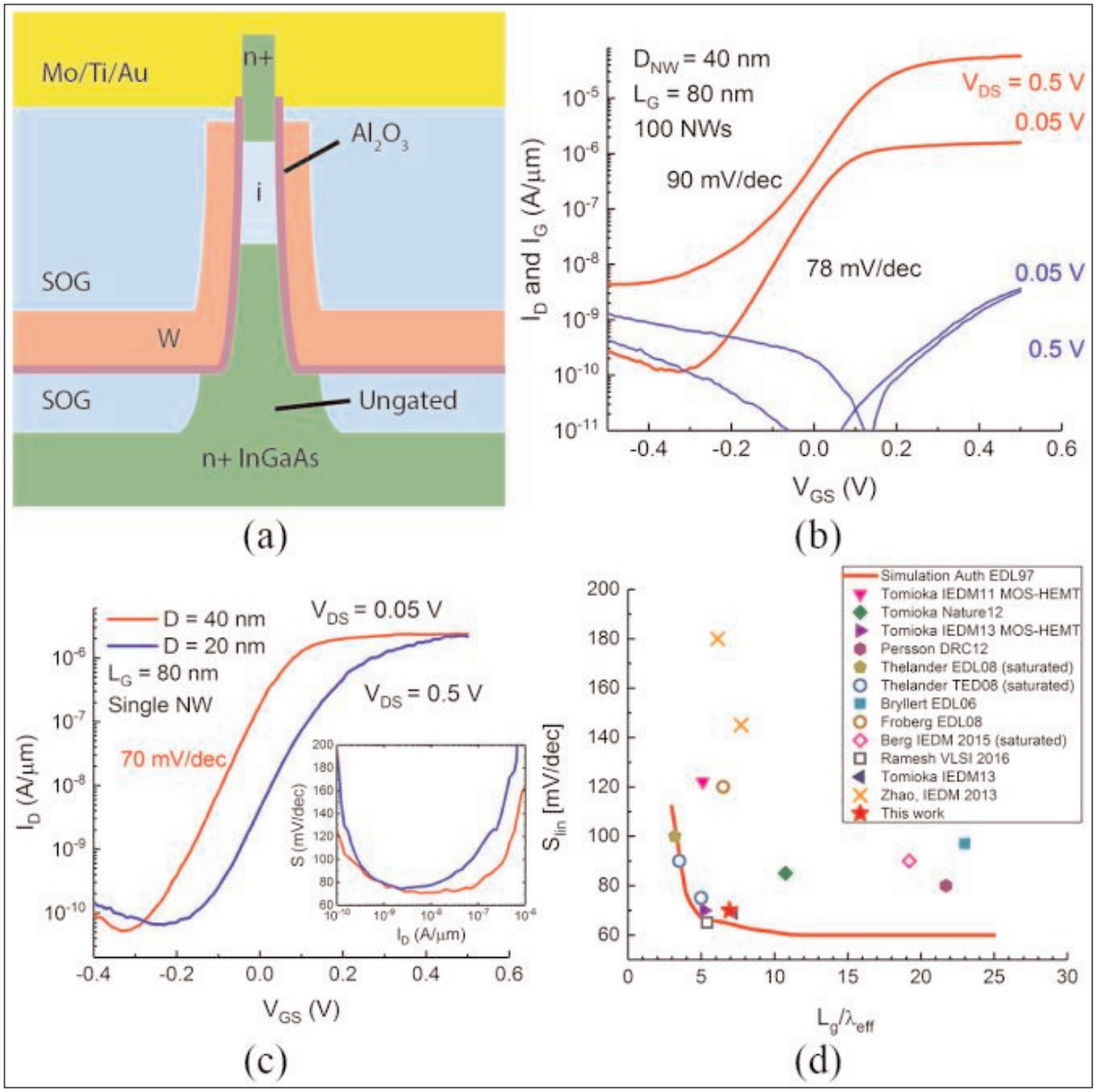

Figure 1. (a) Schematic cross section of InGaAs VNW-MOSFET; (b) subthreshold characteristics for transistor array with 100 40nm-diameter VNWs, treated with 5 DE cycles in H_2SO_4:methanol; (c) subthreshold characteristics of single 40nm-diameter VNW transistor with lowest linear swing of 70mV/decde. Inset: swing versus drain current. (d) Linear subthreshold swing versus ratio of gate length to natural length of InGaAs VNW MOSFETs.

Previous digital etch work on arsenide VNWs has been limited to 11–15nm diameters, according to the researchers.

To test the electronic effectiveness of the 5-cycle H_2SO_4:methanol digital etch, the MIT team produced InGaAs VNW transistors (Figure 1). The gate stack consisted of 2nm aluminium oxide (1nm equivalent oxide thickness) and tungsten electrode. The ohmic source–drain contacts were molybdenum. The NW diameters were in the range 20–40nm. The channel was 80nm long.

The linear subthreshold swing of 40nm-diameter devices in an array of 100 NWs was 78mV/decade. A single NW transistor achieved a minimum of 70mV/decade. A 20nm-diameter NW transistor had a slightly higher swing of 74mV/decade with 0.5V drain bias. The researchers used the subthreshold characteristics to extract an estimate of the interface trap density at 3.9×10^{12}/eV-cm^2.

The team points out that the subthreshold swing remains below 80mV/decade over two orders of magnitude in drain current, adding: "This is one of the best linear subthreshold swings reported in InGaAs VNW-MOSFETs." ■

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Author: Mike Cooke

Epitaxial lift-off and wafer bonding for III-V photodetectors on silicon

Researchers seek low production costs through speed up of wet etch process.

Researchers in Korea have been developing low-production-cost epitaxial lift off (ELO) techniques for wafer-bonded III-V photodetector (PD) transfer to silicon (Si) [SangHyeon Kim et al, Appl. Phys. Lett., vol110, p153505, 2017]. The devices were based on 'pin' (p-type/intrinsic/n-type) absorbing structures, but the researchers from Korea Institute of Science and Technology, University of Science and Technology (UST) and Seoul National University believe that the method is extendable to typical gallium arsenide photodetector structures such as quantum well infrared photodetectors and quantum dot infrared photodetectors.

GaAs-based PDs benefit from the better carrier photogeneration response to photons, resulting from having a direct bandgap (unlike Si, which has an indirect bandgap). However, GaAs is a more expensive material. Wafer-bonding on silicon and reuse of the III-V growth substrate could be a route to reducing costs. In addition, hybrid integration could allow III-V photodetectors to be integrated to versatile silicon electronics readout and data processing capabilities.

Contact	p^+-GaAs	200nm
Etch stop	p^+-$Al_{0.3}Ga_{0.7}As$	50nm
Instrinsic	GaAs	1000nm
Contact	n^+-GaAs	600nm
Sacrificial	$Al_{0.8}Ga_{0.2}As$	10nm
Substrate	Semi-insulating GaAs (100)	

Figure 1. Layer growth of pin diode structure.

The ELO works by dividing up the material to be transferred to silicon into mesas, allowing the etchant used to release the III-V growth substrate by more speedy access to an aluminium gallium arsenide (AlGaAs) sacrificial layer. The pin diodes were grown on 1.5cmx1.5cm semi-insulating GaAs (100) substrate by molecular beam epitaxy (MBE) — see Figure 1.

The ELO process (Figure 2) began with depositing palladium/gold on both the pin diode material and the

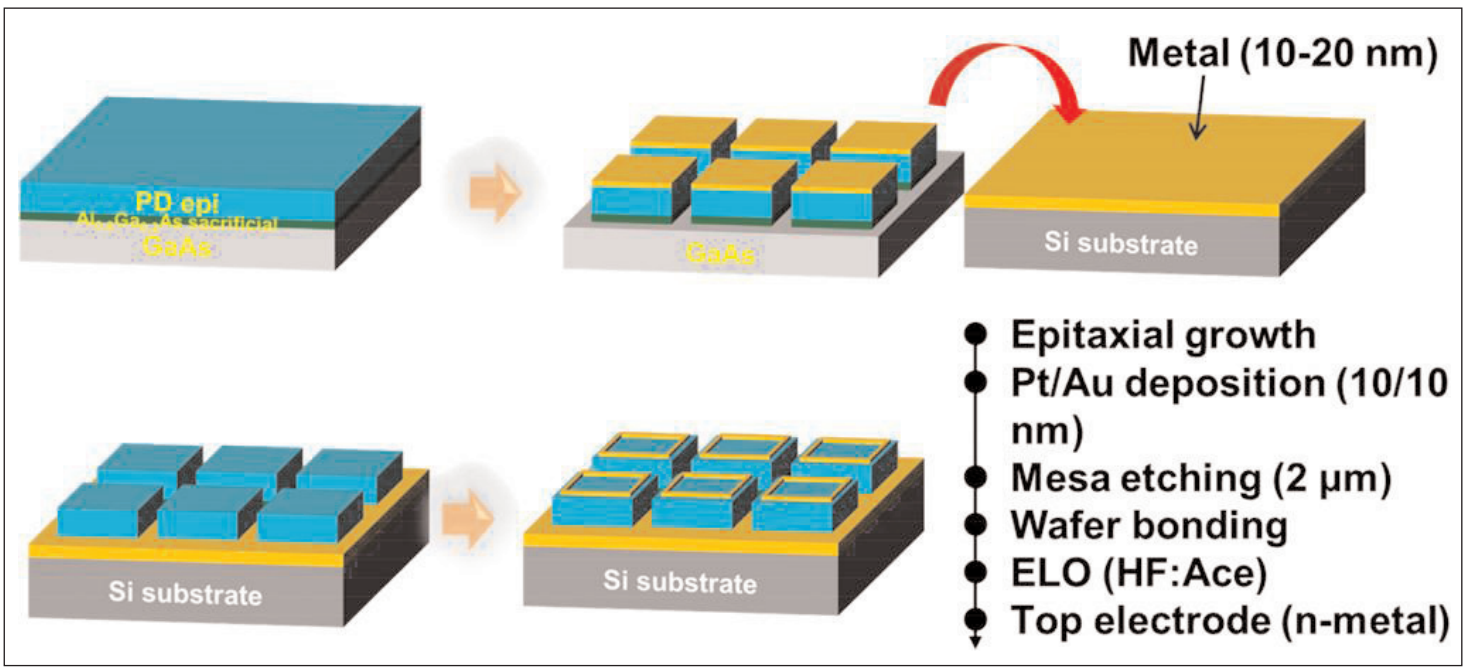

Figure 2. Fabrication scheme for GaAs pin photodetectors on silicon using wafer bonding and ELO.

target silicon substrate. The metal stack acted both as bonding for the III-V/silicon structure and as a bottom electrode for the p^+GaAs contact of the photodetectors.

Before bonding, the III-V wafer was patterned and etched with phosphoric acid (H_3PO_4) solution down to the sacrificial AlGaAs layer.

The ELO process continued with argon plasma activation of the metal surfaces for wafer bonding at room temperature with uniaxial 20kgf/cm^2 pressure. The GaAs growth substrate was then removed using hydrofluoric acid in acetone solution. Raman and x-ray analysis suggested that the ELO process did not introduce any strain or other degradation into the photodetector structures.

The ELO etch time was reduced to 5 minutes for 50μmx50μm mesas from over an hour for 400μmx400μm mesas. These mesas were separated by 100μm. However, the researchers also found that reducing the mesa spacing to 20μm did not have much impact on etch time.

Although the work used relatively small GaAs growth substrates, the team believes the process can be scaled-up with the use of stirring or some other technique to enhance flow of the etch solutions. Also, multiple small growth substrates could be bonded to a single silicon substrate.

The top electrode for the n^+-GaAs contact consisted of annealed nickel/gold/germanium/nickel/gold.

The dark on/off current ratio was 106 (between +1V and –1V) for photodetectors with 1900μm^2 mesas. By varying the surface area and perimeter length of the mesas, the researchers found that most of the dark current was related to charge flow near the sidewall surfaces: "It should be noted that the surface leakage current is 3.7 times higher than the bulk leakage current in the present GaAs pin photodetector array, indicating that reduction of surface leakage is very important to pursue the pitch scaling of the photodetector array. Also, these results suggest that dark current can be still reduced if we apply surface passivation techniques to suppress the surface leakage."

The photocurrent was tested using 635nm laser-diode illumination with light output powers up to 100μW (Figure 3). With 700μmx700μm mesas, the response was 0.6A/W. The low performance is blamed on the intrinsic absorbing region being too far from the top surface. The device also suffered from not having an anti-reflective top coating (ARC), which is estimated to reduce the incoming light by 30% through reflection. "Responsivity can be significantly improved by the optimization of the epitaxial structure, electrode pattern design, and introduction of ARC," the team believes.

The external quantum efficiency (EQE) increased with illumination wavelength up to near the band edge, above 800nm. The reduced response at shorter, visible wavelengths is attributed to higher reflectance, lack of passivation, and shorter penetration depth. The researchers suggest that passivation could be included in an ARC structure.

Extracted resistance and capacitance parameters suggest that the 3dB bandwidth for response speed of 1900μm^2 devices should be around 14.2GHz, "quite close to that of the state-of-the-art device with a similar window size," according to the team. The researchers add: "We believe that the response speed of our device can reach to that of samples typically fabricated using as-grown GaAs." ■

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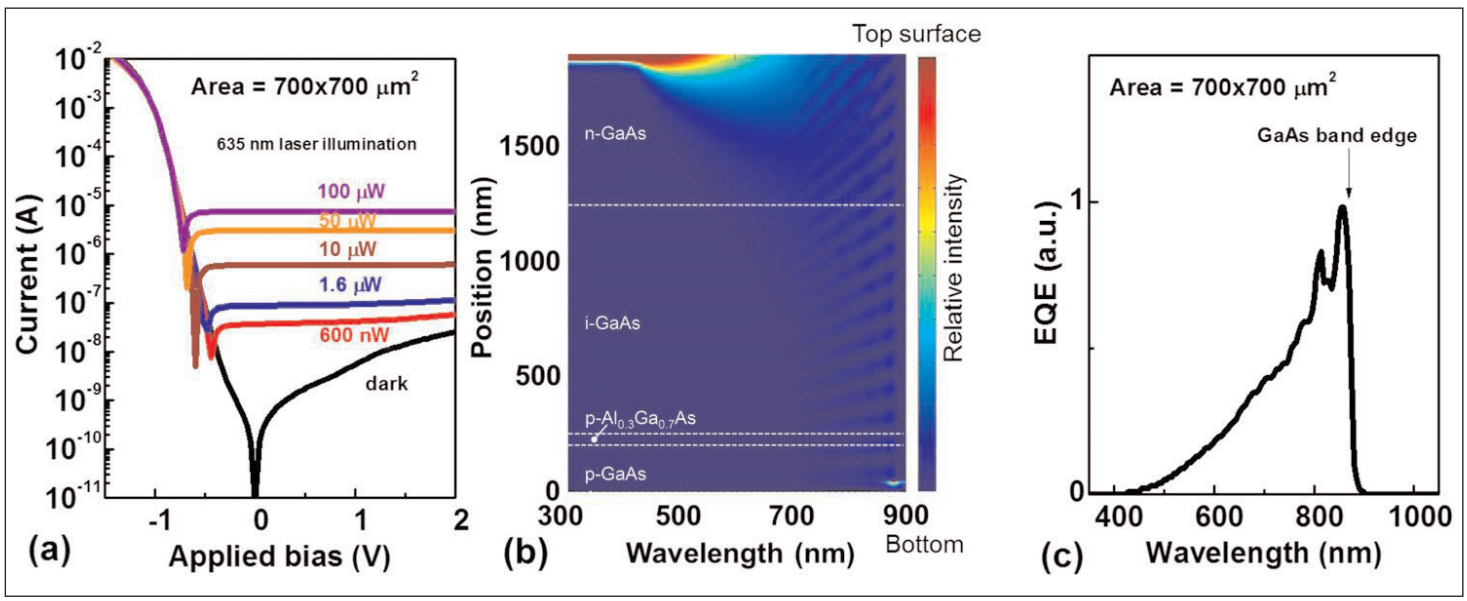

Figure 3. (a) Photocurrent and dark current characteristics of GaAs pin PD on Si as function of applied bias voltage with different optical powers. (b) Simulated optical intensity distribution in active layer as a function of light wavelength. (c) EQE spectrum of fabricated GaAs pin photodetector on Si as function of light wavelength.

Ultraviolet photodetection with gallium nitride nanoflowers on silicon

Researchers claim the highest responsivity over both GaN/Si and commercial silicon devices.

India's CSIR-National Physical Laboratory (CSIR-NPL) has developed gallium nitride (GaN) nanoflower (NF) structures on silicon as metal-semiconductor-metal ultraviolet (UV) photodetectors (PDs) [Neha Aggarwal et al, Adv. Electron. Mater., vol3, p1700036, 2017]. The team claims: "The reported responsivity is the highest among the GaN UV photodetectors on Si substrates and commercially available silicon-based UV photodetectors."

The researchers see potential visible-blind UV applications in instrumentation for solar UV monitoring, astronomy, highly secure space-to-space communications, biological sensors, and military uses such as missile detection.

III-nitride materials offer advantages over silicon photodetectors in terms of cut-off wavelength tunability, high thermal stability, high electron saturation velocity, small dielectric constant, and high breakdown field.

The GaN nanoflowers were grown by plasma-assisted molecular beam epitaxy (PAMBE) on a 30nm 825°C aluminium nitride buffer on (111) silicon (Figure 1). The GaN growth began with an 80nm thin layer followed by the nanoflowers. The GaN growth temperature was 730°C.

The photodetector electrodes were gold/chromium (150nm/5nm). Nanoflower density was $8.8 \times 10^7/cm^2$. The nanoflower structure had a ~200nm diameter at the base, opening up to 300–450nm at the top.

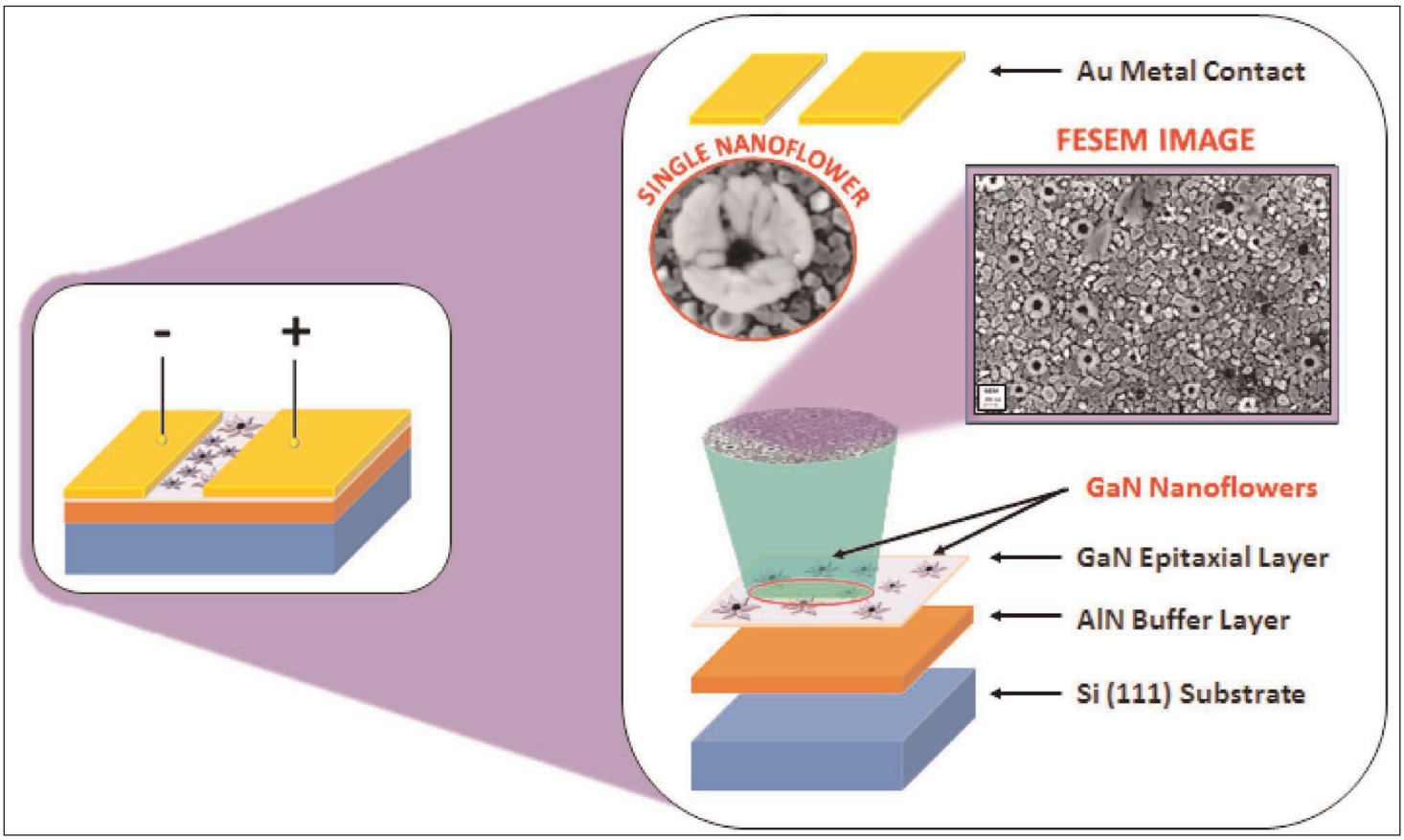

Figure 1. Fabricated device and exploded model representing field emission secondary electron microscopy image of epitaxial GaN film as well as nanoflowers in grown heterostructure.

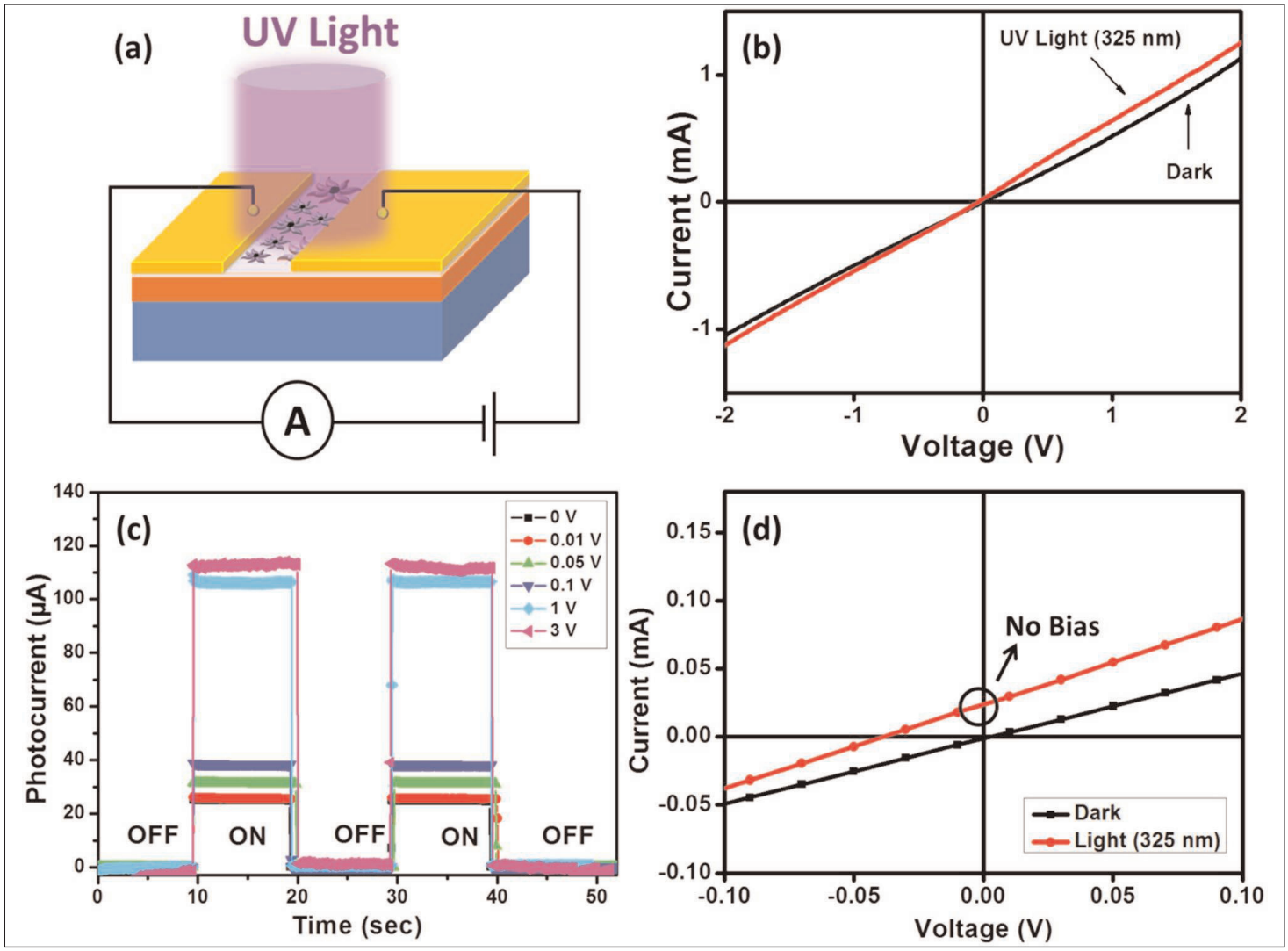

Figure 2. (a) Layout of GaN nanoflower-based UV photodetector device under UV illumination. (b) Current–voltage characteristics under dark and UV light conditions. (c) Time-correlated response of photocurrent

The devices were tested under 325nm UV light. The dark current leakage was attributed to thermionic emission, which increased with the applied bias.

The researchers also found a photocurrent at zero bias. This photocurrent was attributed to the effects of different size electrodes leading to a tilt in the depletion layer inducing charge separation and transport. In particular, a large electrode attracts more photo-generated holes, reducing the barrier height.

The response at zero bias was 132mA/W with 325nm UV of 13mW power. The researchers comment: "The value stated at no bias in the present study is significantly higher than the recently reported self-driven GaN-based photodetector which shows the photoresponsivity of 0.037, 0.083, and 0.104AW^{-1}using different contact electrodes and a flexible self-powered GaN UV photo-switch which possesses responsivities of 0.03 and 0.0116AW^{-1} at the power density of ≈3.5 and 35$mWcm^{-2}$, respectively."

The response to 13W UV power pulsed at 10s intervals showed a zero-bias light-to-dark current ratio of 260. The dark current was 90nA. The detectivity — (response (132mA/W) x (active area)$^{1/2}$)/(2 x (electron charge) x (dark current))$^{1/2}$ — was 2.4x10^{10}Jones. The rise time was 63ms and the fall time 27ms.

Lower-power illumination of 1mW resulted in a higher response of 10.5A/W. The researchers say that this response level is higher than for commercially available UV photodetectors.

A comparison planar GaN photodetector had a maximum photocurrent of 25.9mA — a 1.5A/W response — at 1V bias under 1mW illumination.

The increased response for GaN NFs is attributed to their higher surface-to-volume ratio, giving a higher rate for absorption of photons and generation of electrons and holes.

The planar device had a noise equivalent power of 60pW/Hz$^{1/2}$, which is much higher than the 1.2pW/Hz$^{1/2}$ value found for the photodetectors using GaN nanoflowers. The researchers attribute the lower noise in the GaN nanoflower photodetectors to the reduction of stress and defect states. ■

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Author: Mike Cooke

Non-polar gallium nitride ultraviolet photodetector on sapphire

Researchers in India have improved the performance of a-plane gallium nitride UV photodetectors grown on r-plane sapphire substrate

CSIR-National Physical Laboratory (CSIR-NPL) in India has used non-polar (NP) a-plane ($11\bar{2}0$) gallium nitride (GaN) on r-plane ($1\bar{1}02$) sapphire to create an ultraviolet (UV) photodetector with improved performance over previous devices using the same crystal structures [Abhiram Gundimeda et al, Appl. Phys. Lett., vol110, p103507, 2017]. In particular, the responsivity of 340mA/W at 5V bias is the best performance reported for a-GaN/r-sapphire films, the team claims.

The researchers see the high thermal stability, high radiation resistance and other properties of GaN as offering high-gain and high-speed UV photodetection for applications such as space communications, flame sensors, atmospheric ozone detection, biophotonics, and electromagnetic polarization-sensitive detection.

Normally GaN is grown in the polar c-plane orientation, where the charge polarization of the chemical bonds leads to strain-dependent and spontaneous electric fields that hamper device performance. Other orientations such as a-plane often involves growth on free-standing or bulk GaN substrates, which are much more expensive than c-plane sapphire. A-plane material can result from growth on r-plane sapphire, but the resulting epitaxial GaN usually has poor quality.

Plasma-assisted molecular beam epitaxy (PAMBE) was used to grow non-polar a-plane GaN on r-plane sapphire substrate. Growth began with 490°C nitridation and low-temperature 530°C GaN buffer. Further PAMBE at 745°C gave a 631nm GaN layer. The atomic composition was 51% gallium and 49% nitrogen, according to Rutherford back-scattering analysis.

X-ray analysis suggested that the material was nearly stress-free. The threading dislocation density was estimated to be $8x10^9/cm^2$ on the basis of x-ray rocking curve peak widths. The researchers claim that the material had the lowest dislocation density and narrowest peak width compared with non-polar GaN grown on r-plane sapphire by other techniques. These other techniques tend to give threading dislocation densities of $10^{10}/cm^2$ and greater.

Photoluminescence gave a narrow near-band-edge

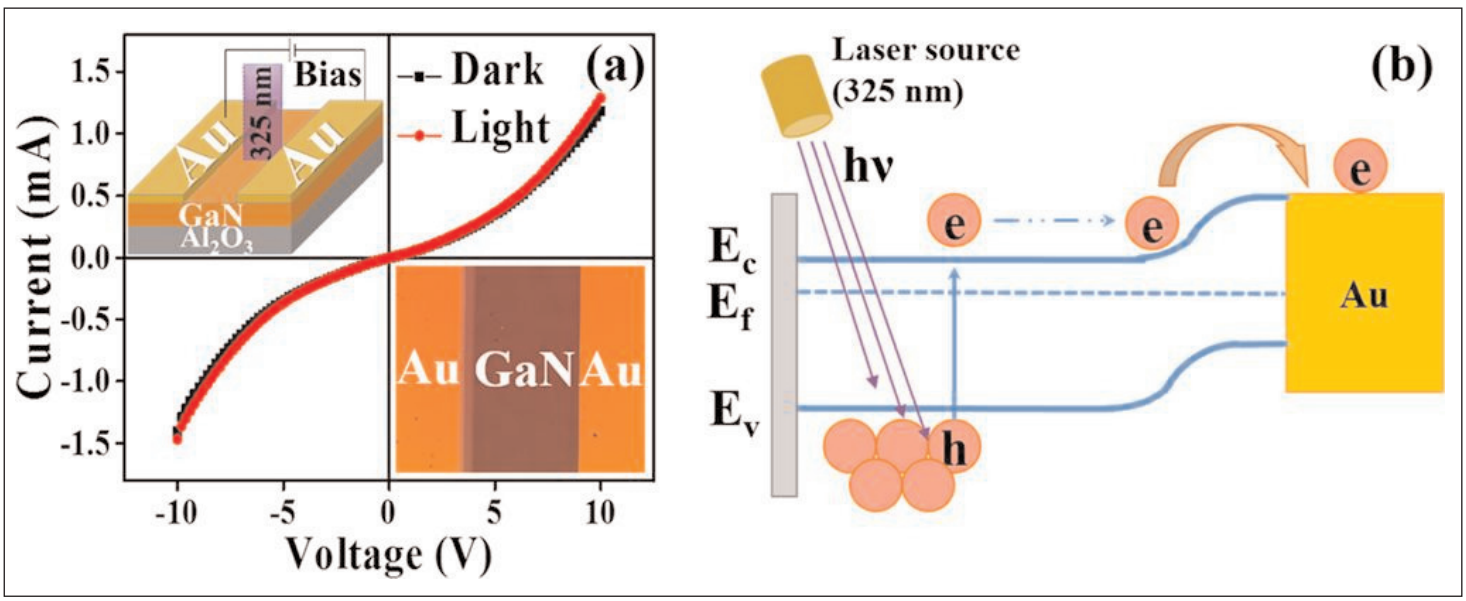

Figure 1. (a) Current–voltage curve of GaN PD under dark and light conditions. Inset: schematic diagram and optical image of fabricated UV PD. (b) Energy-level diagram of Au/GaN junction showing charge transfer under UV illumination.

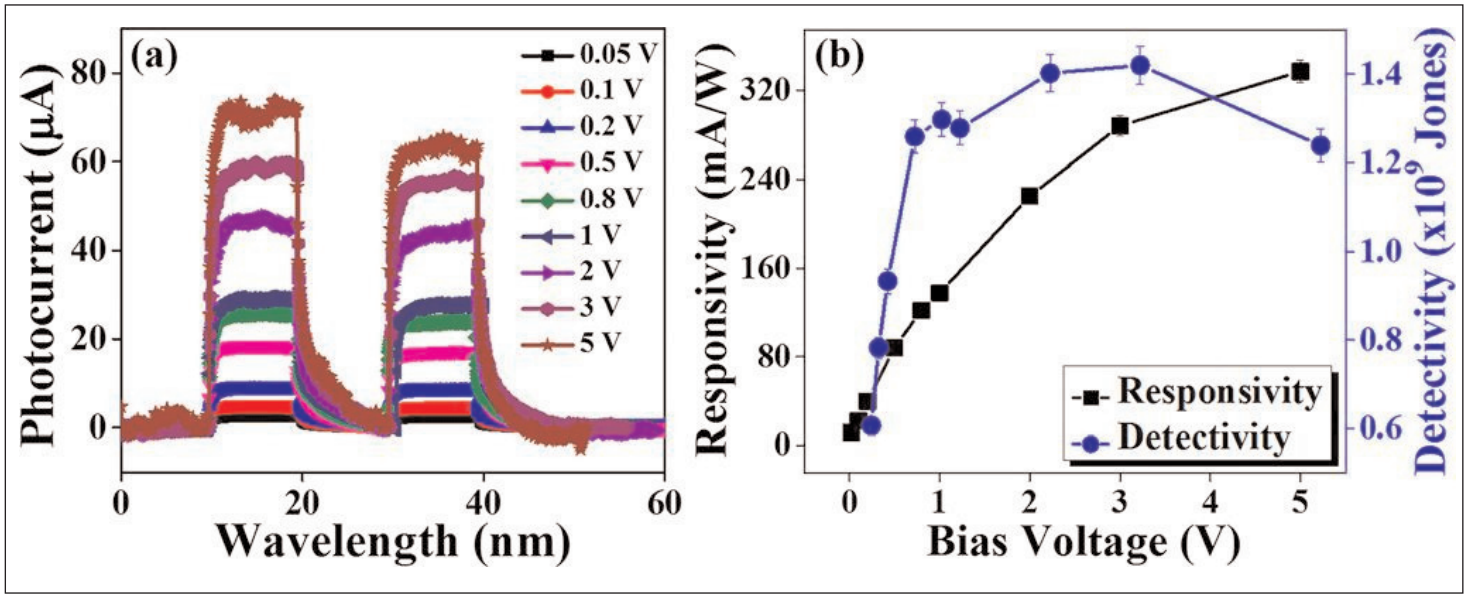

Figure 2. (a) Time-dependent photo-response of GaN UV PD with varying bias under 325nm illumination and (b) variation in responsivity and detectivity with respect to bias voltage.

peak at 3.39eV, a 10meV red-shift from strain-free GaN (3.40eV). There were also low-intensity broad peaks in the yellow (~2.2eV) and blue (~3.0eV) bands. Yellow emission is often associated with defects. The blue luminescence is attributed to dissociation of excitons (electron–hole pairs) bounded to neutral donors.

The researchers comment: "The strong, narrow band-edge emission along with low intense defect bands exhibits that the GaN layer has a superior optical quality (implies a low density of native defects)."

The surface of the GaN layer had two-faceted triangular island structures, which resulted in the low stress, according to Raman analysis.

UV photodiodes were fabricated by depositing and patterning 150nm-thick gold contacts separated by 60μm to give a metal-semiconductor-metal geometry. With 5V bias, the dark current was 1.5μA (Figure 1). The relatively large dark current "suggests the presence of electrical leakage, which may be associated with extended defects in the epitaxial layers (most likely basal plane stacking faults in NP nitride films)," say the researchers. The difference with the current under 325nm laser illumination was very small. The team suggests that tunneling through defect states may be to blame.

Switching the laser on and off at 10 second intervals gave increased response (Figure 2). The on-current was 2.53μA and 74.49μA with 50mV and 5V bias, respectively. The light power density was 13mW/cm^2 and the measurements were at room temperature. The response for 5V bias was 340mA/W.

These obtained values of responsivity and detectivity are the highest reported values than any other UV PD device fabricated using epitaxial non-polar GaN films on sapphire substrate and are comparable with UV photodetectors made of other materials such as oxides and SiC, etc

The researchers comment: "Such a significant enhancement in the photocurrent can be attributed to the dominance of charge generation over charge recombination, thereby producing more charge carriers with increasing bias. Also, the higher bias voltage will enhance the collection of the photo-excited carriers which leads to increased photocurrent."

The noise equivalent power (NEP) at 5V bias was 2.4×10^{-11}W/√Hz, less than for silicon photodiodes. The corresponding specific detectivity figure of merit was 1.24×10^{9}Jones. The specific detectivity is inversely proportion to NEP, while normalizing for the effects of device area and frequency bandwidth. A higher detectivity of 1.42×10^{9}Jones was achieved at 3V bias.

The researchers comment: "These obtained values of responsivity and detectivity are the highest reported values than any other UV PD device fabricated using epitaxial NP GaN films on sapphire substrate and are comparable with UV PDs made of other materials such as oxides and SiC, etc."

Finally, the team report on the rise and fall times at 5V bias — 280ms and 450ms, respectively. The longer fall time is attributed to delays in decay of photo-generated carrier density. They comment: "In comparison with previous reports, which show response times in seconds, our detectors are producing response times in the order of milliseconds. Such a high-speed and enhanced photo-response is conceivable due to low-trap-density, high-crystalline GaN film." ■

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Author: Mike Cooke

Direct hole injection plugs for InGaN LEDs

Technique can increase light output power and wall-plug efficiency at higher current.

Researchers in South Korea have used direct hole injection plugs (DHIPs) in indium gallium nitride (InGaN) light-emitting diodes to improve light output power and wall-plug efficiency (WPE) at higher currents [Sungjoon Kim et al, Optics Express, vol25, p6440, 2017].

Poor hole injection reduces the effectiveness of InGaN LEDs, and DHIPs are an attempt to overcome this. Seoul National University, Samsung Electronics Co Ltd and Gachon University in South Korea used LED material grown on 2-inch c-plane sapphire. The target wavelength was 445nm. The DHIPs were formed by dry etch with a plasma-enhanced chemical vapor deposition (PECVD) silicon dioxide mask, followed by filling with epitaxial p-GaN.

The etch depth reached down to the multiple quantum well (MQW) layers, leaving three of the four wells intact, preventing loss of active region and excessive overflow of carriers and leakage at high operating current. The researchers used time-control to determine the etch end-point, but they suggest that detection of indium in the etch equipment could also be used as a signal. The etched circular holes were completely filled and capped with hexagonal pyramid islands, resulting from particular facet directions.

After removal of the silicon dioxide mask, lateral LEDs were fabricated with 440μmx370μm active area. An indium tin oxide (ITO) transparent p-electrode was used for current spreading.

With 3μm-radius DHIPs, improved power output and droop performance was seen at higher current in devices with a total DHIP circumference of 62.6mm, compared with a reference LED with no DHIPs (Figure 2). The increase in light output power was 23.2% at 100A/cm^2 injection current. Comparing with an LED with 104.2mm-circumference DHIPs, the output power and wall-plug efficiency was better in the 62.6mm-circumference device.

The DHIP devices showed more reverse-bias leakage, but also had lower turn-on voltage — 0.25V less for 62.6mm total circumference and 100A/cm^2 current density. The team comments: "It seems that the leak-

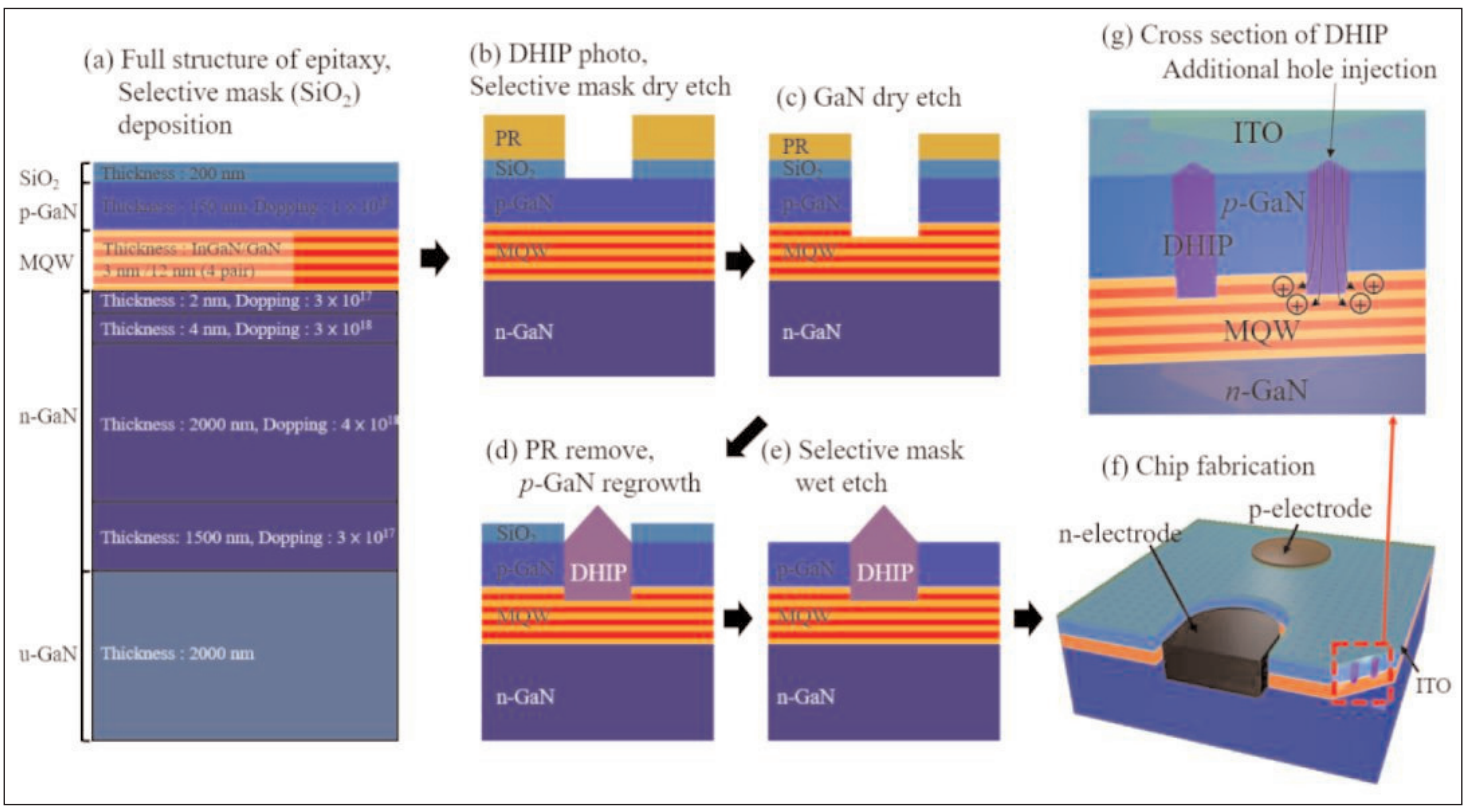

Figure 1. DHIP LED fabrication process and schematic of mechanism for increased hole injection.

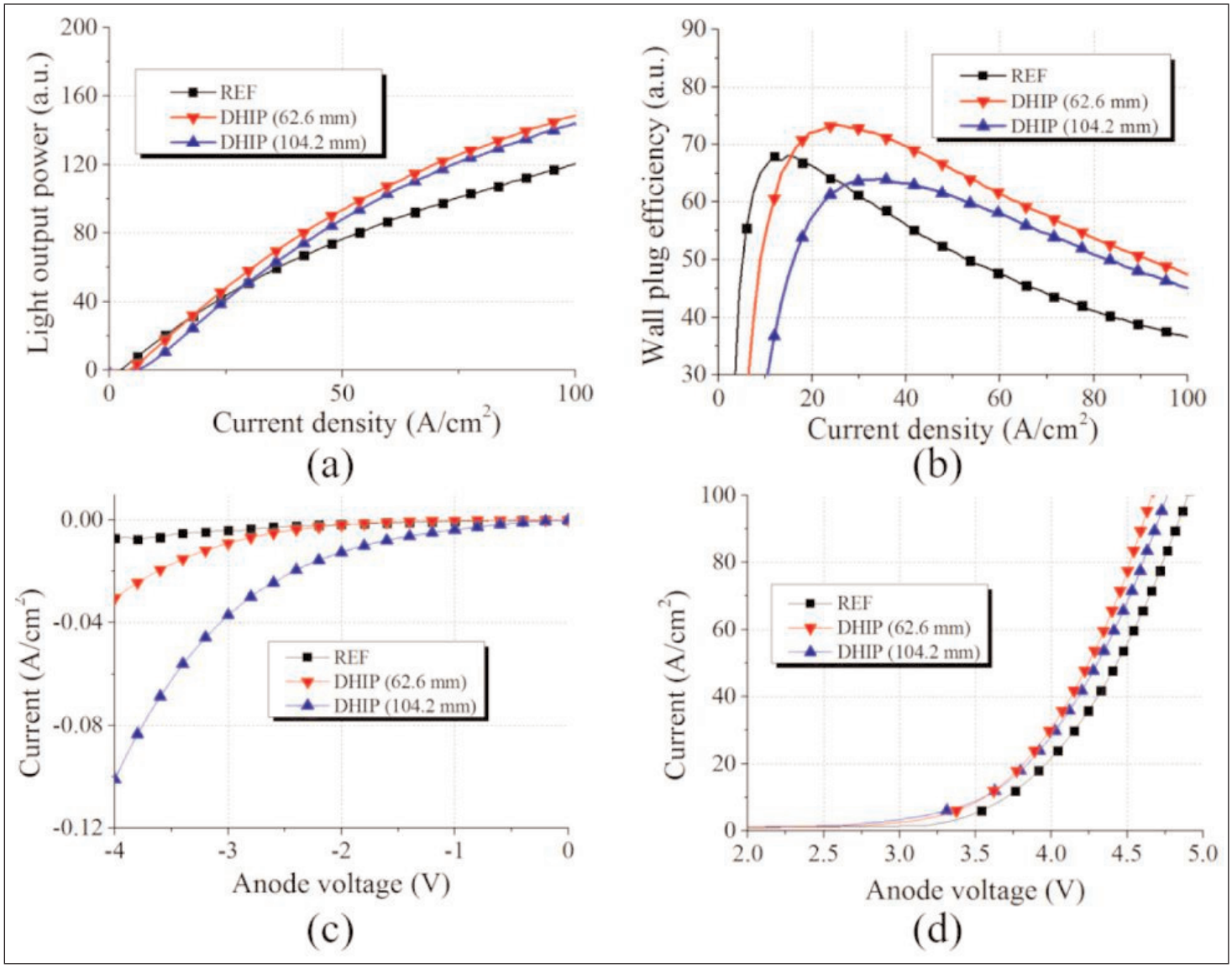

Figure 2. Comparison of optical and electrical performances of reference, and DHIP LEDs having total circumferences of 62.6mm and 104.2mm. (a) Measured light output power versus current density. (b) Wall plug efficiency versus current density. (c) Reverse leakage current density versus anode voltage. (d) Forward current density versus anode voltage.

age path originates from the plasma damage and defects along the DHIP edge. Therefore, the total length of DHIP edge needs to be minimized to achieve higher optical output power and lower leakage current at the same time."

By analyzing electroluminescence decay behavior from 4μs pulses, the researchers decomposed the Shockley-Read-Hall (SRH), radiative and 'Auger' recombination according to the ABC model (Table 1).

Table 1. Calculated recombination parameters (A, SRH, B, radiative, and C, Auger recombination).

	A (/s)	B (cm^3/s)	C (cm^6/s)
REF LED	$4.7x10^6$	$1.8x10^{-11}$	$1.5x10^{-31}$
DHIP LED (104.2 mm)	$7.6x10^6$	$2.4x10^{-11}$	$1.5x10^{-31}$
DHIP LED (62.6 mm)	$6.0x10^6$	$2.5x10^{-11}$	$1.5x10^{-31}$

The A coefficient is linear in carrier density (n), and is attributed to SRH recombination through defect levels. The quadratic (n^2) B coefficient represents the desired radiative recombination of electrons and holes. Finally, the C coefficient gives a cubic (n^3) dependence, which is often associated with non-radiative three-carrier energy transfers.

The DHIPs increase radiative recombination (B), but at the expense of increased SRH recombination (A). The trade-off gives the improved performance of the 62.6mm-circumference LED.

A large run of different DHIP radii (2–3.5μm) and circumferences (up to 300mm) suggested that an optimum circumference was around 70mm for 75A/cm^2 injection current. ■

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Author: Mike Cooke

Monolithic amber-green-blue nanopillar LEDs

Strain engineering could provide a viable approach for micro-displays based on indium gallium nitride technology with existing manufacturing infrastructure.

University of Michigan in the USA has developed monolithically integrated amber–green–blue LEDs (Figure 1) based on strain engineering of indium gallium nitride (InGaN) multiple quantum wells [Kunook Chung et al, Appl. Phys. Lett., vol110, p111103, 2017]. The strain engineering was achieved by etching nanopillars of varying diameter.

The researchers hope in future to create red–green–blue LEDs using quantum wells with 635nm photoluminescence, giving a viable approach for micro-displays based on such pixel LEDs. Further potential applications include lighting, biosensors, and optogenetics.

In addition to backing from the US National Science Foundation (NSF), Samsung gave fabrication and device design support. In their work, the researchers were keen to develop a chip-scale multi-color LED platform based on existing manufacturing infrastructures.

The epitaxial material was grown by metal-organic chemical vapor deposition (MOCVD) on 2-inch unpatterned sapphire. The light-emitting active region consisted of five 2.5nm InGaN wells separated by 12nm GaN barriers. The electron-blocking and p-contact layers consisted of 20nm aluminium gallium nitride (p-$Al_{0.2}Ga_{0.8}N$) and 150nm p-GaN, respectively.

The pillars were defined using electron-beam lithography and created by hybrid dry and wet etch processing with a nickel mask. The bulk of the etch was dry, inductively coupled plasma, with the wet stage used to achieve the final diameter and remove damage from the dry step. The etch depth was around 300nm. The etch mask was maintained throughout fabrication to protect the p-GaN surface.

Spin-on-glass was used to planarize the structure after the plasma-enhanced chemical vapor deposition

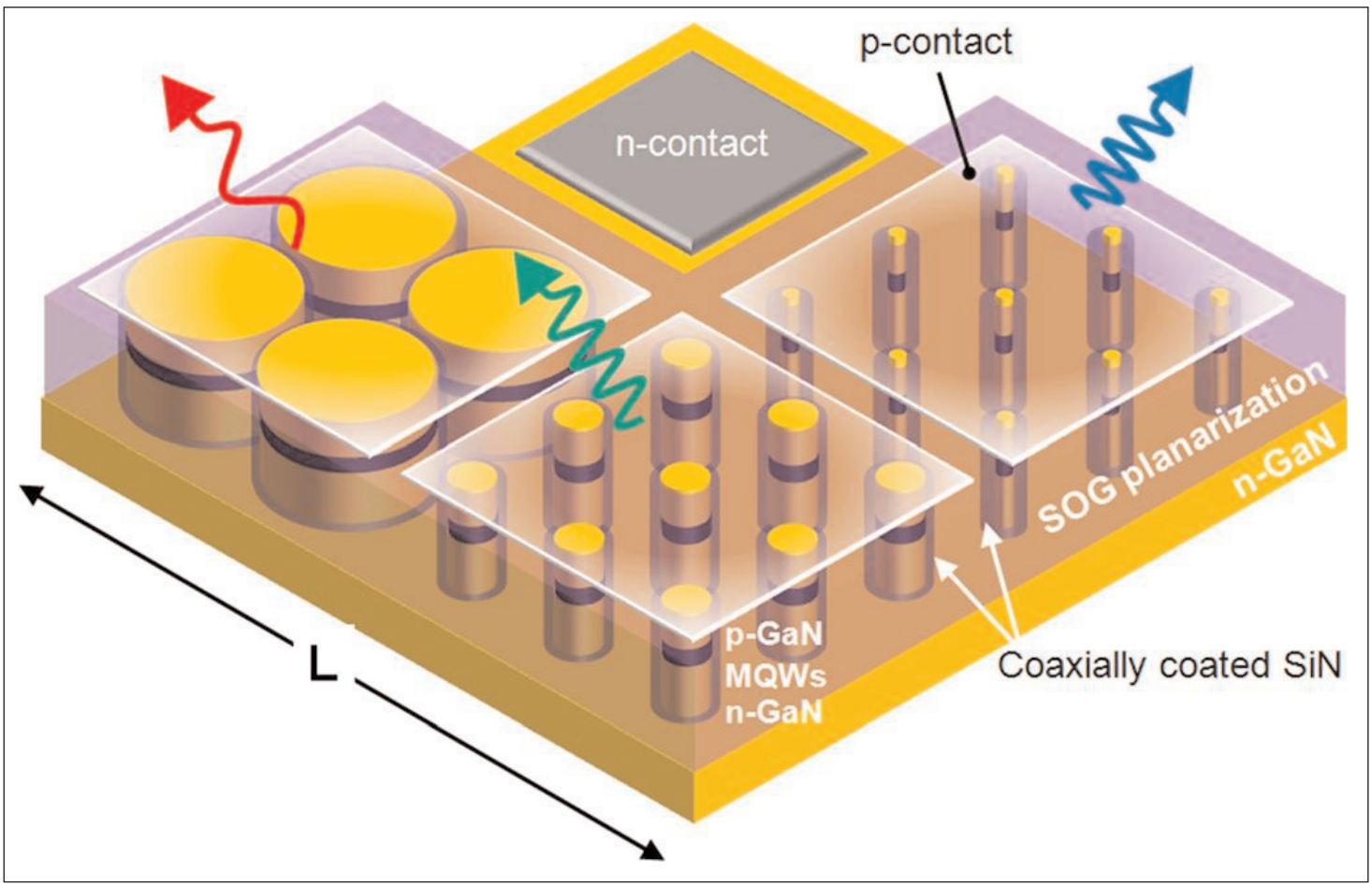


Figure 1. Schematic of top-down fabrication of nanopillar LED arrays with various diameters.

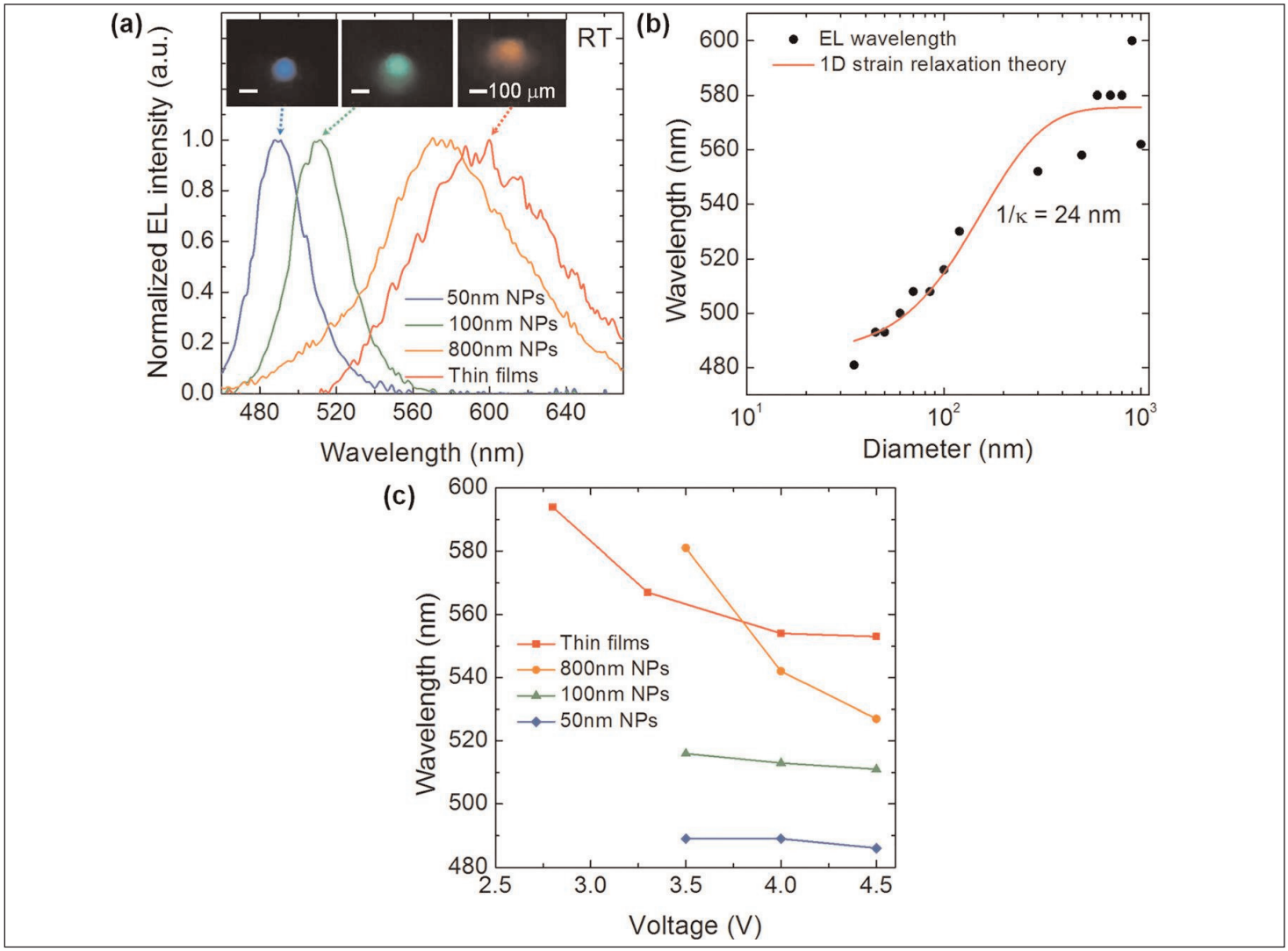


Figure 2. (a) Room-temperature electroluminescence spectra of blue (487nm), green (512nm), orange (575nm) and amber (600nm) emissions obtained from 50nm-, 100nm- and 800nm-diameter nanopillar, and thin-film LED pixels, respectively. Inset: corresponding photographs. (b) Measured emission wavelength as function of nanopillar diameter (black circles) with fitting curve from one-dimensional strain relaxation theory. (c) Dominant peak positions at various applied bias voltages.

(PECVD) of 50nm silicon nitride to electrically isolate the n- and p-GaN parts of the structure.

The planarized structure was dry etched back to expose the pillar tips. The nickel mask material was removed with nitric acid solution. The p-contact nickel/gold metalization was thermally annealed in air.

The electrical performance of the devices showed low leakage of around $3x10^{-7}$A per pixel at 5V reverse bias. The low leakage is attributed to two factors — flat quantum wells giving low current-crowding effects, and strain-induced confinement of carriers to the center of the nanopillars. The risk of droop effects from the greater current density in the narrower nanopillars is ameliorated by reduced strain, and hence lower (QCSE) quantum-confined Stark effect) from electric fields arising from the charge polarization of the chemical bond in III-nitrides.

The pixels were constructed from pillars with different diameters giving different colors (Figure 2). As the diameter increased, the wavelength became longer and more variable. The researchers attribute the variability to variations in quantum well thickness across the wafer.

The more relaxed narrow nanopillars also showed less blue-shift in wavelength as the voltage and current injection increased. The blue-shift for 800nm-diameter nanopillar pixels was 40nm between 2.8V and 4V. This is attributed by the team to screening of the strain-dependent piezoelectric field in the wells.

The team foresees stabilizing the output wavelengths of pixels by fixing the bias voltage and varying the intensity by pulse frequency modulation. A test of this idea showed that all the pixel types gave stable wavelengths and relative electroluminescence intensities that varied in a nearly linear manner with the duty cycle of the pulsed signal. The pulse width was 400μs. The pulse frequency varied between 200Hz and 2000Hz. ■

http://dx.doi.org/10.1063/1.4978554

Author: Mike Cooke

Monolithic gallium nitride vertical transistor and light-emitting diode

Researchers claim best ever performance for such integrated devices.

South China University of Technology and Hong Kong University of Science and Technology (HKUST) claim the best performance ever reported for the monolithic integration of gallium nitride (GaN) light-emitting diodes (LEDs) with driving transistors [Xing Lu et al, IEEE Electron Device Letters, published online 6 April 2017]. The team used a combination of dry and wet etch, along with selective epitaxial regrowth, to produce vertical metal-oxide-semiconductor field-effect transistors (VMOSFETs) alongside LEDs.

Presently, LEDs are combined with dedicated and bulky electronic driving circuits to achieve functions such as AC–DC conversion, current sourcing, and dimming. The parts are connected using bonding wires that introduce parasitic elements that sap performance in terms of high power consumption and low efficiency. LED systems often fail through the peripheral parts and packaging rather than through the LED chip itself.

Apart from the problems of having separate devices for light emission and electronic control, GaN transistors offer potential benefits of large breakdown voltage, fast operation speed, low power loss, and high temperature endurance. The researchers comment: "By integrating GaN-based LEDs and driving transistors on the same substrate, a compact smart-lighting system can be realized and benefit a range of applications such as solid-state lighting,

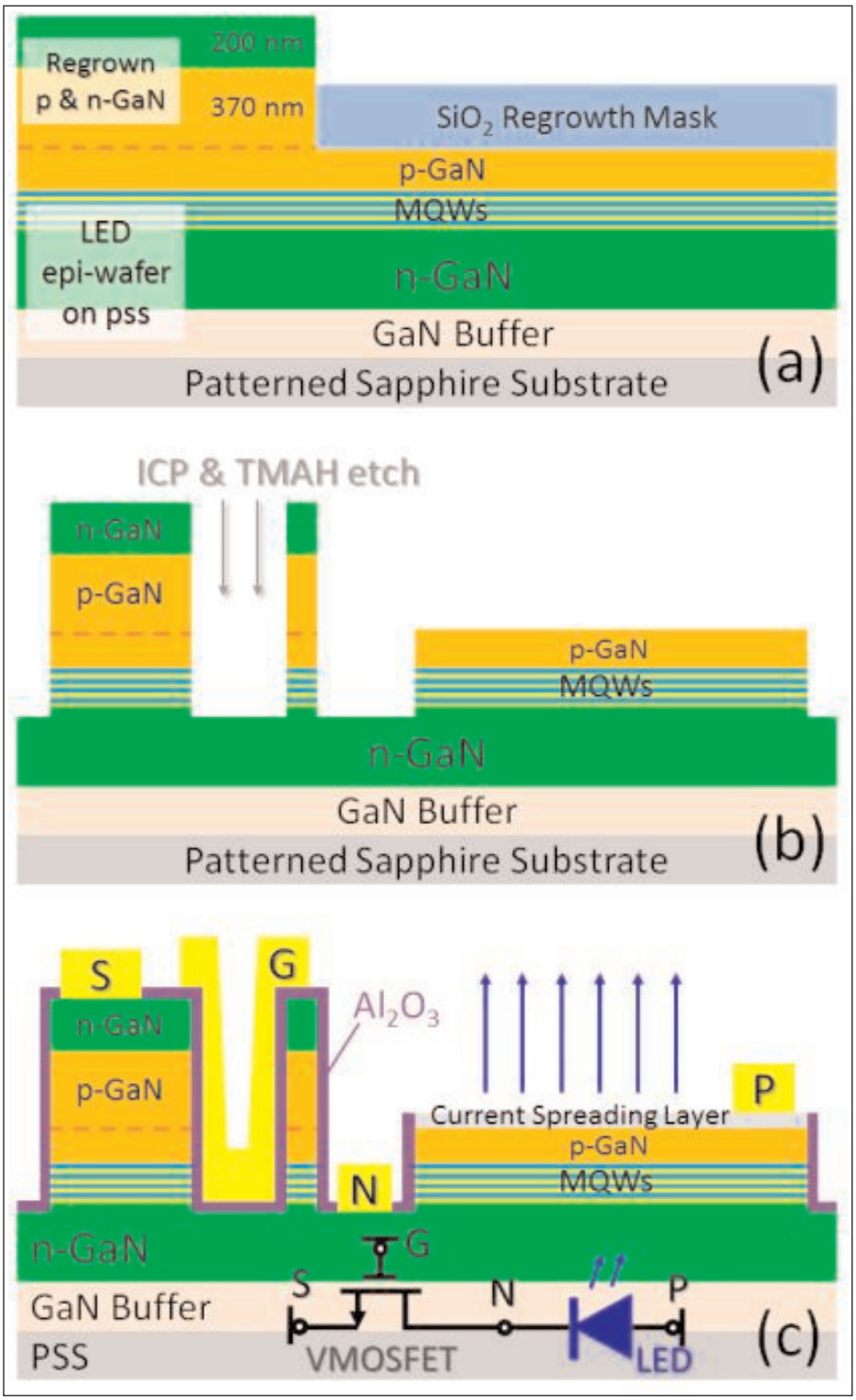


Figure 1. Main steps in fabricating monolithically integrated VMOSFET-LED device: (a) selectively re-grow p- and n-GaN bilayer on LED; (b) gate trenches and device isolation etching; (c) fully processed device.

micro-displays and visible light communications (VLCs)."

The VMOSFET structure results in enhancement-mode operation, which simplifies drive circuitry by allowing use of a single-polarity voltage supply. The team sees an added advantage: "VMOSFETs share similar junction-based vertical structures with LEDs and are more suitable for integration than the lateral ones."

To realize VMOSFETs with high performance, the etch process needs to maintain GaN crystal quality of the sidewalls of trenches through which channel currents flow. Dry etching using plasma tends to result in rough, damaged surfaces. Wet etch is often used to clean up after such processes.

The researchers used 2-inch GaN LED on patterned sapphire substrates (pss) with InGaN/GaN multiple quantum wells. The fabrication of the VMOSFET-LED began with plasma-enhanced chemical vapor deposition (PECVD) silicon dioxide that was patterned using a buffered oxide etch to give a re-growth mask (Figure 1). The re-grown material selectively added p- and n-GaN layers to give an n/p/n structure.

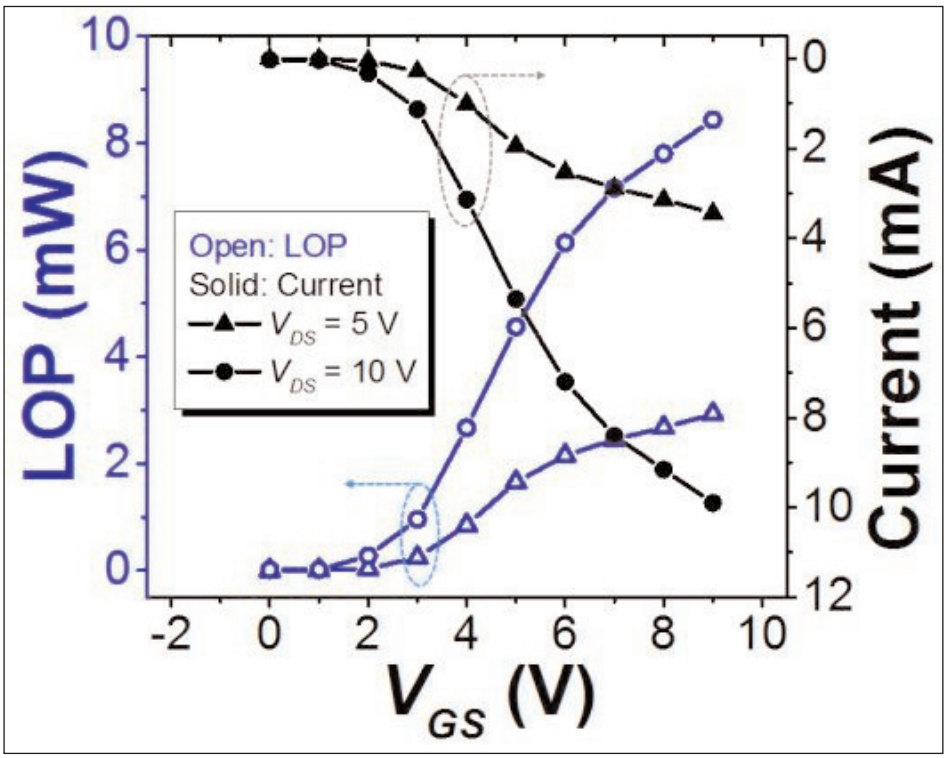


Figure 2. Gate modulated LOP and current–voltage characteristics of integrated VMOSFET-LED device at different drain biases.

Etching for the gate trench and for electrical isolation were achieved by a combination of inductively coupled chlorine plasma dry and tetramethylammonium hydride (TMAH) wet processes. The 25%-solution TMAH etch was carried out at 75°C and lasted for 60 minutes. The wet process was designed to remove damage to the GaN sidewalls by the dry etch.

Annealing at 800°C for 1 minute in nitrogen resulted in a nominal hole concentration in the p-GaN layers of $2x10^{17}/cm^3$.

The gate dielectric for the VMOSFET was 30nm of atomic layer deposition (ALD) aluminium oxide. Annealed nickel/gold was used as a current-spreading layer for the LEDs. The n-electrodes for the LED and VMOSFET ohmic source contact consisted of chromium/aluminium/titanium/gold. The device was completed with deposition of a nickel/gold gate.

The serial connection between the VMOSFET and LED through the bottom n-GaN layer avoids metal interconnection, reducing parasitic losses. The central n-electrode allowed separate characterization of the VMOSFET and 300μmx300μm LED. The VMOSFET had a 30μm-diameter circular shape with the source contact in the center.

The forward voltage at 20mA of the LED was 3.72V; the light output power and external quantum efficiency (EQE) at the same current were 16mW and 23.5%, respectively. Peak EQE (33%) was achieved at 600mA/cm^2 current density (0.54mA). With a reverse bias of −10V, the leakage was 10^{-2}mA. The blue LED wavelength peaked around 440nm.

The researchers comment: "The dramatic improvement in LED brightness compared to the previously reported integration schemes was mainly attributed to the better crystalline quality of LED epiwafer grown on pss than those grown on planar sapphire substrates."

The VMOSFET had a positive threshold of +1.8V, giving desired normally-on 'enhancement-mode' operation. The maximum output current density was 1.4kA/cm^2 with 11V drain bias and 9V gate potential. The team points out that a previous device produced without TMAH-solution etching had an order-of-magnitude lower output current density.

VMOSFET-LED integration allows simpler voltage control rather than current control of the light output. Below the threshold voltage of the VMOSFET there was no measured light output. With 9V gate (V_{GS}) and 10V drain (V_{DS}), the light output power (LOP) was 8.5mW (9.4W/cm^2). The injection current through the transistor was 10mA.

The team writes: "To our knowledge, this is the best performance ever reported for monolithic integration of GaN LEDs with driving transistors. Nevertheless, the high V_{DS} of the integrated VMOSFET-LED leads to a high power consumption. The drive voltage can be reduced by increasing the VMOSFET's device size to improve its drive capability." ■

https://doi.org/10.1109/LED.2017.2691908

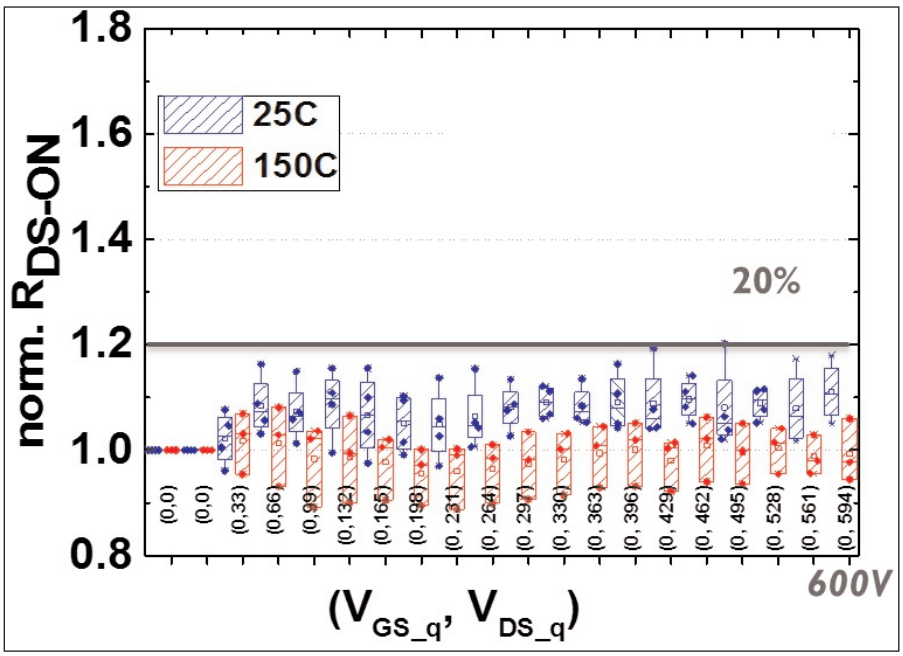
Author: Mike Cooke

Imec develops 200V & 650V dispersion-free normally-off/ E-mode GaN power devices on 200mm silicon

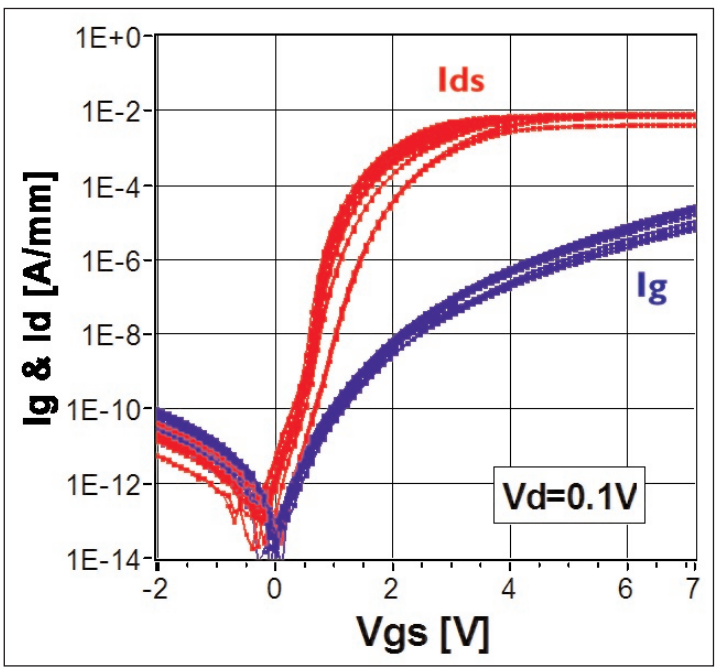
Technology ready for prototyping, customized low-volume production and technology transfer.

Nanoelectronics and photovoltaics research centre Imec of Leuven, Belgium has developed 200V and 650V normally-off/enhancement mode (E-mode) on 200mm/8-inch gallium nitride on silicon (GaN-on-Si) wafers, achieving a very low dynamic R_{on} dispersion (below 20%) and what is claimed to be state-of-the-art performance and reproducibility. Stress tests have also shown good device reliability, it adds. Imec's technology is ready for prototyping, customized low-volume production and technology transfer.

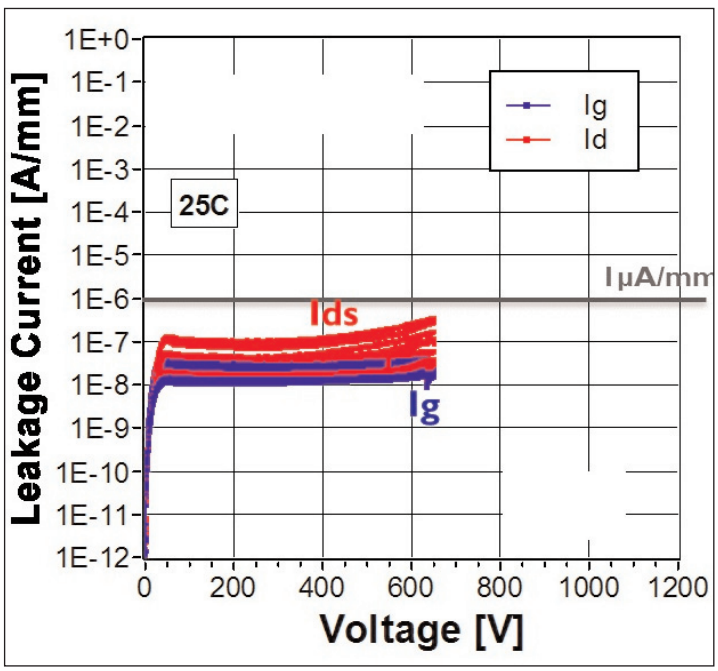
GaN technology offers faster-switching power devices with higher breakdown volt-



Dynamic R_{DS-ON} dispersion (10µs on — 90µs off) of Imec's 650V GaN-on-Si E-mode device technology measured at 25°C and 150°C.



Transfer characteristic of 36mm gate width imec's 650V GaN-on-Si e-mode transistors.



Leakage characteristic at V_{GS}=0V of 36mm gate width imec's 650V GaN-on-Si e-mode transistors.

Parameter	Symbol	Value	Unit	Conditions
Drain-to-Source Breakdown Voltage (Min.)	BV_{DSS}	200	V	V_{GS} = 0V
Drain-to-Source On Resistance (25 °C)	$R_{DS(ON)}$	7	Ω·mm	V_{DS} = 0.1V, V_{GS}=$V_{GS(th)@max\text{-}gm}$+4V, 25 °C
Drain-to-Source On Resistance (150 °C)		12	Ω·mm	V_{DS} = 0.1V, V_{GS}=$V_{GS(th)@max\text{-}gm}$+4V, 150 °C
Dynamic Drain-to-Source On Resistance (RT/150 °C)	$R_{DS(ON)\text{-}DYN}$	< 20	%	From off-state 10 µs on, 90 µs off
Gate Threshold Voltage	$V_{GS(th)}$	1.3	V	I_D=10µA/mm and V_{DS}=V_{GS}
		2.4	V	at max-gm
Drain Leakage Current (25 °C)	I_{DSS}	< 10	nA/mm	V_{DS}=200V, V_{GS}=0V, 25 °C
Drain Leakage Current (150 °C)		< 1	µA/mm	V_{DS}=200V, V_{GS}=0V, 150 °C
Gate-to-Source Voltage	V_{GS}	>4.5	V	I_{GS}=1µA/mm
Gate-to-Source Current	I_{GS}	< 10	µA/mm	V_{DS}=0V, V_{GS}=6V

Normalized spec table of imec's 200V GaN-on-Si e-mode device technology.

Parameter	Symbol	Value	Unit	Conditions
Drain-to-Source Breakdown Voltage (Min.)	BV_{DSS}	650	V	V_{GS} = 0V
Drain-to-Source On Resistance (25 °C)	$R_{DS(ON)}$	13	Ω·mm	V_{DS} = 1V, V_{GS}=$V_{GS(th)@max\text{-}gm}$+4V, 25 °C
Drain-to-Source On Resistance (150 °C)		28	Ω·mm	V_{DS} = 1V, V_{GS}=$V_{GS(th)@max\text{-}gm}$+4V, 150 °C
Dynamic Drain-to-Source On Resistance (RT/150 °C)	$R_{DS(ON)\text{-}DYN}$	< 20	%	From off-state 10 µs on, 90 µs off
Gate Threshold Voltage	$V_{GS(th)}$	1.1	V	I_D=10µA/mm and V_{DS}=V_{GS}
		2.1	V	at max-gm
Drain Leakage Current (25 °C)	I_{DSS}	< 200	nA/mm	V_{DS}=650V, V_{GS}=0V, 25 °C
Drain Leakage Current (150 °C)		< 10	µA/mm	V_{DS}=650V, V_{GS}=0V, 150 °C
Gate-to-Source Voltage	V_{GS}	> 4	V	I_{GS}=1µA/mm
Gate-to-Source Current	I_{GS}	< 10	µA/mm	V_{DS}=0V, V_{GS}=6V

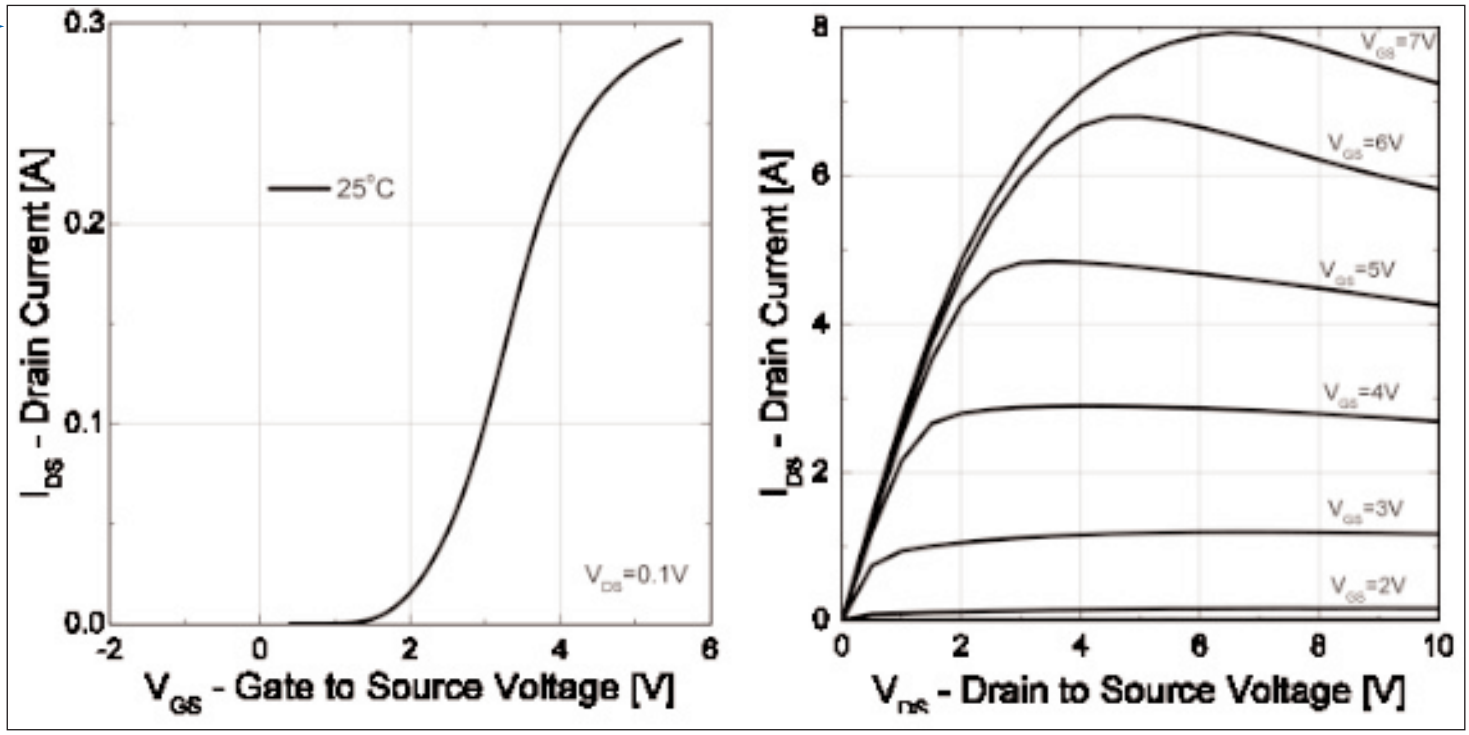
Normalized spec table of imec's 650V GaN-on-Si e-mode device technology.

age and lower on-resistance than silicon, making it a suitable material for advanced power electronic components. Imec says that its GaN-on-Si device technology is gold (Au)-free and compatible with the wafer handling and contamination requirements for processing in a silicon fabrication plant.

A key component of the GaN device structure is the buffer layer, which is required to accommodate the large difference in lattice parameters and thermal expansion coefficient between the AlGaN/GaN materials system and the silicon substrate. Imec has developed a patent pending buffer design that allows growth of buffers qualified for 650V on large-diameter 200mm wafers. This, in combination with the choice of the silicon substrate thickness and doping, increased the GaN substrate yield on 200mm to competitive levels, enabling low-cost production of GaN power devices, says Imec.

In addition, the cleaning and dielectric deposition conditions have been optimized, and the field plate design (a common technique for achieving performance improvement) has been studied extensively. As a result, the devices exhibit dynamic R_{on} dispersion below 20% up to 650V over the full temperature range of 25–150°C. This means that there is almost no change in the transistor on-state after switching from the off-state (a challenge typical for GaN technology).

"Having pioneered the development of GaN-on-Si power device technology on large-diameter substrates (200mm/8-inch), Imec now offers companies access to its normally-off/e-mode GaN power device technology through prototyping, low-volume manufacturing as



Typical output characteristic and transfer characteristic of 36mm-gate-width 650V GaN-on-Si e-mode device technology.

well as via a full technology transfer," says Stefaan Decoutere, Imec's program director for GaN technology. "Next to enhancement-mode power device switches, Imec also provides lateral Schottky diodes for power switching applications," he adds. "Based on Imec's proprietary device architecture, the diode combines low turn-on voltage with low leakage current, up to 650V — a combination that is very challenging to achieve." ■

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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

10 July 2017
Imec Technology Forum (ITF2017 USA) – Semiconductor & System Scaling Beyond Tomorrow
San Francisco Marriott Marquis hotel, San Francisco, CA, USA
www2.imec.be/be_en/events.html

10–12 July 2017
IEEE Photonics Society's 2017 Summer Topicals Meeting Series
San Juan, Puerto Rico
E-mail: i.donnelly@ieee.org
www.sum-ieee.org

10–12 July 2017
Intersolar North America
San Francisco, CA, USA
E-mail: info@intersolar.de
www.intersolar.us

11–13 July, 2017
SEMICON West 2017
Moscone Center, San Francisco, CA, USA
E-mail: semiconwest@xpressreg.net
www.semiconwest.org

12–13 July 2017
UK Semiconductors 2017 (UKS'17)
Sheffield Hallam University - City Campus, Sheffield, UK
E-mail: edmund.clarke@sheffield.ac.uk
http://uksemiconductors.com

13 July 2017
TMD-UK 2017 International Conference
Sheffield Hallam University - City Campus, Sheffield, UK
E-mail: edmund.clarke@sheffield.ac.uk
http://uksemiconductors.com/?page_id=1181

15–18 July 2017
ALD 2017: 17th International Conference on Atomic Layer Deposition, featuring the 4th International Atomic Layer Etching Workshop (ALE2017)
Sheraton Denver, CO, USA
E-mail: della@avs.org
www.ald-avs.org

16–19 July 2017
1st International Semiconductor Conference for Global Challenges (ISCGC-2017)
International Conference Center of Nanjing University (XianLin Campus), Nanjing, China
E-mail: ISCGC2017@nju.edu.cn
http://iscgc2017.csp.escience.cn

31 July – 4 August 2017
Conference on Lasers and Electro-Optics – Pacific Rim (CLEO – Pacific Rim 2017)
Opto-Electronics and Communications Conference (OECC)
Photonics Global Conference (PGC)
Sands Expo and Convention Centre, Singapore
E-mail: admin@photonics2017.org
http://photonics2017.org/orgcleo.php

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6–10 August 2017
SPIE Optics + Photonics 2017
San Diego Convention Center, CA, USA
E-mail: customerservice@spie.org
http://spie.org/optics-photonics1

23–25 August 2017
IEEE 14th International Conference on Group IV Photonics (GFP 2017)
Berlin, Germany
E-mail: m.figueroa@ieee.org
www.gfp-ieee.org

13–15 September 2017
SEMICON Taiwan 2017
Taipei Nangang Exhibition Center, Taipei, Taiwan
E-mail: semicontaiwan@semi.org
www.semicontaiwan.org

17–21 September 2017
ECOC 2017: 43rd European Conference on Optical Communication
Svenska Mässan (The Swedish Exhibition & Congress Centre), Gothenburg, Sweden
E-mail: ecoc2017@meetx.se
http://ecoc2017.org

17–22 September 2017
ICSCRM 2017: International Conference on Silicon Carbide and Related Materials
Wardman Park Marriott, Washington DC, USA
E-mail: info@mrs.org
www.mrs.org/icscrm-2017

1–5 October 2017
2017 IEEE Photonics Conference (IPC), 30th Annual Conference of the IEEE Photonics Society
Orlando, FL, USA
E-mail: i.donnelly@ieee.org
www.ipc-ieee.org

22–25 October 2017
IEEE Compound Semiconductor Integrated Circuit Symposium (CSICS 2017)
Miami, FL USA
E-mail: l.lelong@ieee.org
https://csics.org

24–26 October 2017
BIT's 7th Annual World Congress of Nano Science & Technology (Nano S & T-2017)
Hilton Fukuoka Sea Hawk Hotel, Japan
E-mail: linhui@bitlifesciences.com
www.bitcongress.com/Nano2017

26–28 October 2017
International Conference on Advanced Materials and Nanotechnology
Osaka, Japan
http://advancedmaterials.conferenceseries.com/events-list/photonics-and-semiconductor-nanophysics

30 October – 1 November 2017
5th IEEE Workshop on Wide Bandgap Power Devices and Applications (WiPDA 2017)
Hyatt Regency Tamaya Resort, Albuquerque, NM, USA
E-mail: rjkapla@sandia.gov
www.wipda.org

14–17 November 2017
SEMICON Europa 2017
Messe München, Germany
E-mail: SEMICONEuropa@semi.org
www.semiconeuropa.org

4–6 December 2017
63rd IEEE International Electron Devices Meeting (IEDM 2017)
San Francisco, CA USA
E-mail: info@ieee-iedm.org
www.ieee-iedm.org

6–9 December 2017
48th IEEE Semiconductor Interface Specialists Conference (SISC 2017)
San Francisco, CA USA
www.ieeesisc.org

13–15 December 2017
SEMICON Japan 2017
Tokyo Big Sight, Tokyo, Japan
E-mail: jcustomer@semi.org
www.semiconjapan.org

27 January – 1 February 2018
SPIE Photonics West 2018
Moscone Center San Francisco, California, USA
E-mail: customerservice@spie.org
http://spie.org/SPIE-PHOTONICS-WEST-conference

4–8 February 2018
IEEE International Solid-State Circuits Conference (ISSCC 2018)
San Francisco, CA, USA
www.isscc.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

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