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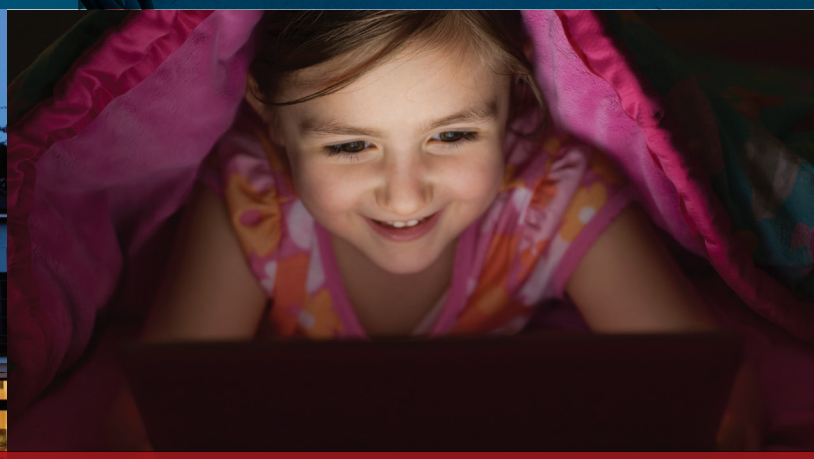
Vertical GaN devices for power electronics

News from Mobile World Congress

Analog Devices buys OneTree • Leonardo DRS acquiring Daylight
SWDM MSA formed • Kaiam buys Compound Photonics' fab

Lower Cost LEDs



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Veeco's New TurboDisc EPIK700 GaN MOCVD System

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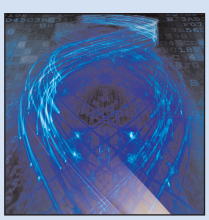
p42 EVG receives 2017 Austrian Innovation Award for its SmartNIL nanoimprint lithography technology.

p44 Monocrystal has demonstrated what is said to be the first 350kg Kyropoulos sapphire crystal, here next to the firm's 300kg and 140kg crystals.

p46 Taiwan's Everlight has opened its US$300m Miaoli Tongluo New Factory, for automotive LED products.



Cover: Specialty foundry TowerJazz has announced availability of H5, a 300GHz SiGe process optimized for 400Gbps optical communications, quadrupling the capacity of the fastest links deployed today at 100Gbps. **p18**

editorial

GaN driven by next-gen technologies

In the December 2016/January 2017 issue we reported how China's Fujian Grand Chip had abandoned its takeover of German deposition equipment maker Aixtron after the Committee on Foreign Investment in the United States (CFIUS) recommended an executive order blocking acquisition of its US subsidiary. However, after suffering from overcapacity in the LED industry in recent years, on page 40 of this issue we report how Aixtron's fourth-quarter 2016 saw a net profit of €6.4m, compared with a net loss of –€3.8m in Q3, contributing to full-year net loss being cut from –€29.2m in 2015 to –€24m in 2016. Following a strong second-half, full-year revenue of €196.5m was near the top of the €170–200m range forecasted at the start of 2016 and almost matched 2015's €197.8m. Equipment revenue in particular actually rose by 3%, driven by growth for optoelectronics applications. Meanwhile, order intake rose by a more-than-expected 35%. Since the blocked takeover, Aixtron is pursuing options to reduce required upfront expenses for developing future technologies, including partnerships or joint ventures (targeting a sustainable return to profit for full-year 2018).

Growth is also being driven by power electronics and RF applications. This is exemplified by a repeat order for 4" MOCVD systems from Japan's Sumitomo Electric Device Innovations Inc (SEDI) to boost its production of gallium nitride on silicon carbide (GaN-on-SiC) devices for RF applications (including for the upcoming 5G wireless mobile network) — see page 42.

Gearing up for 5G is illustrated by Qorvo launching what it says is the first 5G-capable RF front end (see page 10). This follows the US firm recently becoming the first RF supplier to join the China Mobile 5G Innovation Center (an alliance created to develop 5G solutions for the world's largest wireless communications market). Meanwhile, South Korea's Samsung Electronics has announced commercial readiness of its 5G RFIC, and expects the first RFIC-equipped solutions to be announced early in 2018 (page 19).

Such applications are driving what ABI Research forecasts to be growth in GaN RF to almost 25% of the total market for high-power semiconductors for mobile wireless infrastructure in 2017. Revenue growth will be driven by the Asia-Pacific region (and China in particular), fueled over the next five years by LTE and the initial building-out for 5G — see page 6.

In the cable television (CATV) and fiber-to-the-home (FTTH) sectors, California-based firm OneTree Microdevices Inc — which develops GaAs- and GaN-based amplifiers — has been acquired by Massachusetts-based Analog Devices Inc (ADI). The deal "aligns with ADI's strategic focus on GaN technology and extends ADI's broad portfolio of high-performance, RF and microwave signal chain solutions for infrastructure, defense and instrumentation markets," says the firm (see page 18).

Outside of wireless applications, Transphorm (which has just opened its Silicon Valley Center of Excellence for customer support) says that its second-generation JEDEC-qualified high-voltage GaN technology has become the first GaN solution to earn automotive qualification (page 29). In addition, eGaN FET device maker EPC has released a 100V high-current pulsed laser diode driver development board, targeting LiDAR system (for detecting objects in autonomous vehicle applications) — see page 30.

Further ahead, much research is being done on vertically structured devices, on free-standing or bulk GaN substrates, to fully optimize the advantages of using such a wide-bandgap semiconductor for power electronics applications, as detailed in our feature article on pages 88–94.

Mark Telford, Editor

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

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news

RF compound semiconductor revenue to grow to $11bn by 2021

Growth to come from strong adoption of InP, GaN and SiGe as dominant GaAs levels off

While RF compound semiconductor revenue will grow to slightly more than $11bn in 2021, gallium arsenide (GaAs) devices will not be the driver for this revenue growth, according to the Strategy Analytics Advanced Semiconductor Applications (ASA) service report 'RF Compound Semiconductor Forecast and Outlook: 2016–2021'.

Wireless applications have been the primary driver for GaAs device revenue growth, but this segment of the RF market will stagnate, forecasts market research firm Strategy Analytics. Instead, revenue growth will come from strong adoption of indium phosphide (InP), gallium nitride (GaN) and silicon germanium (SiGe).

"GaAs will remain the dominant RF technology, but device revenue will flatten in this application," says Eric Higham, service director, Advanced Semiconductor Applications service. "A slowdown in the wireless segment will open the door for the other RF compound semiconductor device technologies and additional market segments to really propel revenue growth," Higham forecasts.

The aerospace and defense market will be one of the bright spots for GaAs device revenue. The increasing usage of GaAs and GaN devices in this segment will result in strong growth for RF compound semiconductor revenue

"The aerospace and defense market will be one of the bright spots for GaAs device revenue," notes Asif Anwar, service director, Advanced Defense Systems service. "The increasing usage of GaAs and GaN devices in this segment will result in strong growth for RF compound semiconductor revenue," he concludes.

www.strategyanalytics.com

GaN RF power devices to represent nearly 25% of high-power semiconductors for mobile wireless infrastructure in 2017

Asia-Pacific region, including China, to drive future revenue growth

Despite a lackluster year in 2016, gallium nitride (GaN) RF power semiconductor devices have gained meaningful market share over the last two years, and will represent nearly 25% of all high-power semiconductors for mobile wireless infrastructure in 2017, forecasts ABI Research in its 'RF Power Semiconductor Devices for Mobile Wireless Infrastructure report'. Future revenue growth will be driven by the Asia-Pacific region, including China.

"The increasing and critical need for wireless data remains an important market driver," says research director Lance Wilson. "LTE and the initial building blocks of 5G will fuel the market's growth for the next five years," he adds.

RF power amplifiers (RFPA) are integral parts of all base-stations for cellular and mobile wireless infrastructure. They represent one of the most expensive component sub-assemblies in modern wireless infrastructure equipment, and both their performance and cost are important drivers in base-station design. The RF power semiconductors used in these power amplifiers must keep pace with the economic and technical realities facing designers and users of these RF power amplifiers, says ABI Research.

LTE and the initial building blocks of 5G will fuel the market's growth for the next five years

"Efficiency, physical size, linearity, and reliability are among the principal concerns," concludes Wilson. "As price pressures become fiercer, new and innovative techniques and materials must be used to reduce the cost of this important component part while still maintaining performance."

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Qorvo launches first 5G RF front end, developed in collaboration with global chipset provider

Qorvo Inc of Greensboro, NC, USA has launched what it claims is the first 5G-capable RF front end (RFFE) for smartphones, laptops, tablets and other wireless mobile devices. The firm says that the highly integrated QM19000 RFFE — which has been developed in collaboration with a leading global chipset provider — delivers high linearity, ultra-low latency and high throughput to meet or exceed the developing requirements of upcoming 5G applications.

Qorvo is helping to define 5G standards as a delegate to 3GPP and through close collaboration with wireless infrastructure manufacturers, network operators, chipset providers and smartphone makers. The firm has helped to conduct dozens of 5G field trials, and reckons that it is positioned to accelerate the transition to 5G with a broad portfolio of RF products spanning frequencies from 600MHz to 80GHz.

Strategy Analytics forecasts that 5G networks will be operational by 2020 and that by 2022 about 25% of new subscriptions in North America will feature 5G.

"Qorvo is leveraging our industry-leading product and technology portfolio for ultra-high, high, mid, and low cellular frequency bands," says Eric Creviston, president of Qorvo's Mobile Products group. "We are building more functionality into our RF solutions by combining our BAW, TC-SAW and SAW filters, our high-throw-count switches and our multi-mode, multi-band power amplifiers," he adds. "We are enthusiastic about the broadening set of opportunities for Qorvo in ultra-high-speed 4G LTE, LTE-A and 5G connectivity."

www.qorvo.com/innovation/5g
www.strategyanalytics.com/strategy-analytics/blogs/automotive/

Qorvo joins China Mobile 5G Innovation Center

Qorvo says that it is the first RF supplier to join the China Mobile 5G Innovation Center — an alliance created to develop 5G solutions for China (the world's largest wireless communications market). The center is driving the development of 5G end-to-end capabilities with partners for applications including self-driving cars, industrial connectivity and virtual reality.

According to Strategy Analytics, the number of 5G connections will reach 690 million by 2025, with more than 300 million 5G handsets (including a substantial number in China).

Qorvo says that its membership of the China Mobile 5G Innovation Center complements its broad range of 5G initiatives. The firm is helping to define 5G standards as a delegate to 3GPP (the 3rd Generation Partnership Program) and has supported more than twenty 5G field trials with global wireless infrastructure companies. The 5G standard is expected to utilize spectrum ranging from 600MHz to at least 80GHz. Qorvo reckons that its expertise in advanced module packaging and steerable antenna arrays will be essential in developing RF solutions for 5G.

"This is a unique opportunity to engage with the world's largest mobile operator and its ecosystem partners," comments Eric Creviston, president of Qorvo's Mobile Products Group. "By participating in development at the Center's Open Labs and in field trials, our goal is to accelerate the creation and delivery of market-leading 5G solutions."

Qorvo says that its RF solutions simplify design, reduce product footprint, conserve power, improve system performance and accelerate the adoption of carrier aggregation. The firm combines systems-level expertise, broad manufacturing scale, and what is claimed to be the industry's most comprehensive product and technology portfolio to help manufacturers accelerate the delivery of next-generation LTE, LTE-A and IoT (Internet of Things) products.

www.qorvo.com/mobile

Qorvo unveils RF solutions at Mobile World Congress

At the GSMA Mobile World Congress (MWC 2017) in Barcelona, Spain (27 February – 2 March), Qorvo showcased its expanding portfolio of radio-frequency solutions, from highly integrated power amplifiers, filters, multiplexers and switches to antenna tuners and other high-performance solutions for 4G LTE, LTE-A, pre-5G/5G and IoT applications.

Qorvo says that, as the growing demand for data and increasing carrier requirements for optimized spectral efficiency drive RF complexity, it is simplifying connectivity by solving the most critical RF challenges. During Mobile World Congress, Qorvo highlighted new RF solutions including its high-performance RF Fusion portfolio, the adaptable and scalable RF Flex portfolio, and an expanding portfolio of multiplexers and other solutions optimized to solve advanced carrier aggregation (CA) challenges.

Qorvo says that its high-performance RF solutions simplify design, reduce product footprint, conserve power, improve system performance and accelerate the adoption of carrier aggregation. The firm combines systems-level expertise, broad manufacturing scale, and a comprehensive product and technology portfolio to help manufacturers accelerate the delivery of next-generation 4G LTE, LTE-A, pre-5G/5G and IoT products. Its core RF solutions set the standard for next-generation connectivity, delivering what is claimed to be unmatched integration and performance.

www.mobileworldcongress.com
www.qorvo.com/applications/mobile-products

Qorvo delivers dual-switch-LNA modules for pre-5G massive MIMO networks, complementing GaN driver amplifier-PA modules

At the GSMA Mobile World Congress (MWC 2017) in Barcelona, Spain (27 February – 2 March), Qorvo Inc of Greensboro, NC, USA (which provides core technologies and RF solutions for mobile, infrastructure and defense applications) launched two highly integrated dual-channel switch-LNA modules for base-station implementations of massive multiple-input/multiple-output (MIMO). When combined with Qorvo's gallium nitride (GaN)-based integrated driver and power amplifier module, the dual-channel switch-LNA modules provide a complete, highly integrated solution for wireless infrastructure manufacturers seeking to quickly implement pre-5G massive MIMO networks, says the firm.

Mobile operators are increasing data capacity with the deployment of sub-6GHz massive MIMO networks. Market research firm Strategy Analytics predicts that 5G networks using massive MIMO will be operational by 2020 and that there will be about 700 million 5G connections by 2025. Massive MIMO allows base stations to transmit multiple streams of data, while beam-forming will bring higher gain and power, allowing for greater data capacity.

"Qorvo is uniquely positioned to deliver complete system solutions that leverage our broad portfolio of highly differentiated products and internally developed technologies," claims James Klein, president of Infrastructure and Defense (IDP) at Qorvo. "We are expanding our portfolio of receive and transmit front-end modules for additional frequency bands targeted at pre-5G and 5G wireless infrastructure, in anticipation of more spectrum being made available below 6GHz."

The QPB9318 and QPB9319 are highly integrated dual-channel switch-LNA modules that support frequency bands below 5GHz.

Operating at 2.3–2.7GHz, the QPB9318 is claimed to be the first integrated dual-channel receive solution for TDD bands 38, 40 & 41. It features a low 1.3dB noise figure for improved link budgets, a small 5mm x 5mm surface-mount form factor for reduced board space, and has 10W average power handling for improved Rx robustness.

Operating at 1.8–4.2GHz, the QPB9319 covers all major TDD bands up to 4.2 GHz, targeting massive MIMO base-station architectures. A high-power switch with LNA bypass function is integrated in a dual-channel configuration, while a silicon-on-insulator (SOI)-based switch eliminates the need for a costly pin-diode driver circuit and high-voltage supply. An internally matched bias allows for ease of use.

To provide a complete massive MIMO RF solution, the modules pair with Qorvo's GaN-based QPA2705, an integrated 5W GaN driver and GaN Doherty power amplifier with 36dB gain and power-added efficiency (PAE) of 43% in a compact 6mm x 10mm surface-mount package. At the IEEE International Microwave Symposium (IMS 2016), Qorvo demonstrated what were claimed to be industry-leading ultra-wideband linearization results with the QPA2705.

With Qorvo's complete solution, operators can implement highly efficient, small-form-factor massive MIMO transceivers for next-generation base stations. The QPB9318 and QPA2705 are shipping in production volumes to large base-station OEMs, and samples of the QPB9319 will be available in the June quarter (with further 4.5–5.0GHz pin-compatible solutions in development).

www.qorvo.com

Qorvo launches multiplexers supporting carrier aggregation for 4G LTE smartphones

Qorvo Inc of Greensboro, NC, USA has launched multiplexers that support challenging carrier aggregation (CA) requirements in 4G LTE smartphones. Based on the firm's BAW 5 bulk acoustic wave filter technology, the new multiplexers deliver what is claimed to be superior performance for Band 1/3 and Band 25/66 CA deployments.

"Device manufacturers seeking to launch smartphones with advanced CA band combinations face a growing list of challenges," notes Eric Creviston, president of Qorvo's Mobile Products group. "Qorvo's newest multiplexers, using our superior BAW 5 process and advanced packaging technologies, make it easier to meet these CA requirements and quickly launch next-generation handsets," he adds.

Qorvo's newest multiplexers, using our superior BAW 5 process and advanced packaging technologies, make it easier to meet these CA requirements

The new BAW 5-based multiplexers deliver low insertion loss, with what is said to be superior in-band isolation and cross-isolation, to enable aggregation of closely spaced LTE bands. The new multiplexers are:

- The QM25002, which includes all transmit and receive filters required for downlink and uplink CA on Bands 1 and 3 (the most widely used band combination in China).
- The QM25008, which includes all transmit and receive filters required for downlink and uplink CA on Bands 25 and 66 (for North America). It also supports aggregation of Bands 2 and 66, enabling deployments on all major regional carrier networks.

www.qorvo.com/applications/mobile-products/advanced-filter-solutions

Qorvo powering smartphones with full suite of RF Fusion front-ends

Qorvo says that multiple leading and emerging smartphone makers have selected complete reference platforms of its RF Fusion split-band solutions to support the launch of performance-tier smartphones.

RF Fusion RF front-end (RFFE) solutions integrate Qorvo's premium filters, high-throw-count switches and multi-mode, multi-band power amplifiers to deliver full coverage of high, mid and low cellular frequency bands.

"Manufacturers of performance-tier smartphones are increasingly adopting the full suite of Qorvo's high-, mid- and low-band RF Fusion solutions to solve RF complexity, meet carrier certification requirements, achieve launch schedules, and better manage inventories across geographies," says Eric Creviston, president of Qorvo's Mobile Products group.

High-band RF Fusion solutions support the emerging Power Class 2/high-performance user equipment (HPUE) LTE requirement. Additionally, RF Fusion solutions comprise what is claimed to be the only complete reference platform to support all leading envelope-tracking-capable cellular chipsets.

www.qorvo.com/applications/mobile-products/rf-fusion
www.mobileworldcongress.com

Qorvo's new mobile Wi-Fi front-ends designed into upcoming flagship smartphones

Qorvo Inc of Greensboro, NC, USA says that multiple leading smartphone makers have selected its newest RF Fusion mobile Wi-Fi integrated front-end modules (iFEMs) to support upcoming flagship smartphone launches, reflecting broad and growing adoption of its new iFEM architecture. "We anticipate continued content growth," says Eric Creviston, president of Qorvo's Mobile Products group.

"Qorvo's newest iFEM solutions leverage our proprietary BAW 5 technology and combine our premium filters, power amplifiers (PAs), switches and low-noise amplifiers (LNAs) to simplify smartphone design, improve performance, reduce product footprint and accelerate product time-to-market," notes Creviston.

In addition to the smartphone design wins, Qorvo is also collaborating with a leading 4G LTE chipset provider to develop iFEMs for their most advanced cellular reference designs.

Qorvo's expanding mobile Wi-Fi portfolio comprises:

- the QM48858 iFEM, which integrates the 5GHz PA, 2.4GHz BAW 5 Wi-Fi coexistence filter, LNA, switch, diplexer, and coupler, in a compact 3mm x 3mm package;
- the QM48859 iFEM, which expands on the capabilities of the QM48858 with advanced integration for antenna sharing designs; and
- the QM48861 iFEM, which expands on the capabilities of the QM48859 by adding the 2.4GHz PA.

www.qorvo.com/applications/mobile-products

Qorvo expands RF Flex portfolio to Gen-5, to accelerate mid-tier smartphone deployment

Qorvo Inc of Greensboro, NC, USA has expanded its RF Flex RF front-end (RFFE) product range. The new Gen-5 portfolio combines high performance with design flexibility, allowing manufacturers to rapidly develop and launch mid-tier smartphones that meet the challenging requirements of carrier aggregation (CA), says the firm, noting that mid-tier smartphones represent the largest and fastest-growing segment of the smartphone market.

"Leading smartphone manufacturers helped drive the rapid adoption of our highly adaptable and scalable RF Flex modules in 2016," says Eric Creviston, president of Qorvo's Mobile Products group. "Our newest RF Flex RFFEs, the Gen-5 portfolio, build on this success and support both uplink and downlink CA to dramatically reduce handset design cycles and accelerate the introduction of mid-tier smartphones," he adds.

Smartphone makers can customize the RF Flex Gen-5 portfolio by adding Qorvo's premium filters for regional coverage. RF Flex Gen-5 supports all major 4G basebands.

RF Flex Gen-5 delivers power output and linearity as well as ultra-low insertion loss across low, medium and high bands. This maximizes performance headroom, helping smartphone makers meet the challenging requirements for intra-band uplink CA as well as three-carrier inter-band downlink CA, says Qorvo.

Our newest RF Flex RFFEs support both uplink and downlink CA to dramatically reduce handset design cycles and accelerate the introduction of mid-tier smartphones

The QM56022 features low-, medium- and high-band power amplifiers (PAs) and band-select switches in the most popular footprint for mid-tier smartphones. It delivers linearity, output power and current consumption that meets strict operator requirements for uplink intra-band CA. It also supports the newly emerging standard for Power Class 2/ high-performance user equipment (HPUE) on Band 41.

The QM57508 features an antenna coupler and 2G PA module optimized to overcome the increasing post-PA losses in today's most complex antenna configurations. It includes a low-loss, high-throw-count switch supporting CA, and supports three-antenna architectures, offering what is claimed to be excellent isolation and rejection with four high-band, five mid-band and seven low-band TRx ports.

www.qorvo.com/design-hub/videos/rf-flex-mobile-solutions-from-qorvo

Qorvo RF Fusion front ends chosen for new gigabit phone

Qorvo Inc of Greensboro, NC, USA says that four of its highly integrated RF front end (RFFE) solutions have been selected to support a recently launched gigabit phone. The firm reckons that the gigabit phone represents a step forward in performance, with download speeds of 1Gbps and potential for new mobile experiences like 360° panoramic VR, 4K video and instant cloud storage on the move.

"Qorvo is very pleased to have helped reach this milestone achievement in ultra-high-speed 4G LTE connectivity," says Eric Creviston, president of the firm's Mobile Products group. "Our newest-generation RF Fusion solutions combine all major RF functionality to deliver superior performance across the low, mid, high and ultra-high cellular frequency bands. Additionally, our newest RF Fusion Mobile Wi-Fi iFEMs [integrated front-end modules] deliver higher performance than discrete components while simplifying design and miniaturizing product footprint."

The four Qorvo Mobile solutions supporting the first gigabit LTE smartphone are as follows:

- The ultra-high-band QM52042, a 3.5GHz power amplifier (PA) with full support for TD-LTE bands 42 and 43.
- The high-band QM75001, which combines multi-mode multi-band PAs, FDD- and TD-LTE-capable transmit/receive switches, Qorvo LowDrift filters for bands 38, 40 and 41-wide, and full support for intra-band uplink carrier aggregation, inter-band downlink carrier aggregation, advanced power tracking and envelope tracking.
- The mid-band QM78013, which combines multi-mode, multi-band PAs, mode switching, a LowDrift band 25 duplexer, a LowDrift-based multiplexer capable of multi-downlink carrier aggregation for bands 1 and 3 in addition to band 4, along with an antenna switch and coupler. The PA chains in the QM78013 support intra-band uplink carrier aggregation in FDD and TD-LTE bands as well as inter-band downlink carrier aggregation, while operating in advanced power tracking and envelope tracking modes.
- The QM48858 Mobile Wi-Fi iFEM combines a 5GHz PA, low-noise amplifier (LNA), switch, diplexer and coupler with Qorvo's premium 2.4GHz BAW 5 (bulk acoustic wave) Wi-Fi coexistence filter.

Qorvo showcased its portfolio of RF front ends at Mobile World Congress (MWC 2017) in Barcelona, Spain (27 February – 2 March).

www.mobileworldcongress.com

Skyworks launches amplifier family for small-cell market

Skyworks Solutions Inc of Woburn, MA, USA (which makes analog and mixed-signal semiconductors) has launched a suite of solutions targeting emerging small-cell applications. The new family of power-efficient amplifiers meet stringent data rate and power consumption requirements for indoor and outdoor network systems. The devices support the world's most popular frequency bands and can be incorporated in FDD and TDD 4G LTE, 4.5G and 5G systems, as well as the recently launched Citizen's Broadband Radio Service (CBRS).

Currently in production, the SKY6629x family of high-efficiency, 4W power amplifiers for enterprise small-cell applications comprises: SKY66299 (1900–2000MHz), SKY66297 (2490–2690MHz), SKY66296 (700–800MHz), SKY66295 (800–900MHz), SKY66294 (2000–2300MHz), SKY66293 (3400–3800MHz), SKY66292 (2300–2400MHz), and SKY66291 (1805–1880MHz).

SpiderCloud Wireless, a provider of small-cell systems whose customers include Verizon, Vodafone and other global operators, has deployed the amplifiers for its Enterprise RAN system. "By utilizing Skyworks' highly efficient solutions, SpiderCloud has further enhanced its market-proven LTE small-cell network platforms, giving mobile operators the ability to deliver unprecedented cellular coverage, capacity and smart applications to enterprises and other customers," comments Amit Jain, SpiderCloud's VP of product management & marketing.

"With the addition of these small-cell solutions, Skyworks continues to expand its world class portfolio across another key segment of the wireless ecosystem," says David Stasey, Skyworks' VP & general manager of diversified analog solutions. "At a higher level, wireless infrastructure customers are increasingly requiring network-scalable, power-efficient and high-performance RF solutions to meet carrier bandwidth demands," he adds. "We are well positioned to meet these challenging product requirements in support of global roadmaps, particularly with 5G on the horizon."

Customers are increasingly requiring network-scalable, power-efficient and high-performance RF solutions

According to a recent MarketandMarkets research report, increasing demand for higher bandwidth spectrum, rising mobile data traffic on present networks, and telecom-based technological growth are all boosting the demand for small-cell networks. The increasing usage of smartphones and data services by consumers has resulted in huge data traffic over the current networks, leading to network congestion and dropped calls. Small cells can offload data from licensed spectrum/unlicensed spectrum by using the combination of technologies such as 2G, 3G, and LTE along with carrier-grade Wi-Fi. As a result, MarketsandMarkets expects the global small-cell networks market to rise at a compound annual growth rate (CAGR) of 30% from $1.1bn in 2015 to $3.9bn in 2020.

www.skyworksinc.com/Category/850/Small_Cells

Skyworks unveils SkyOne Ultra 3.0 front-end module

At the Mobile World Congress (MWC 2017) in Barcelona, Spain (27 February – 2 March), Skyworks introduced SkyOne Ultra 3.0, a highly integrated front-end solution for premium mobile device and smartphone manufacturers worldwide utilizing the firm's SkyBlue technology.

SkyOne Ultra 3.0 is a fully optimized front-end system that incorporates all of the high-performance RF and analog functionality including power amplification, duplex filtering and antenna switching into a single device. The module integrates low-noise receive amplifiers, allowing much better sensitivity levels than previously possible, it is claimed. SkyOne Ultra 3.0 supports all major carrier aggregation (CA) combinations, meets class 2 high-power user equipment (HPUE) requirements and addresses 2.5G/3G/4G handsets for more than 23 bands of LTE.

"By leveraging our broad systems expertise and in-house filter capabilities, Skyworks continues to push the integration envelope, bringing best-in-class, high-performance solutions to customers worldwide," says Joel King, Skyworks' VP & general manager of Advanced Mobile Solutions. "Through systems like SkyOne Ultra 3.0, we turn complexity into a simple and turnkey solution, unburdening our customers from demanding RF challenges and ensuring a seamless connectivity experience while reducing their time to market," he adds.

The SkyOne Ultra 3.0 range consists of the following:

- SKY78130 — front-end module for WCDMA/LTE (low bands);
- SKY78131 — front-end module for WCDMA/LTE (mid bands);
- SKY78132 — front-end module for WCDMA/LTE (high bands);
- SKY77365 — power amplifier for quad-band GSM/GPRS/EDGE; and
- SKY87021 — power management IC with SkyBlue enabling technology.

SkyOne Ultra 3.0 is being released for volume production in second-half 2017.

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

Skyworks devices used in Sierra Wireless' modules for Internet of Things applications

Skyworks Solutions Inc of Woburn, MA, USA (which makes analog and mixed-signal semiconductors) says that a broad suite of its 3G/4G connectivity solutions are being used by Sierra Wireless of Richmond, British Columbia, Canada — which provides mobile computing and machine-to-machine (M2M) communications products for cellular networks — to power their AirPrime HL Series wireless modules targeting M2M and device-to-cloud applications.

In total, Sierra Wireless is utilizing 17 Skyworks devices spanning high-performance multi-mode, multi-band power amplifiers (MMPAs), transmit/receive front-end modules, RF switches and DC–DC converters. With the integration of Skyworks' devices, Sierra Wireless' modules combine voice and connectivity functionality that can be deployed in any region and on any wireless mobile network.

"By partnering with market leaders like Sierra Wireless, Skyworks is diversifying into new, fast-growing markets across the Internet of Things (IoT)," says Carlos Bori, VP of sales & marketing for Skyworks. "Our unique connectivity portfolio and integration capabilities enable us to solve our customers' challenges and deliver efficient, scalable solutions," he adds.

"Sierra Wireless' HL Series modules provide unprecedented scalability between networks," claims Dan Schieler, senior VP & general manager, OEM Solutions, at Sierra Wireless. "By leveraging Skyworks' analog and RF expertise, we are able to support various data rates, enable global coverage and offer industrial-grade solutions for OEMs who are looking to standardize connectivity across multiple products and markets."

According to a GSMA Intelligence report, global cellular M2M connections are increasing at a compound annual growth rate (CAGR) of 25% from 2015 to nearly 1 billion by 2020.

www.skyworksinc.com/products_IoT_M2M.aspx

Autoroad and ST showcase 77GHz and 79GHz automotive radar based on SiGe front-end ICs

At the China (Chongqing) International Automotive Technology Expo 2017 (22–24 March), Beijing Autoroad Tech Co Ltd, which designs automotive millimeter-wave (mmW) radar systems and products for applications such as advanced driver assistance systems (ADAS) and smart driving, and STMicroelectronics of Geneva, Switzerland jointly showcased automotive radar solutions incorporating ST's silicon germanium (SiGe)-based front-end ICs.

Autonomous driving requires the broad adoption of advanced safety technologies that use a combination of cameras and lasers, ultrasonic and infrared (IR) sensors, and mmW radar. In particular, autonomous vehicles need radar solutions with high resolution — based on mmW-radar ICs that detect objects at long range in bad weather conditions with a high signal-to-noise ratio (SNR) — that complement the other sensors.

At Auto Tech 2017, Autoroad presented its modules and solutions, which embed ST's fully integrated 77GHz mmW radar products, and also introduced an evolution in radar imaging using 79GHz synthetic aperture radar (SAR).

Autoroad's 77GHz radar solution (claimed to be the first developed in China) was launched on the market in 2015. The version displayed at the Automotive expo in Chongqing, based on ST's mmW products, is its second generation. ST's latest 77GHz mmW wideband radar ICs are said to provide high integration and compact size, along with a multi-channel architecture that has high object recognition and resolution for forward-collision warning (FCW), adaptive cruise control (ACC), autonomous emergency braking (AEB), and other safety features in all weather conditions.

ST's latest 77GHz mmW wideband radar ICs are said to provide high integration and compact size, along with a multi-channel architecture that has high object recognition

Also at Auto Tech 2017, regarding 79GHz SAR imaging, Autoroad reported that it has demonstrated a new approach to object detection and recognition in all weather conditions, such as rain, snow and smog, or in extremely low light, by combining range resolution produced by broadband signals with azimuth resolution produced by using relative vehicle movement. Implemented using ST's 79GHz RF front-end ICs, the SAR technology presents 2D and 3D images at high resolution using the relative movement between the installed radar and the target. It enables detection, recognition, positioning and size estimation of vehicles, pedestrians and other targets around a car in all weather and light conditions.

www.st.com/web/en/about_st/bicmos.html
www.autoroad.cn/en
http://e.chautotechexpo.com

Peregrine acquires MIT spin-off Arctic Sand

Low-power semiconductors for DC–DC power conversion to enhance Murata's power module business

Peregrine Semiconductor Corp of San Diego, CA, USA — a fabless provider of radio-frequency integrated circuits (RFICs) based on silicon-on-insulator (SOI) — has acquired Arctic Sand Technologies of Burlington, MA, USA.

Founded to bring power conversion semiconductors to market based on technology developed at Massachusetts Institute of Technology (MIT), Arctic Sand designs and makes low-power semiconductors for use in DC–DC power conversion. The firm has product design centers in Burlington, MA and Santa Clara, CA, as well as sales/customer support offices in Silicon Valley and Taiwan.

Peregrine was bought in December 2014 by Murata Manufacturing Co Ltd, which designs and manufactures ceramic-based passive electronic components & solutions, communication modules and power supply modules. The strategic acquisition of Arctic Sand is intended to accelerate Murata's aim to revolutionize power electronics with the smallest, most efficient power solutions.

"Peregrine and Murata gain Arctic Sand's disruptive technology, strong IP portfolio and world-class team," says Jim Cable, chairman & chief technology officer of Peregrine and global R&D director at Murata Manufacturing. "We're building the power integrated circuit (IC) 'dream team'. We will now leverage Peregrine's semiconductor expertise to accelerate the adoption of Arctic Sand's technology and their ability to ship in volume," he adds. "With this acquisition, we're one step closer to dramatically smaller, lighter, faster and more efficient power solutions."

Arctic's low-power semiconductors will be added to Murata's existing product lineup in order to enhance and expand its power module business in not just the telecoms market but also the datacoms and industrial electrical markets. Further, Murata aims to accelerate Arctic Sand's existing business targeting applications in mobile computing, smartphones and LCD display panels. The start-up will continue to develop high-efficiency power conversion ICs and now gains Peregrine's SOI semiconductor expertise and Murata's inductors, capacitors and packaging.

"Bringing together Arctic Sand's low-power semiconductor technologies and Murata's technologies will allow us to lead the way in providing products that satisfy the needs of customers in growing markets where there is demand for small footprints, low profiles and power savings," says Norio Nakajima, executive VP of Murata's Communication & Sensor business unit/ Energy business unit.

Arctic Sand's technology delivers power conversion efficiency so that platforms for a variety of applications can be made thinner. In certain applications, its technology reduces the space occupied by power components by 50%, reduces the height of component by 3x, reduces losses in power management by up to one half, and increases platform run time by more than 1 hour. Combining this technology with Murata's modular technologies will make it possible to provide solutions with high integration and excellent conversion efficiency in a wide range of low-power fields, it is reckoned. Demand for these technologies is expected to grow even further as electrical and electronic components become smaller and thinner.

Peregrine originally identified Arctic Sand's technology as a key component for the development of disruptive power management solutions. Since it became a Murata company in December 2014, Peregrine has added a power electronics design team with focused efforts on fast-switching active devices and innovative circuit design. With design centers in London, UK and San Diego, CA, USA, Peregrine's power IC team will integrate and collaborate with Arctic Sand's teams in Boston and Silicon Valley.

"This highly synergistic acquisition will enable Arctic Sand's disruptive technology to gain widespread market traction," believes Arctic Sand's CEO Gary Davison. "With the added strengths of Murata and Peregrine, we can bring game-changing innovation to a power electronics market that desperately needs it."

www.arcticsand.com
www.psemi.com

Peregrine hires general manager of Intel's mobile communications business as CEO as Cable steps back to chief technology officer

Parent firm Murata forming semiconductor division

As part of changes to its executive team in order to increase its semiconductor capability, Peregrine Semiconductor Corp of San Diego, CA, USA — a fabless provider of radio-frequency integrated circuits (RFICs) based on silicon-on-insulator (SOI) — has appointed Stefan Wolff as its new chief executive officer. Existing CEO Jim Cable is stepping into the role of chairman & chief technology officer and will serve as global R&D director for parent company Murata Manufacturing Co Ltd.

In nearly 15 years of general management experience in semiconductor and communications technologies, Wolff served most recently as VP & general manager of Intel's mobile communications business in Munich, Germany. While at Intel, he led a global team in developing and producing cellular modem and mobile connectivity products, securing high-profile development contracts and scoring major wins with leading vendors. Prior to Intel, Wolff managed the smartphones and RF business unit at Infineon and led an RF development center for Siemens Mobile in the USA. He started his career in automotive electronics as RF design engineer at Bosch. Wolff also has a technical background that includes a B.S. degree in electrical engineering from the University of Applied Sciences in Berlin. Peregrine reckons that Wolff is suited to his new role as CEO, in which his education and accomplishments will enable him to guide the firm's technological growth at an executive level.

"We have known Stefan and have collaborated with him and his team for many years, and I am delighted to bring him on board to accelerate our growth and the growth of our parent company Murata," says Cable. "I am eager to get back to my technology roots and focus on shaping innovation for Murata," he adds.

New CEO Stefan Wolff, formerly VP & general manager of Intel's mobile communications business.

Outgoing CEO Jim Cable, now chairman & chief technology officer, and new chief operating officer Dylan Kelly.

"I have admired the Murata and Peregrine teams for years. There is such synergy in the two groups," comments Wolff. "Together, I see innovations not possible from any other company," he adds.

In addition, Cable has appointed Dylan Kelly as chief operating officer. Kelly has held the position of VP & general manager of Peregrine's mobile wireless solutions business unit since 2010. He joined Peregrine in 2000 and has held technical and management positions in product development, marketing, and sales. Prior to joining Peregrine, Kelly was with Motorola engaged in transceiver design. He holds a B.S. degree in electrical engineering from the University of Texas at Austin and an M.S. degree in electrical engineering from the University of California, San Diego. He is also the author of numerous technical papers and has 37 issued and pending patents.

"Dylan has been instrumental to the growth of our mobile business for many, many years," says Cable. "He is widely respected both inside and outside the company," he adds.

"We have seen tremendous growth since we were acquired by Murata so these new management additions reflect the next step in empowering our team to be even more innovative," notes Kelly.

"We see semiconductors as important part of our technology portfolio," says Norio Nakajima, executive VP, Communication & Sensor business unit/Energy business unit, Murata Manufacturing Co Ltd. "While we have always had semiconductors as part of our solutions, we will be dedicating more resources and taking those products to new levels. To formalize this effort, we will be forming a new semiconductor division," he adds.

"We are looking to the Peregrine team to help us develop leading-edge RF semiconductors and unique new products," continues Nakajima. "The team of Jim, Stefan and Dylan is ideal for achieving this vision. I have known, respected and worked with Stefan for 20 years and welcome him to the Peregrine team. Dylan has successfully grown and managed Peregrine's mobile efforts for many years, and Jim is a visionary technologist whom we need to champion additional innovations in semiconductors by Peregrine in support of the Murata vision."

www.psemi.com

Anokiwave expands to new headquarters in San Diego

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 electronically scanned array (AESA)-based terminals, has relocated its headquarters to a custom remodeled office, doubling the floorspace from its prior location to accommodate its growing team in San Diego (complementing the firm's other office and lab space in Billerica, MA).

The new open-concept floor plan features a low noise environment suitable for engineering teams with areas suitable for large groups, allowing interaction with adequate space for a planned engineering laboratory.

Opening of new San Diego HQ.

"Anokiwave's leadership in the 5G, radar and SatCom active antenna ICs for mmW markets required a larger office space to accommodate our growing product portfolio, capabilities, and staff," says founder & chief technology officer Nitin Jain.

"Highly integrated silicon IC design expertise and innovative culture is at the core of Anokiwave's mission," says CEO Bob Donahue. Product launches in the next few months will build on last year's launch of the AWMF-0108, the world's first commercial 5G 28GHz active antenna IC.

www.anokiwave.com

Analog Devices acquires OneTree Microdevices

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 acquired OneTree Microdevices Inc of Santa Rosa, CA, a privately held fabless semiconductor company for emerging broadband networks that develops components for cable television (CATV) and fiber-to-the-home (FTTH) networks.

ADI says that, with the acquisition of OneTree's gallium arsenide (GaAs) and gallium nitride (GaN) amplifier portfolio, it now supports the complete signal chain for next-generation cable access networks.

"Analog Devices, in combination with OneTree Microdevices, is uniquely positioned to solve the bandwidth and power efficiency challenges facing cable operators today in their efforts to increase broadband internet services for homes and businesses," says Greg Henderson, Analog Devices' VP of RF and Microwave business. "OneTree's expertise aligns with ADI's strategic focus on GaN technology and extends ADI's broad portfolio of high-performance, RF and microwave signal chain solutions for infrastructure, defense and instrumentation markets."

Cable operators are counting on next-generation architectures such as DOCSIS 3.1 (Data Over Cable Service Interface Specification) and Remote PHY to increase the capacity of cable networks, says ADI. "Both ADI and OneTree are directly engaged with customers, cable operators and industry standards groups to drive cable standards discussions," notes OneTree's co-founder Chris Day. "Together, we will be able to effectively assist cable operators in their quest to provide compelling cost and data rates to home and business users."

www.onetreemicro.com.
www.analog.com

Guerrilla RF completes $2.8m Series D funding round

Existing facility to be expanded to accommodate 20 staff by year-end

Guerrilla RF Inc of Greensboro, NC, USA, a provider of radio frequency (RF) and monolithic microwave integrated circuits (MMICs) for wireless applications, has closed a Series D funding round worth $2.8m (composed of a combination of equity and debt) with participation from multiple angel investors. The firm has now raised $7.8m in funding and has more than 30 products shipping in production volumes.

Guerrilla RF expects to employ 20 total associates by year-end. To accommodate this projected growth, the firm will be expanding its current facility.

"Coming out of an exciting year, we see even larger opportunities ahead of us," says CEO Ryan Pratt (who founded the firm in April 2013). "We need to expand our facilities and team to capitalize on the amount of additional business that we have in front of us," he adds.

"This Series D funding round will give us the capital to do exactly that, as well as fueling our working capital needs and new product development pipeline."

According to Research and Markets, the overall wireless network infrastructure market will rise at a compound annual growth rate (CAGR) of over 5% to more than $104bn in annual spending by the end of 2020.

http://guerrilla-rf.com

Samsung announces commercial readiness of 5G RFIC, paving the way for 5G product releases in early 2018

At a 5G mobile technologies workshop held at the Korean Institute of Communications and Information Sciences, South Korea's Samsung Electronics Co Ltd has announced commercial readiness of its 5G radio-frequency integrated circuit (RFIC) — a key component in the production and commercialization of next-generation base-station and other radio access products.

"Samsung has been hard at work for several years on the various foundation technologies that go into the 5G RFIC," says Paul Kyungwhoon Cheun, executive VP & head of Next Generation Communications Business Team at Samsung Electronics. "This will have a big role to play in the upcoming connectivity revolution."

The RFIC itself is designed to strengthen the overall performance of 5G access units (base station) and Samsung has placed a strong emphasis on designing for low cost, high efficiency and compact form factors. Each of these criteria is expected to play a critical role in delivering on the promises of 5G.

The RFIC incorporates a high-gain/high-efficiency power amplifier (announced in June 2016), so the chip can provide extended coverage in the millimeter-wave (mmWave) band, overcoming one of the primary challenges of high frequency spectrum. At the same time, Samsung's RFIC is capable of greatly improved transmission and reception performance. The RFIC's ability to reduce phase noise in its operating band enables clearer radio signals even in noisy environments where signal quality loss would otherwise disrupt high-speed communications. Completing the chip is a compact chain of 16 low-loss antennae, which further enhance overall efficiency and performance.

The RFIC incorporates a high-gain/high-efficiency PA (announced in June 2016), so the chip can provide extended coverage in the mmWave band

Samsung's existing RFIC is scheduled for use in the 28GHz mmWave spectrum band that has very quickly become a primary target for early 5G deployments in markets such as the USA, Korea and Japan. With development of the chip complete, Samsung is now accelerating its plans for 5G commercial product readiness, with the first RFIC-equipped solutions expected to be announced early in 2018.

www.samsung.com

MACOM launches SMT-packaged millimeter-wave switch for 5G wireless demonstration systems

At the Mobile World Congress (MWC 2017) in Barcelona, Spain (27 February – 2 March), MACOM Technology Solutions Holdings Inc of Lowell, MA, USA (which makes semiconductors, components and subassemblies for analog RF, microwave, millimeter-wave and photonic applications) announced the newest entry in its portfolio of components and integrated modules for 5G wireless infrastructure. Suitable for 28GHz, 37GHz and 39GHz frequency bands, the new SMT-packaged MASW-011098 millimeter-wave (mmW) switch is designed to meet the demanding bandwidth and link margin requirements of next-generation 5G demonstration systems.

Leveraging decades of expertise in active antennas and monolithic microwave integrated circuits (MMICs), MACOM says that it is utilizing its experience in beam-forming radar design and applying it to 5G applications. MACOM's product portfolio supports both sub-6GHz wireless infrastructure utilizing massive MIMO (massive in massive out) architectures, and high-frequency mmW technologies supporting a multitude of power and integration requirements. The phased-array technology is reckoned to be a valuable asset for developing antennae arrays supporting 5G beam-forming capabilities.

The MASW-011098 leverages the firm's patented aluminium gallium arsenide (AlGaAs) technology process to maintain low insertion loss and high isolation while enabling higher power-per-element ratios for 5G demonstration systems. Low insertion loss reduces the power requirement from the power amplifier (PA), alleviating thermal challenges and extending the link range while simultaneously enabling improved receiver sensitivity. The MASW-011098 also provides flexible biasing options to ensure greater overall ease of use.

"The patented switch technology within the MASW-011098 today underpins tens of thousands of transmit/receive channels in advanced 5G demonstration systems, enabling customers to speed their time to market with differentiated, cost-effective 5G system architectures that deliver breakthrough gains in wireless throughput and capacity," says Preet Virk, MACOM's senior VP & general manager, Networks.

The MASW-011098 millimeter-wave switches are available now to qualified customers.

www.macom.com/5G

TowerJazz announces 300GHz SiGe technology optimized for 400GbE

Specialty foundry TowerJazz (which has fabrication plants at Tower Semiconductor Ltd in Migdal Haemek, Israel, and at its US subsidiaries Jazz Semiconductor Inc in Newport Beach, CA and TowerJazz Texas Inc in San Antonio, TX, and at TowerJazz Japan Ltd) has announced availability of H5, a 300GHz silicon germanium (SiGe) process optimized for 400Gbps optical communications (or 400GbE) which promise to quadruple the capacity of even the fastest links deployed today at 100Gbps.

Wireline data traffic is increasing dramatically, and TowerJazz is addressing this growing market through a family of customized foundry SiGe BiCMOS technologies, including its highest-performance process to date. In the H5 process, enhancements include increased device fT and Gm as well as other proprietary features to address the 400GbE product space.

TowerJazz says that customers can quickly migrate existing products to H5, as layouts are virtually identical to prior generations of technology. H5 can help to reduce power consumption in lower-data-rate products or boost data rates to address newer standards. The firm says that it tailors its roadmaps to meet customers' next-generation needs. TowerJazz has hence worked with leaders in the market to optimize technology for the 400GbE era and already has key design wins in this space, such as Broadcom Ltd, which designs and supplies digital and analog semiconductor connectivity solutions.

"TowerJazz's SiGe technology has enabled us to successfully deliver high-performing optical ICs across multiple market segments and applications, including 400GbE data-center interconnects," says Dr Faouzi Chaahoub, senior director of Broadcom's Fiber Optic Products Division.

"We strongly value our collaboration with Broadcom in this market and continue to invest aggressively in high-speed SiGe to support all of our customers' next-generation requirements," says Dr Marco Racanelli, senior VP & general manager of TowerJazz's RF & High Performance Analog business unit.

"SiGe has become the technology of choice for front-end components in high-speed data communications."

SiGe Terabit Platform — HX, H2, H3, H4, H5

TowerJazz's SiGe Terabit Platform includes CMOS, together with low-noise, high-speed, and high-power SiGe devices and patented features that enable what is claimed to be best-in-class performance for the most demanding ICs in high-speed communication links. These components include, for example, trans-impedance amplifiers (TIAs) on the receive path and laser drivers on the transmit path.

The addition of H5 to the SiGe Terabit Platform extends a history of process technologies that include HX and H2 (which address 10Gbps to 28Gbps requirements), H3 with SiGe speeds of 280GHz (which addresses requirements up to 100Gbps), and now H4 and H5 with transistor speeds that exceed 300GHz and can reduce power consumption by nearly an order of magnitude.

www.towerjazz.com
www.tpsemico.com

TowerJazz expands support for fast-growing base of Chinese customers with SiGe BiCMOS for wireless & wireline communications

TowerJazz says that, at SEMICON China 2017 in Shanghai (14–16 March), its presentation by Dr Edward Preisler in Session 3 ('Compound Semiconductors in Communications') addressed the role of silicon germanium (SiGe) technology in providing solutions for advanced wireless and wireline communication systems such as 4G and 5G handsets, Internet of Things (IoT) devices, automotive radar systems, high-speed data networks and data-center communications.

TowerJazz will discuss the challenge of wireless front-end module integration and small package requirements solved with its 0.18µm SiGe power amplifier technology that builds all the elements of a wireless front-end module on a single chip. This technology combines a power amplifier with a low-noise-amplifier, a switch, digital circuitry and power control, all on a single die.

The presentation also included demonstrations of TowerJazz's SiGe technology for very high-data-rate wireless links at 60GHz (WiFi 802.11ad), results for 5G wireless communications, as well as circuit blocks for next-generation 100GbE and 400GbE wireline data networks.

"TowerJazz has a long history and legacy in SiGe BiCMOS technology development and a proven record of manufacturing excellence," says Lei Quin, TowerJazz China country manager. "We continue to provide great support in China as it consumes a huge percentage of the world's ICs and internal China fabs can only cover a small percentage of the country's need," he adds. "We have been consistently growing our customer base in China and are committed to meeting the rising manufacturing needs in this region."

www.towerjazz.com
www.tpsemico.com

Pasternack debuts mm-wave transmitter module covering 60GHz global unlicensed frequency spectrum

Pasternack Inc of Irvine, CA, USA (which makes both passive and active RF, microwave and millimeter-wave products) has launched the PEM010, a complete millimeter-wave transmitter module suitable for use in the development of multi-gigabit, high-speed, point-to-point wireless communication links, which provide low-cost, gigabit wireless throughput for applications involving telecom 'last kilometer' distribution, telecom cellular backhaul, millimeter-wave wireless gigabit Ethernet data communications, building-to-building high-speed networks and mesh-based LAN infrastructures.

The PEM010 is a highly integrated millimeter-wave transmitter (Tx) module that operates in the global unlicensed frequency spectrum from 57.0 to 64.8GHz. It also supports IEEE 802.11ad and 802.11aj Wi-Fi protocols for wireless, multi-gigabit, high-speed networking. The module's design incorporates a silicon germanium (SiGe) MMIC-based frequency synthesizer and power amplifier. Its small, lightweight, low-cost aluminum package is precisely machined and features a complete waveguide interface with low-loss transition between the chip and WR-15 waveguide port. A multi-pin ST4 connector is used for power, reference clock, digital control port and baseband signals.

Typical performance includes 38dB gain, +12dBm output P1dB, 34dB image rejection, up to 1.8GHz modulation bandwidth, and phase noise of –111dBc/Hz @ 10MHz offset. Either of the two reference clocks can be used for setting the 540MHz or 500MHz channel spacing. The module's I/Q analog baseband interface accepts analog baseband signals, providing flexibility in design and applications. The optional baseband input supports FSK/MSK modulation for non-coherent applications and the WR-15 waveguide port can support available gain horn antennas for extended-transmission-range applications.

The PEM010 Tx module is in-stock and ready for immediate shipment with no minimum order quantity, says Pasternack.

www.pasternack.com/pages/Featured_Products/pem010-60-ghz-wr-15-waveguide-tx-module.html

IQ mixers with 4–38GHz RF and LO frequency bands

Pasternack Inc of Irvine, CA, USA (which makes passive and active RF, microwave and millimeter-wave products) has launched six IQ mixers with RF and LO frequency bands ranging from 4GHz to 38GHz and in-phase and quadrature IF bandwidths ranging from DC to 4.5GHz. Typical applications include point-to-point and point-to-multi-point radio, VSAT, military radar, electronic warfare (EW), satellite communications, sensors, and test & measurement equipment.

The new IQ mixer modules are composed of monolithic microwave integrated circuit (MMIC)-based assemblies that use a highly reliable gallium arsenide (GaAs) metal-semiconductor field-effect transistor (MESFET) process that consists of a pair of matched double-balanced mixer cells, a 90° hybrid and a 0° splitter/combiner. This level of integration offers advantages in size and performance compared with discrete module assemblies, says Pasternack. With the addition of an external 90° IF hybrid module, the IQ mixers can be configured as an image reject mixer or single-sideband upconverter mixer. Image rejection and sideband suppression can reduce overall system cost and complexity by removing the need for preselection filtering.

Pasternack's new IQ mixers

The IQ mixers' performance as an image reject mixer (IRM) includes low conversion loss ranging from 7.5 to 10dBm, high image rejection up to 35dB typical, and LO to RF isolation up to 42dB typical. The designs offer what is claimed to be excellent linearity, with input 1dB compression as high as +20dB typical and input IP3 as high as +35dB typical. LO drive power ranges from +15 to +19dBm.

The new models are offered in hermetically sealed Kovar drop-in metal packages that are gold-over-nickel-plated and support field-replaceable SMA connectors. All units are RoHS compliant, export classified as EAR99, and guaranteed to meet MIL-STD-883 environmental test conditions for fine and gross leak and temperature cycle.

"Products like these usually command very long lead-times, but Pasternack has all six models ready and available to ship today," notes active component product manager Tim Galla. The new IQ mixers are in-stock and ready for immediate shipment with no minimum order quantity.

www.pasternack.com/pages/RF-Microwave-and-Millimeter-Wave-Products/iq-mixers.html

Littelfuse invests a further $15m in Monolith, taking a majority stake

SiC power device start-up moving closer to commercialization

Littelfuse Inc has made an incremental $15m investment in silicon carbide (SiC) diode and MOSFET power device start-up Monolith Semiconductor Inc of Round Rock, TX, USA. This follows a prior investment in December 2015.

Monolith notes that silicon carbide enables power devices to operate at higher switching frequencies and temperatures versus conventional silicon technology, allowing inverters and other energy conversion systems such as motor drives to be operate with significantly improved energy efficiency and reduced system cost.

Founded in 1927, Littelfuse provides circuit protection technologies (including fuses, semiconductors, polymers, ceramics, relays and sensors) to the electronics, automotive and industrial markets, with growing global platforms in power control and sensing. The firm has over 10,000 staff in more than 40 locations worldwide.

"We are pleased to expand our partnership with Monolith's experienced team of silicon carbide and power semiconductor experts," says Ian Highley, senior VP & general manager, semiconductor products and chief technology officer for Littelfuse. "With the increasing needs to make power electronic devices that will be stronger and more efficient, we are excited about the opportunities this game-changing technology provides," he adds.

"Littelfuse has been a great partner with us as we move closer to the commercialization of our technology," comments Monolith's CEO Sujit Banerjee PhD. "We are working closely with Littelfuse to position our combined portfolios to develop innovative solutions."

As a result of the additional investment, Littelfuse now has majority ownership of Monolith and will begin including Monolith in its operating financial results. Littelfuse previously announced that its first-quarter 2017 earnings per share guidance included $0.03 of expense to fund development activities with Monolith. The additional investment is expected to reduce earnings per share by $0.09 across the second through fourth quarters of 2017.

Under the terms of its agreement with Monolith, Littelfuse has committed to add to its investment once Monolith has achieved certain milestones.

www.monolithsemi.com

US Army awards GE Aviation $4.1m contract over 24 months to develop SiC power electronics

SiC MOSFET technology to be demonstrated in a 200kW starter generator controller

GE Aviation has been awarded a $4.1m contract from the US Army to develop and demonstrate silicon carbide (SiC)-based power electronics supporting high-voltage next-generation ground vehicle electrical power architecture.

"We continue to invest in silicon carbide and high-density packaging to help the US Army to better manage on-board power," says Vic Bonneau, president of Electrical Power Systems for GE Aviation. "This component provides the additional benefit of eliminating the need for an electronic cooling system," he adds. "Our similar silicon carbide-based programs and planned re-use have led to this new critical high-temperature application."

The $4.1m contract will result in three hardware deliverables after a 24-month development program that will demonstrate the benefits of GE's SiC MOSFET technology in a 200kW starter generator controller. The integrated starter generator controller (ISGC) will provide sensored and sensorless control for multiple generator types in a single line replaceable unit weighing less than 50 pounds.

The integrated starter generator controller will provide sensored and sensorless control for multiple generator types in a single line replaceable unit weighing less than 50 pounds

It will operate at 125ºC ambient in bi-directional operation for engine start. The ISGC will utilize 105ºC coolant and will be CANbus programmable.

The contract is GE's 5th in support of the US Army's Tank Automotive Research, Development and Engineering Center (TARDEC) next-generation vehicle electrical power architecture leap-ahead technology development. It will result in a prototype demonstration in 2018.

DCS Corp is the contracting agent for US Army TARDEC. DCS develops technology solutions and provides acquisition management expertise for US Army aviation, ground vehicle, soldier systems, and missile systems.

www.ge.com/aviation

Mitsubishi develops smallest SiC inverter for HEVs

Full-SiC power semiconductor modules yield highest power density of 86kVA/L for two-motor hybrid electric vehicles

Supported partially by Japan's New Energy and Industrial Technology Development Organization (NEDO), Mitsubishi Electric Corp has developed a working model of an ultra-compact silicon carbide (SiC) inverter for hybrid electrical vehicles (HEVs) that is believed to be the smallest SiC of its type, at just 5 liters in volume. It is also believed to offer the highest power density of 86kVA/L for two-motor HEVs, due to incorporation of full-SiC power semiconductor modules that achieve superior heat dissipation. The new inverter is said to offer improved placement, fuel and energy efficiency, and frees up vehicle interior space. Commercialization for HEVs, electrical vehicles (EVs) and other applications is expected sometime around 2021.

With fuel-efficiency regulations growing increasingly stringent, the new ultra-compact SiC inverter is expected to help to meet the increasing demand for HEVs by reducing the amount of on-board space that must be allotted to electrical apparatus, such as inverters and motors. Mitsubishi Electric says that, to develop the smallest inverter, it created a superior heat dissipation structure that ensures long-term reliability by connecting the power semiconductor modules and heat-sink with solder.

In future, Mitsubishi Electric aims to continue developing its compact SiC inverter for mass production, targeting commercialization in 2021.

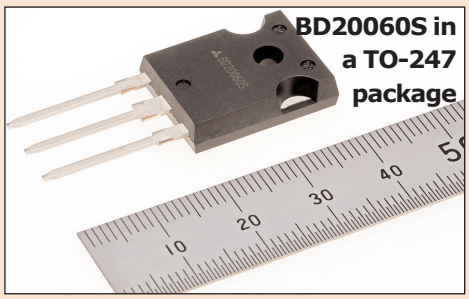
Technical details of the new inverter were presented at the National Convention of the Institute of Electrical Engineers (IEEJ) on 15–17 March.

www.MitsubishiElectric.com

Mitsubishi Electric launches SiC Schottky barrier diode incorporating junction-barrier Schottky

Tokyo-based Mitsubishi Electric Corp has launched a silicon carbide Schottky barrier diode (SiC-SBD) that incorporates a junction-barrier Schottky (JBS) structure to reduce the power loss and physical size of power supply systems for air conditioners, photovoltaic power systems etc. In line with the growing demand for energy-efficiency in such systems, consumers are increasingly choosing products that incorporate SiC-SBDs, says the firm.

The use of silicon carbide yields improved energy conversion, resulting in about 21% less power loss compared with silicon products, reckons Mitsubishi Electric. It also enables high-speed switching and downsizing of peripheral components, the firm adds.



In addition, by combining a Schottky barrier with p-n junction, the junction-barrier Schottky (JBS) structure helps to achieve improved reliability.

The BD20060T (in a 10.1mm^2 29.0mm x 4.7mm TO-220 package) is shipping from 1 March; the BD20060S (in a 15.9mm^2 41.0mm x 5.0mm TO-247 package) will ship from 1 September. With a specification of 20A/600V, surge non-repetitive forward current is 155A (8.3ms, sine wave) and diode forward voltage is 1.35V.

Development of the new products was supported partially by Japan's New Energy and Industrial Technology Development Organization (NEDO).

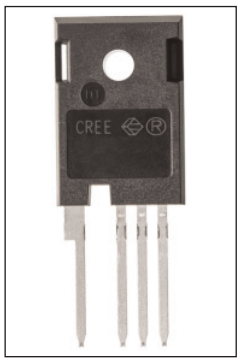
Wolfspeed expands third-gen MOSFETs to 1200V

Wolfspeed of Research Triangle Park, NC, USA — a Cree Company that makes silicon carbide (SiC) power products including MOSFETs, Schottky diodes, and modules — has expanded its C3M platform by introducing the C3M0075120K, a 1200V, 75mΩ MOSFET in its recently released low-inductance discrete packaging. The new device simplifies designs and enables an increase in frequency while maintaining efficiency, lowering system cost, reducing circuit EMI and enabling 99% efficiency levels in three-phase power factor correction circuits, reckons Wolfspeed.

These features enable designers of applications such as telecom power supplies, elevators, grid-tied storage, onboard and offboard electric vehicle (EV) charging as well as factory automation to increase switching frequency while maintaining efficiency, decreasing system size and bill of materials.

"These new package options, such as the surface-mount 7L D2PAK, allow us to explore new topologies not possible with existing products available on the market," comments Kurt Goepfrich, a hardware architect at Siemens.

The new device achieves what is claimed to be the industry's lowest figure-of-merit for any SiC MOSFET at 1200V. Launched in a 4L TO-247 package, it will be available in a 7L D2PAK in the coming weeks.



Wolfspeed's new C3M0075120K 1200V, 75mW SiC MOSFET, in a 4L TO-247 package.

"SiC MOSFETs have proven to be beneficial for many high-power applications connected to a battery simply due to the improved efficiency," says chief technology officer John Palmour. "In the case where power is bi-directional, such as grid-connected AC–DC, the potential cost savings are significantly increased due to the reduction in the size of the input filter."

The new device features Wolfspeed's third-generation C3M planar MOSFET technology, which engineers have already designed into various automotive and industrial applications. It features low on-resistance (75mΩ) combined with a low gate charge, making it suitable for three-phase, bridgeless power factor correction (PFC) topologies as well as AC–AC converters and chargers.

Wolfspeed says the new packages allow engineers to take full advantage of the high-frequency capability of its latest SiC MOSFET chips. The 4L TO247 package delivers a three-fold reduction in total switching losses compared with a conventional TO-247-3 package.

The 7L D2PAK surface-mount package, specifically designed for high-voltage MOSFETs, practically eliminates the source inductance found in other packages and has a footprint 52% smaller than D3PAKs, Wolfspeed reckons. This is made possible by the small die size and high-blocking capability of C3M planar MOS technology.

The firm notes that designers can reduce component-count by moving from silicon-based, three-level topologies to simpler two-level topologies made possible by the improved switching performance. These higher-voltage SiC MOSFETs solve many of the limitations of silicon super-junction MOSFETs that make them impractical to use in two-level topologies, adds Wolfspeed. SiC has significantly lower output capacitance nonlinearity, making it possible to reduce the dead-time and hence minimizing total harmonic distortion at higher switching frequencies.

The new C3M0075120K 1200V, 75mΩ MOSFET is available in a through-hole, 4L TO247 package and is currently available for purchase from several distributors. The surface-mount version C3M0075120J will be released in the coming weeks. Like the 4L-TO247, the surface-mount devices include a Kelvin-source pin to help minimize gate-ringing and reduce system losses.

www.wolfspeed.com/c3m0075120k

Wolfspeed launches 12.7–13.25GHz 60W three-stage GaN-on-SiC PA

Wolfspeed exhibited and contributed to the technical program at the SATELLITE 2017 event in Washington DC (6–9 March).

Wolfspeed introduced a monolithic microwave integrated circuit (MMIC) power amplifier for lower Ku-band satellite communication applications. Operating from 12.7–13.25GHz instantaneously with an output power of 60W, the CMPA1D1C060D three-stage GaN-on-SiC power amplifier provides three times higher gain than competing GaAs and GaN input-matched transistors currently on the market, it is claimed. A power efficiency increase of about 30% is also achieved by leveraging Wolfspeed's GaN MMIC technology, the firm adds.

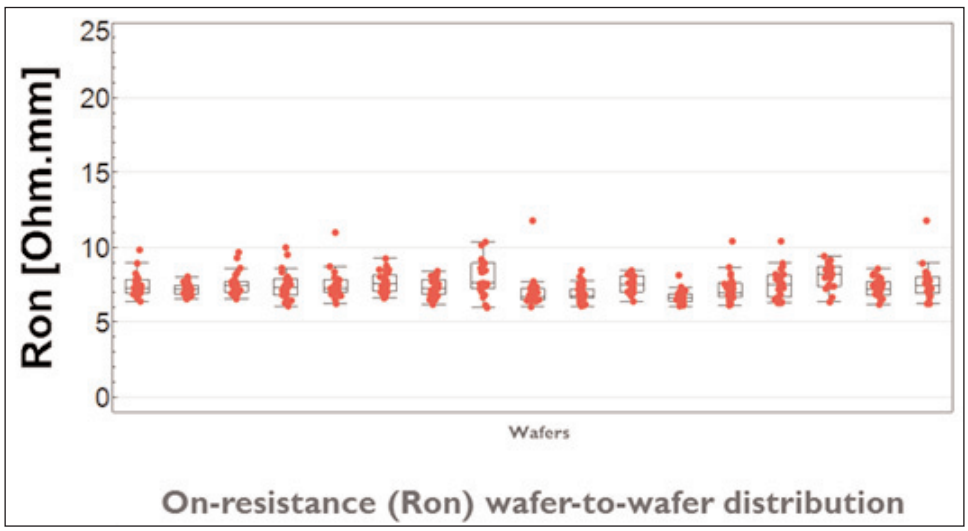
"Satellite technology is advancing rapidly, and the wide bandwidth and higher efficiency advantages of GaN will be a key part of next-generation payloads for both commercial and military applications," says RF & microwave director Jim Milligan. "With Wolfspeed's proven track record of faster cycle times, higher first-pass design successes, and greater reliability than our competitors, we're looking forward to joining the discussion on the future of satellite technology," Milligan adds.

http://2017.satshow.com
www.wolfspeed.com/RF

Imec's 200mm GaN-on-Si e-mode power devices withstand heavy ion and neutron irradiation

Radiation hardness of enhancement-mode devices confirms maturity of 200mm GaN-on-Si platform

Nanoelectronics and photovoltaics research centre imec of Leuven, Belgium says that — in tests performed in collaboration with Thales Alenia Space Belgium (the country's largest manufacturer of space electronics) — its 200mm gallium nitride-on-silicon (GaN-on-Si) enhancement-mode (E-mode) power devices with a p-GaN gate architecture have shown no degradation after heavy ion and neutron irradiation, demonstrating that its 200mm GaN-on-Si platform delivers GaN-based power devices for earth as well as for space applications.



Since GaN-on-Si transistors operate at higher voltages, frequencies and temperatures than their silicon counterparts, they are ideal candidates for power conversion devices as they show less power losses in electricity conversion. First-generation GaN-based power devices are used currently and will play a key role in the power conversion of future electronic devices such as battery chargers, smartphones, computers, servers, automotive, lighting systems and photovoltaics.

Imec has been developing the next-generation of GaN-based power devices with improved performance and reliability. It says that its latest 200mm GaN-on-Si platform (currently available for dedicated development or technology transfer to imec's current and future partners) shows good wafer-to-wafer reproducibility and low dynamic R_{dson}.

Imec's latest generation of 200mm GaN-on-Si e-mode p-GaN devices were irradiated with heavy ions (xenon) and neutrons. Pre- and post-irradiation tests revealed that there was no permanent degradation of transistor characteristics: neither shifts in threshold voltage nor gate rupture. Radiation hardness of the devices is important, as it enables applications in space, where fluxes of heavy ions and neutrons can damage electronic circuits in satellites and space stations. Wide-bandgap devices promise a significant increase in performance, but robustness to space radiation is essential. The result obtained with Imec's GaN-on-Si devices is a key step on the path to space-based power conversion applications, it is reckoned.

"It demonstrates that our 200mm GaN-on-Si platform has reached a high level of technology readiness and can be adopted by industry," believes executive VP Rudi Cartuyvels. "At imec, we use 200mm silicon substrates for GaN epitaxy and this technology can be used on 200mm CMOS-compatible infrastructure," he adds. "Thanks to innovations in transistor architecture and substrate technology, we've succeeded in making GaN devices on larger wafer diameters than used today, which brings lower-cost perspectives for the second generation of GaN-on-Si power devices. Imec is also looking beyond today's technology, exploring novel substrates, higher levels of integration and novel devices."

At imec, we use 200mm silicon substrates for GaN epitaxy and this technology can be used on 200mm CMOS-compatible infrastructure

The results were achieved in the framework of the European Space Agency (ESA) project 'ESA AO/1-7688/13/NL/RA: GaN devices for space based DC-DC power conversion applications'. "GaN is a critical technology for future space missions with a wide range of potential applications, including smaller-size, higher-efficiency DC–DC power conversion subsystems," says Andrew Barnes ESA technical officer overseeing the project.

Obtained from the first phase of an ESA GSTP project, the results show that the p-GaN devices developed by imec offer excellent radiation robustness for operation in space. In the second phase of the project it is planned to industrialize this technology in readiness for a future space qualification program".

www.esa.int
www.imec.be

Power Electronics Industry Collaborative completes technology roadmap

Workforce development programs target power electronics engineers

As part of its mission to accelerate growth of the US power electronics industry, the Power Electronics Industry Collaborative (PEIC) recently completed a comprehensive technology roadmap designed to provide a path for US manufacturers to develop a robust domestic power electronics ecosystem.

As a national, industry-focused, member-based consortium consisting of industry, academic and government stakeholders in power electronics, PEIC undertook the roadmap project to provide an in-depth analysis of the domestic supply chain to identify its strengths and weaknesses and to apply that analysis towards advancing power electronics technology development in the USA. The two-year study 'Strengthening the Domestic Power Electronics Ecosystem' was funded by a grant from the National Institute of Standards & Technology's Advanced Manufacturing Technology Consortia (NIST AMTech).

"Recent advances in power semiconductor technology, particularly in wide-bandgap materials, have opened up significant new opportunities for the US power electronics industry, along with corresponding challenges," says PEIC president Keith Evans (president & CEO of Kyma Technologies Inc). "The goal of PEIC's participation in creating the report was to identify those technology and manufacturing challenges, and to present key strategic recommendations for the US to develop effective solutions to meet the growing demands for efficient power electronics," he adds.

Roadmap presented at PEIC annual meeting

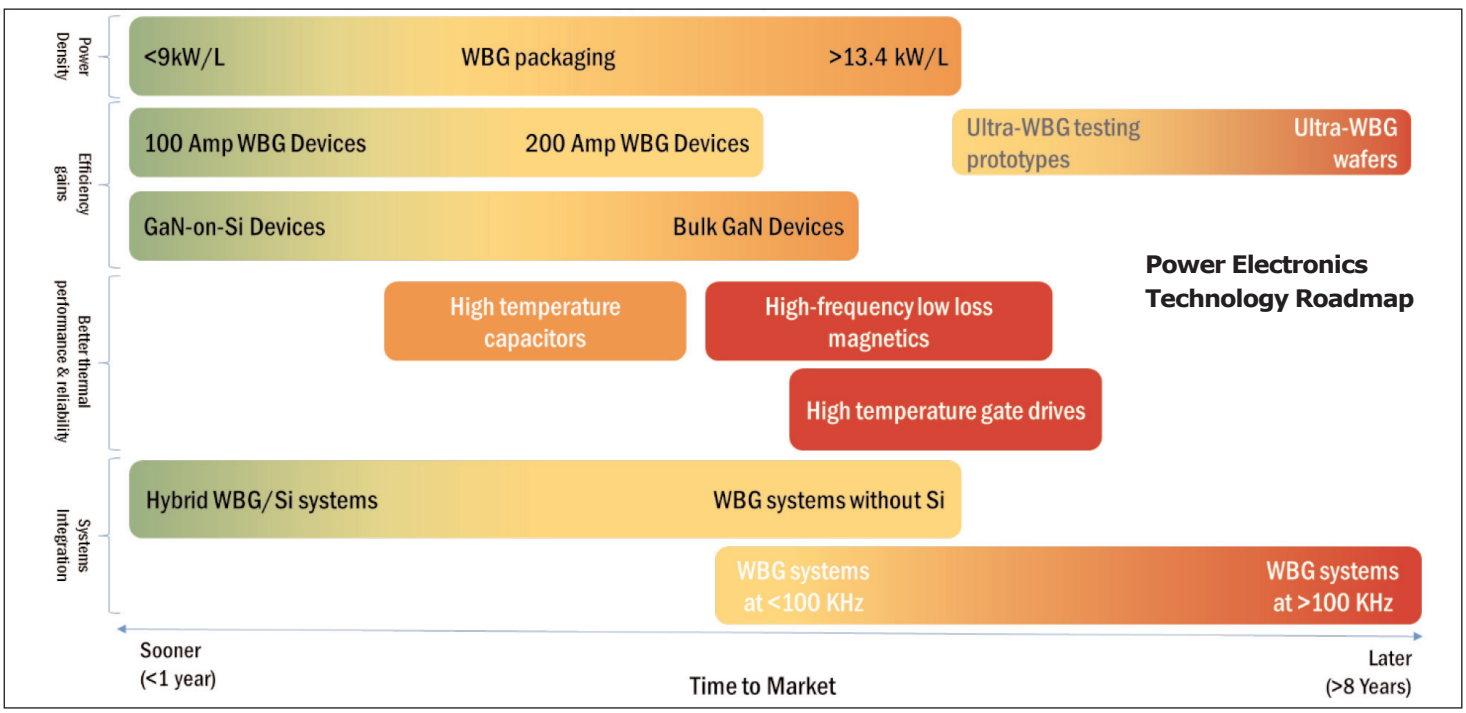
The completed technology roadmap/supply chain report 'US Power Electronics Technology and Manufacturing Roadmap' was presented to members at PEIC's 2016 annual meeting last November at PowerAmerica (a private–public partnership between the US Department of Energy, industry and academia) on North Carolina State University's Centennial Campus. The report's full text is available to PEIC members, and for purchase by non-members — for an executive summary and pricing, e-mail info@peic.org.

With a record number of member companies, academic institutions and government laboratories and agencies in attendance, the PEIC annual meeting, which was co-sponsored by PEIC members Infineon Technologies, Quora Technology and PowerAmerica, also featured a tour of the Future Renewable Electric Energy Delivery & Management (FREEDM) Center facilities at NCSU, as well as a panel discussion led by representatives of several federal research laboratories engaged in next-generation power electronics research. In addition, the program included presentations by both member companies and invited guests.

Focus on power electronics workforce development in 2017

As an integral part of its mission to advance the US power electronics industry's competitiveness in the global economy, during 2017 PEIC is engaging in discussions with member organizations and other industry, academic institutions and government labs to develop workforce development programs specific to power electronics engineers.

www.peic-us.org



Danfoss and GE collaborate on SiC power module production as part of New York Power Electronics Manufacturing Consortium

Germany's Danfoss to package power modules in New York State using SiC chips provided by GE

Danfoss Silicon Power of Flensburg, Germany is establishing production in the USA and entering into a collaboration to manufacture silicon carbide power modules using SiC chips provided by General Electric (GE).

Danfoss Silicon Power is part of the Danfoss Group, which has more than 25,000 staff globally. As a manufacturer of power modules for the industrial, renewable energy and automotive sectors, it has provided modules for more than 25 million, mainly European cars.

Danfoss says that the SiC power modules will create smaller, faster and more effective electronic devices, and are expected to advance the technology within solar and wind energy as well as the future generations of electric and hybrid cars.

The transatlantic collaboration between Danfoss and GE will be part of New York Power Electronics Manufacturing Consortium (NY-PEMC) in Utica, upstate New York. The private–public consortium and other similar programs were established in 2014 by the state of New York with a total investment of more than $20bn for the creation of high-tech jobs.

The NY-PEMC facility in Utica, upstate New York.

By early 2018, Danfoss Silicon Power will establish SiC power module packaging operations in Utica, and is expected to create hundreds of jobs in the coming years.

The news was announced by Andrew M. Cuomo, governor of New York State, which is financing all startup costs as well as production facilities. Danfoss will lease both the facility and equipment from New York State and occupy the entire facility in Utica, which includes two cleanrooms, labs, offices and logistics space.

"The US is our biggest market and essential to our business," says Danfoss' executive VP & chief operating officer Kim Fausing. "The cooperation with GE has great strategic impact for Danfoss — it is important for our future growth plans in the US, and we have big expectations for the further developments in this highly specialized area," he adds.

"Danfoss Silicon Power is gaining a unique position as the only independent SiC module manufacturer in the US, and GE has been a customer from day one," says Claus A. Petersen, general manager & VP of Danfoss Silicon Power. "Similarly, it has opened the door to the US market, where demand for the power modules manufactured by Danfoss Silicon Power is expected to grow explosively."

www.geglobalresearch.com
www.ny-pemc.org
www.danfoss.com

IXYS launches dual 1200V SiC Schottkys in SOT-227

IXYS Corp of Milpitas, CA, USA and Leiden, The Netherlands (which provides power semiconductors and mixed-signal ICs for power conversion and motor control applications) has announced availability of the DCG85X1200NA and DCG100X1200NA — both dual 1200V-rated SiC Schottky diodes in fully isolated MiniBLOC (SOT-227) packages.

Both offer two SiC Schottky diodes with an average forward current of 43A and 49A, respectively, at 80°C case temperature. Both are rated at 1200V blocking voltage in MiniBLOC SOT-227 package featuring 3kV isolation to heat sink and low thermal impedance based on IXYS' proprietary technology. Both products offer higher power density, lower assembly cost, and smaller size.

"With this addition to our fast diode portfolio, IXYS enables higher power in switching and control for solar inverters, uninterruptible power supplies (UPS) and rapid charger solutions," says Dr Elmar Wisotzki, director of technology for IXYS Germany. "The devices use our matching assembly technology to harvest the full advantage of the IXYS SiC power diodes," he adds.

"IXYS also offers the best driver ICs, such as the IXDD609SI, for high-power SiC MOSFETs. Thus, we offer the total solution to our customers to improve efficiency at best performance over cost ratio," he claims.

Both diodes are electrically isolated from each other inside the package, allowing it to be free to connect to a common source or phase leg configuration. Also, the positive temperature coefficient of the forward voltage supports paralleling options for higher-power applications.

www.ixys.com

Transphorm introduces Silicon Valley Center of Excellence

Customer support center enables high-speed, high-voltage GaN power systems development

Transphorm Inc of Goleta, near Santa Barbara, CA, USA, which designs and manufactures what it claims are the industry's only JEDEC-qualified 650V gallium nitride (GaN) field-effect transistors (FETs) for high-voltage power conversion applications, has formally introduced its Silicon Valley Center of Excellence.

Established over the past year, the center is Transphorm's customer support initiative for high-voltage GaN-based power application development. Its mission is to educate and support customers developing with high-voltage GaN. It will also build out a technical library consisting of application notes, white papers and open-source reference designs. To that end, a reference design suite for targeted markets (automotive, data center, servo/motor, renewables) is scheduled as the next release on the center's product roadmap.

Products and services released from the center fall under four primary focus areas: Design Tools, Education, Support, Technical Library. Further, Transphorm says that these products and services will reinforce its commitment to high quality and reliability (Q+R) standards, enabling customers to build with and maintain confidence in high-voltage GaN technology.

"We've added over 150 man-years of power management design experience and, with that, the ability to optimize solutions for performance, system cost and manufacturability," says Mike White, senior VP, sales & marketing. "Our objective is to be the trusted advisor; we are educating the market on how to design with GaN technology. And, we're taking a hands-on approach to helping our customers solve their most challenging issues," he adds.

Located in San Jose, CA, the center has regional team members worldwide. The staff comprises experienced power supply design engineers and technical marketers with backgrounds in magnetics, noise control, PCB design, Q+R testing, tool development, topologies and other relevant subjects. Transphorm's technical library includes the following:

- Design Tools — evaluation kits, reference designs, simulation models (SPICE);
- Education — topical information, such as EMI control methods, high-power application concepts, optimization techniques, topology comparisons, etc;
- Support — global field applications team, Q+R testing, system component selection analysis, technical marketing; and
- Technical Library — application notes, design guides, PCB layouts, schematics, technical white papers.

The center's latest releases include the 'GaN FETs in Parallel Using Drain Ferrite Beads and RC Snubbers for High-power Applications' application note, the TPH3212PS FET SPICE model and the 2.5kW Half Bridge Buck or Boost evaluation kit.

Also, products will be posted to the online Design Resources section at www.transphormusa.com/design-resources.

Inquiries on specific project guidance, appropriate GaN devices, or system development can be sent to **www.transphormusa.com/design-support-request**

Raytheon awarded $10m MDA contract to upgrade X-band ballistic missile defense radar to GaN

The US Missile Defense Agency (MDA) has awarded Raytheon Company of Waltham, MA, USA a $10m contract modification to continue the development of hardware and software that will add gallium nitride technology to the AN/TPY-2 ballistic missile defense radar.

GaN increases the radar's range, search capabilities and enables the system to better discriminate between threats and non-threats. It also increases the system's overall reliability while maintaining production and operational costs.

"AN/TPY-2 is already the world's most capable land-based, X-band, ballistic missile defense radar," says Raytheon's Dave Gulla, VP of the Integrated Defense Systems (IDS) Mission Systems and Sensors business area. "Adding GaN technology modernizes the system so it can defeat all classes of ballistic missiles in extreme operational environments."

Raytheon says that the AN/TPY-2 is on track to be the world's first transportable, land-based ballistic missile defense radar to use GaN technology.

Raytheon says that it has been developing GaN for 19 years and has invested over $200m to get this latest technology into the hands of military members faster and at lower cost and risk. The firm has demonstrated the technology's maturity, including exceeding the reliability requirement for insertion into the production of military systems.

www.raytheon.com/capabilities/products/antpy2

Transphorm launches first automotive-qualified GaN FETs

Transphorm says that its second-generation JEDEC-qualified high-voltage gallium nitride technology is now the industry's first GaN solution to earn automotive qualification, having passed the Automotive Electronics Council's AEC-Q101 stress tests for automotive-grade discrete semiconductors.

In production now and available for $13.89 in 1000-unit quantities, the TPH3205WSBQA automotive GaN FET offers an on-resistance of 49mΩ in an industry-standard TO-247 package. It initially targets on-board charger (OBC) and DC-to-DC systems for plug-in hybrid electric vehicles (PHEVs) and battery electric vehicles (BEV). Currently, OBCs are uni-directional (AC to DC) using standard boost topologies. However, as GaN FETs are bi-directional by nature, they are a fit for bridgeless totem-pole power factor correction (PFC) topologies. Hence, a bi-directional OBC can then be designed with GaN in order to reduce the number of silicon devices, weight and overall system cost of existing solutions.

"With the electrification of the automobile, the industry faces new system size, weight, performance and cost challenges that can be addressed by GaN," says Philip Zuk, senior director of technical marketing. "However, supplying this market means devices must meet the highest possible standards for quality and reliability, those set by the AEC," he adds.

Transphorm says that its quality and reliability (Q+R) culture feeds into every aspect of its GaN-on-Si products. The firm is vertically integrated through the whole design and development cycle — innovating at the epi layer, adapting the fab process to the product, configuring the device and developing customer design tools and resources — enabling it to deliver what is said to be the industry's only GaN devices with proven quality, reliability and intrinsic lifetime data extending beyond JEDEC requirements.

Transphorm says that Q+R played a critical role in achieving AEC-Q101 qualification. The firm's GaN technology was subjected to a series of rigorous tests including parametric verification, high-temperature reverse bias and high-temperature gate bias. Devices receive a simple pass/fail rating and must pass all modules to become qualified.

The automotive market is one of the fastest-growing segments for all power semiconductors and will rise to $3bn in annual revenue by 2022, forecasts analyst firm IHS Markit. Due to its inherent attributes, Transphorm's GaN can support a large portion of the market. Compared with incumbent technology such as superjunction MOSFETs, insulated-gate bipolar transistors (IGBTs) and silicon carbide (SiC), those attributes include: up to 40% greater power density; increased efficiency; lower thermal budget; reduced system weight; up to 20% decrease in overall system cost; and high-volume manufacturing with 6" GaN-on-silicon. As a result, Transphorm's GaN also can be used in other high-voltage DC-to-DC automotive systems including air conditioning, heating, oil pumps and power steering.

www.transphormusa.com

Qorvo adds new Spatium amplifiers for EW systems

Qorvo Inc of Greensboro, NC, USA (which provides core technologies and RF solutions for mobile, infrastructure and defense applications) has launched three new solid-state power amplifier (SSPA) modules that further expand the power and frequency range of its Spatium amplifier family. The modules are optimized for electronic warfare applications, enabling defense customers to use ultra-wideband SSPA technology as an alternative to traveling-wave tube amplifiers (TWTAs).

"The need for wider bandwidth, higher frequency and higher performance will drive growth for gallium nitride in defense applications, with the market approaching $342m by 2020," says Asif Anwar, director of Strategy Analytics' Strategic Technologies Practice. "The Spatium technology with GaN places Qorvo in an ideal position to address defense TWTA replacements without compromising high power and broadband performance."

Spatium products feature ultra-efficient RF power-combining capabilities built on GaN on silicon carbide (SiC) monolithic microwave integrated circuit (MMIC) technology. This creates a highly stable, reliable, high-performance TWTA alternative for demanding airborne, electronic warfare, test and simulation applications, says Qorvo. Solid-state Spatium modules have longer service lifetimes than comparable TWTAs, and offer advantages in size, weight, power and cost (SWAP-C), the firm claims.

"Our new Spatium amplifiers give RF designers unprecedented efficiency with output power from hundreds to thousands of watts," says Roger Hall, general manager of High Performance Solutions at Qorvo. "Spatium excels in broadband applications; now solid-state solutions can outperform TWTAs with a much lower total ownership cost," he claims.

The new modules include a 2–6GHz/300W unit, a 2–18GHz/60W unit, and a 2–8GHz/150W unit. Each is available in two configurations — as a solo Spatium amplifier building block or a Spatium-based rack-mountable box with a driver, internal power supply and fan, suitable for bench-top demonstration or lab test equipment. Limited demonstration units are available to qualified defense customers.

www.qorvo.com/defense

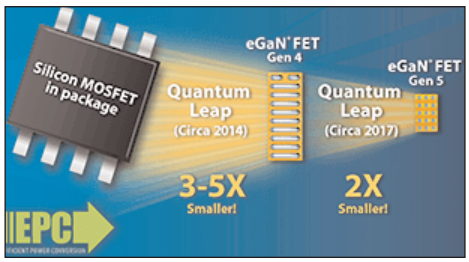
EPC launches eGaN FETs that halve size while increasing performance and cost

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 and ICs — has advanced the performance capability while lowering the cost of off-the-shelf GaN transistors with the launch of the EPC2045 (7mΩ, 100V) and the EPC2047 (10mΩ, 200V) eGaN FETs.

Widening the performance/cost gap with equivalent silicon power transistors, the EPC2045 cuts the die size in half compared with the prior-generation EPC2001C eGaN FET. The EPC2047 eGaN FET also cuts the size in half so that it is now about 15 times smaller than equivalently rated silicon MOSFETs.

Applications for the EPC2045 include single-stage 48V to load Open Rack server architectures, point-of-load converters, USB-C, and LiDAR. Applications for the 200V EPC2047 include wireless charging, multi-level AC–DC power supplies, robotics, and solar micro inverters.

EPC says that designers no longer have to choose between size and performance, as they can now have both. The chip-scale packaging of eGaN products handles thermal



conditions far better than plastic-packaged MOSFETs, says the firm, since heat is dissipated directly to the environment with chip-scale devices whereas heat from the MOSFET die is held within a plastic package.

"These new products demonstrate how EPC and gallium nitride transistor technology is increasing the performance and reducing the cost of eGaN devices for applications currently being served by MOSFETs," notes co-founder & CEO Alex Lidow. "Advancements in EPC's GaN technology will continue to enable new end-use applications that go beyond the capability of silicon devices," he adds. "These products are evidence that the performance and cost gap with MOSFET technology continues to widen."

There are three development boards available to support easy in-circuit performance evaluation of the EPC2045 and EPC2047 respectively. The EPC9078 and EPC9080 support the 100V EPC2045; the EPC9081 features the 200V EPC2047.

A virtue of underlying GaN process developments is that these devices have significantly lower capacitance than silicon counterparts, says EPC. This condition translates into lower gate drive losses and lower device switching losses at higher frequencies for the same on-resistance and voltage rating. For the EPC2045, a 30% reduction in power loss with a 2.5 percentage point better efficiency than the best comparable MOSFET was achieved in a 48V-to-5V circuit at 500kHz switching frequency.

In contrast to silicon MOSFETs, the switching performance of eGaN FETs improves even though they are significantly smaller — this attribute introduces a 'virtuous cycle' for eGaN products going forward that will result in the continued introduction of smaller devices with higher performance, adds EPC.

The performance, size and cost improvement of the new products was enabled by a new method of both reducing the electric fields in the drain region during breakdown and significantly reducing the number of traps that could cause electrons to become inactive, notes EPC.

www.epc-co.com

Development board for evaluating eGaN FETs as LiDAR laser drivers

The EPC9126, a 100V high-current pulsed laser diode driver evaluation board, is now available.

In a LiDAR system (for detecting objects in autonomous vehicle applications) speed and accuracy of detection is key. As demonstrated by the new board, the rapid transition ability of eGaN FETs provides power pulses to drive the laser up to ten times faster than an equivalent MOSFET.

Intended for driving laser diodes, the EPC9126 development board features an EPC2016C ground-referenced eGaN FET driven by a Texas Instruments UCC27611 gate driver. The EPC2016C is a 100V maximum voltage device capable of current pulses up to 75A with total pulse widths as low as 5ns. For higher current capability, the board can accommodate an EPC2001C 100V eGaN FET with a pulse current rating of up to 150A.

The board includes multiple ultra-low inductance connection options for mounting laser diodes, driven via a discharging capacitor (as shipped) or directly from a power bus. The board does not include a laser diode, which must be supplied by the user to evaluate specific applications. The PCB is designed to minimize power loop inductance while retaining mounting flexibility for the laser. It includes multiple on-board passive probes for voltages and discharge capacitor current measurement, and comes equipped with SMA connections for input and sensing designed for 50Ω measurement systems. Also, the user can enable an optional precision narrow pulse generator. Finally, the board can be used for applications needing a ground-referenced eGaN FET, e.g. in Class E or similar circuits.

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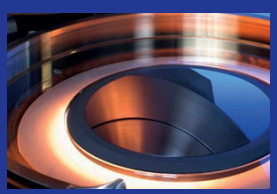

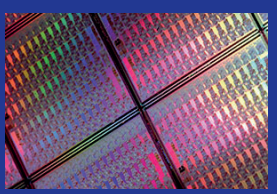

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Akash Systems formed to apply GaN-on-diamond technology to SatComs

Start-up reacquiring GaN-on-diamond patents and IP from RFHIC

Felix Ejeckam and Ty Mitchell, both experts in gallium nitride (GaN)-on-diamond technology, have formed Akash Systems Inc of San Francisco, CA, USA, targeting fast, affordable satellite communications to address the challenge of worldwide data demand outpacing the frequency, bandwidth and power capabilities of existing communications infrastructure.

Akash says that, through the application of GaN-on-diamond materials, its technologies can resolve issues critical to the expansive growth of data use and consumption, enabling smaller, lighter and higher-performing satellites that lead to lower launch costs, reduced cost-per-bit, more launch cycles, and increased communications access and throughput.

"There is a great need and demand for new satellites that are lower cost and allow for faster downlink data rates," says co-founder, CEO and GaN-on-diamond inventor Felix Ejeckam. "Our technology will also create opportunities not envisioned today, including deep space communications, faster data links between spacecraft, and higher-density information access between human communities, no matter where they are in the universe."

Phase one of Akash's business approach includes GaN-on-diamond hybrids and monolithic microwave integrated circuit (MMIC) power amplifiers that are currently on the market. The firm plans to move into phase two — working with satellite system makers to design small satellite (Cubesat) systems and subsystems — by 2019.

The GaN-on-diamond technology was invented in 2003 by Ejeckam while at Group4 Labs Inc by lifting GaN epitaxy from its original growth substrate (for example, silicon) and transferring it to a synthetic CVD diamond substrate. Group4 Labs' assets were acquired in 2013 by Element Six Technologies (a member of the De Beers Group of Companies).

In 2016, Ejeckam, together with Akash co-founder & chief operating officer Ty Mitchell, entered into an agreement with RFHIC Corp of Anyang, South Korea (which designs and makes active RF & microwave high-power components and hybrid modules) to jointly negotiate the repurchase of the GaN-on-diamond intellectual property (IP), with Akash acquiring all patents and other IP rights related to GaN-on-diamond technology for use in satellite communications and related markets.

"Imagine extending the reach of fast, affordable communications to every human on earth. Imagine the possibility of high-bandwidth communications between Earth and deep space, or even human colonies in space. At Akash, we are creating technologies to make that vision come true," says Mitchell, who was previously at Cree Inc of Durham, NC, USA, where he served in roles including executive VP/GM and VP/GM of Cree's Optoelectronics, GaN/SiC materials, and LED Lighting businesses. "Akash is excited to acquire this IP to serve our customer base of satellite system makers around the world. We want to redefine what people believe are limitations in satellite communications," he adds.

www.AkashSystemsInc.com

Advantech Wireless receives follow-on order for X-band line of SATCOM GaN-based SSPAs and BUCs

Advantech Wireless Inc of Montreal, Canada (which makes satellite, RF equipment and microwave broadband communications systems) has received follow-on orders from military customers for its X-band line of gallium nitride (GaN)-based solid-state power amplifiers (SSPAs) and block up-converters (BUCs) for tactical mobile military applications.

This latest generation of X-band GaN-based SSPAs/BUCs features what are claimed to be exceptional linearity and operating efficiency. The versatile systems are suitable for harsh environments, Satcom-on-the Move (SOTM) and man-pack terminal deployments.

"To-date we have received orders for more than 300 units, and our customers appreciate the high linearity combined with small size, and low energy consumption," says Cristi Damian, VP business development. "The GaN X-band line of SSPAs is very versatile, with small-form-factor units for mobile applications, to medium power for maritime, and very high power for large teleports," he adds. "Several models are either already WGS [Wideband Global SATCOM] certified, or in process of certification."

Advantech Wireless says that its X-band GaN based BUCs are weatherproof and constructed in a compact cooling enclosure for outdoor operation. Based on ruggedized designs, the BUCs are claimed to be the smallest fully integrated units on the market and are enabling new terminal designs for both mobile and at-the-halt tactical communication systems.

www.advantechwireless.com

RFHIC acquiring Element Six's GaN-on-diamond epitaxial technology

RFHIC Corp of Anyang, South Korea has signed a deal with Element Six (E6), a member of the De Beers Group of Companies, to acquire its GaN-on-diamond technology.

RFHIC has been investing in GaN technology since 2004; it was the first fabless firm to use commercially available GaN foundry services. In 2008, the firm expanded its core competency from GaN-on-silicon (Si) to GaN-on-silicon carbide (SiC). Applications of the technology include 4G LTE, next generation radar and communication systems, says the firm. The rate of adaptation has exploded as the cost of GaN-based solutions has become competitive compared to LDMOS and other legacy technologies, while the performance advantages are becoming clearer for industry demands.

In 2016, RFHIC started to work with GaN-on-diamond technology. With GaN's ultimate performance limited by factors such as the thermal performance of the substrate material, the firm says it was clear that diamond could unlock opportunities beyond what Si and SiC can ever achieve. RFHIC believes that GaN-on-diamond is the right technology to unleash the full capability of GaN. The power density of GaN-on-diamond transistor is expected to be over three times higher than that of GaN-on-SiC.

RFHIC says it plans to make its GaN-on-diamond technology widely available for applications such as radar, tactical radios, microwave heating, satellite communications, power supplies, and wireless 4G & 5G infrastructure.

"RFHIC expects that this technology will help us to provide a single transistor with RF power of up to 1kW depending on the frequency, significantly reducing combining loss, thus enabling true high-power RF systems for a diverse range of applications," says chairman & chief technology officer Samuel Cho. "The obvious beneficial customers would be the radar makers as the current market's need is to replace tube based transmitter with high-power solid-state based transmitter. This GaN-on-diamond technology will certainly accelerate the transformation of the radar market as well as revolutionize the semiconductor industry," he adds. "Furthermore, we expect the wireless infrastructure's base station and small cell would become more energy efficient and reliable with simultaneously larger bandwidth. This improvement will enable the systems' size to be substantially smaller, reducing the operators' biggest operating cost of space rental. RFHIC will work closely with Element Six and foundry partners for the capability of manufacturing 10,000 6-inch GaN-on-diamond wafers per year in the foreseeable future. RFHIC's technology roadmap is to introduce GaN-on-diamond based solutions covering up to 40GHz by the end of 2018."

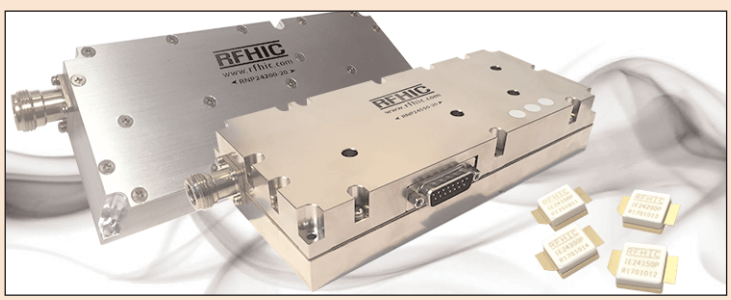
www.rfhic.com
www.e6.com/GaN

RFHIC launches GaN transistors & power amplifiers for ISM bands

RFHIC Corp of Anyang, South Korea, which designs and makes active RF & microwave high-power components and hybrid modules for telecoms, defense industries, consumer goods and customized solutions, has announced immediate availability and full design support capabilities of new gallium nitride (GaN) transistors and power amplifiers optimized for 915MHz, 2.45GHz and 5.8GHz industrial, scientific & medical (ISM) bands, with RF output powers ranging from 30W to 550W.

The new GaN transistors are optimized for continuous-wave applications up to 300W RF output power with power efficiency of more than 70%.

The new GaN power amplifiers achieve over 50dB of power gain and high drain efficiency of over 55–60% including isolators. They are said to be simpler to control and more reliable than the existing magnetron and provide better solutions for compact system designs than silicon-based LDMOS power amplifiers. Moreover, RFHIC's own transistors are used in the power amplifiers, enabling more reliable and cost-competitive solutions, claims the firm.



The firm offers a choice of variation in the use of isolator, voltage-controlled oscillator (VCO) signal generation, forward and reverse power detection etc in order to satisfy diverse and precise requirements in the market, aiming to maximize the flexibility in customers' development environments and conditions.

Furthermore, the development of two-stage compact power amplifiers with a size of 80mm x 40mm x 5mm and efficiencies of 66–70% is in progress (for availability in April). These products will increase the number of choices available for specific system designs.

Compound Semiconductor Applications Catapult launches non-executive board

Understanding of UK R&D plus targeted end-user markets to aid commercialization

The South Wales-based Compound Semiconductor Applications Catapult has appointed four of the UK's leading experts in the field to its non-executive board of directors.

They include Dr Trevor Cross, group chief technology officer of Teledyne e2v; Stephen Duffy, commercial director of Optocap; Jonathan Lyle, chief executive of Dstl; and Dr Wyn Meredith, director of the Cardiff-based Compound Semiconductor Centre (CSC).

The Compound Semiconductor Applications Catapult is the 11th of Government agency Innovate UK's Catapults, which comprise a network of centers where UK businesses, scientists and engineers work side by side on late-stage R&D, with the aim of transforming high-potential ideas in specific areas into new products and services (helping to drive future economic growth).

The Compound Semiconductor Applications Catapult was announced in early 2016, backed by government funding of £50m (£10m per year up to 2020–21) and spearheaded by epiwafer foundry and substrate maker IQE plc of Cardiff, Wales, UK and Cardiff University. Its aim is to support industry's ability to access and exploit the advances made by UK researchers in compound semiconductor technologies over the past two decades, and to bridge the gap between companies developing novel semiconductor materials, topologies and devices, and those developing systems for end-user applications. Key to this is the Catapult's work to ensure that the advances resulting from UK R&D successfully translate into real-world commercial applications. This will be facilitated via translational research facilities that will work to accelerate the commercialization of compound semiconductors in key application areas including: healthcare, the digital economy, energy, transport, defence and security, and space.

"Today's appointments represent a crucial step in establishing a world-class facility to help commercialize compound semiconductor technology in the UK," comments Kevin Crofton, chairman of the Catapult. Operating 'post foundry', the Catapult complements other investments within South Wales, including the Institute for Compound Semiconductors (ICS) at Cardiff University (which involves about £80m investment) and the Compound Semiconductor Centre (CSC), a £40m joint venture formed in August between IQE and Cardiff University (focused on technology translation of research and design in compound semiconductor materials & devices). The Catapult is a member of CS-Connected — the South Wales compound semiconductor cluster.

"Integral to its success is the intention to create an environment that accelerates product development, drawing on the UK's leading-edge research, to address a growing global market," says Crofton. "Each member of our board brings with them an in-depth understanding of the UK's R&D activity as well as the specific needs of the end-user markets we seek to target," he adds. "Insight and experience brought by the newest members of our board will be invaluable in developing effective routes for commercialization."

The newest members of the Catapult board represent a cross section of the UK's leading academic and commercial compound semiconductor industry

The newest members of the Catapult board represent a cross section of the UK's leading academic and commercial compound semiconductor industry.

As the group chief technology officer of Teledyne e2v, Cross has over 30 years of commercial experience, including more than ten years at board level. A former council member of the Particle Physics and Astronomy Research Council (PPARC), he played a pivotal role in e2v's university engagement programs. He was also previously chair of the Technology Strategy Board (TSB)-led Electronics, Sensors and Photonics KTN (Knowledge Transfer Network) and currently chairs Innovate UK's Special Interest Group in Quantum Technologies.

Meredith is an expert advisor to the UK Engineering & Physical Sciences Research Council (EPSRC), Cardiff University Department of Physics, The UK National III-V Centre, and provides executive-level advisory services to numerous small- and medium-sized enterprises (SMEs) in semiconductor technology.

Duffy is commercial director (and, from this June, CEO) of Optocap Ltd, which offers contract semiconductor package design and assembly services. He was co-owner of Optocap and a key part of the management team that purchased it from Scottish Enterprise, and later sold it to German multi-national TUV NORD. Duffy now sits on the Executive Management Committee of TUV NORD's Aerospace business unit.

Finally, bringing relevant experience from the public sector, Lyle is chief executive of the Defence Science and Technology Laboratory (Dstl), a UK government agency that works closely with companies and universities to harness innovative science and technology for the defence and security of the UK. He is Fellow of the Royal Academy of Engineering (RAE) and the Institution of Engineering and Technology (IET) and has held senior roles in the Ministry of Defence (MOD).

www.catapult.org.uk/catapult-centres

Soitec ramping production of 200mm SOI wafers at China manufacturing partner Simgui's fab

Second source enables expansion for communications and power device markets

Soitec of Bernin, near Grenoble, France, which makes engineered substrates including silicon-on-insulator (SOI) wafers, says that the ramp up to high-volume production of 200mm SOI wafers — manufactured with its Smart Cut technology — has begun at the manufacturing facility of its China-based silicon-based materials manufacturing partner Shanghai Simgui Technology Co Ltd (a provider of both SOI wafers and epiwafer foundry services), which has been fully qualified by key Soitec customers.

Soitec says that implementation of a partnership model represents a key milestone in managing its worldwide manufacturing capacity to meet market demand for 200mm SOI wafers used in fabricating semiconductors for the growing communications and power device markets.

"Establishing this second source in China allows us to ensure the needed capacity of 200mm SOI wafers from two sites in different regions of the world, with each facility producing exactly the same products from a specifications and quality standpoint," says Bernard Aspar, executive senior VP of Soitec's Communication & Power business unit. "Our partnership with Simgui is now running in an efficient way and our customers have been supportive and instrumental in this strategic move, which fully validates Soitec's technology-transfer expertise and manufacturing strategy," he adds.

"Simgui has been working on SOI materials for 16 years in China," notes Simgui's CEO Jeffrey Wang. "Partnering with Soitec, Simgui is fully ready to support Soitec's ramp up of 200mm SOI wafers manufactured with the Smart Cut technology at our facility in Shanghai and to help in developing the SOI ecosystem in China."

Soitec says that implementation of a partnership model represents a key milestone in managing its worldwide manufacturing capacity to meet market demand for 200mm silicon-on-insulator wafers used in fabricating semiconductors for the growing communications and power device markets

The first 200mm SOI wafers produced at Simgui's manufacturing facility using Soitec's proprietary Smart Cut technology were qualified by the initial customers at the end of last year. Additional customers are currently in the process of qualifying the wafers.

Producing the wafers in China has been a key objective of Soitec's and Simgui's licensing and technology-transfer agreement (signed in May 2014) and validates Smart Cut as a standard process. The wafer production line in China will boost the industrial manufacturing capacity of 200mm SOI wafers in order to meet increasing worldwide usage and also will be a key element in establishing the SOI ecosystem in China, reckons Soitec.

Soitec's 200mm RF-SOI and Power-SOI products are dedicated to the mobile and automotive markets, respectively. The firm says that, as the leading SOI substrate maker, it has the largest capacity and produces both 200mm and 300mm wafers at multiple fabs in France.

Simgui exhibited Soitec's Smart Cut-based 200mm product line at SEMICON China in Shanghai (14–16 March).

www.simgui.com.cn/en

SiGen and Soitec terminate ITC patent lawsuit

Soitec and Silicon Genesis Corp (SiGen) of Santa Clara, CA, USA (which was founded in 1997 to provide engineered substrate process technology and equipment for the semiconductor, display and optoelectronics markets) have brought an end to their dispute regarding the importation and sale in the USA of certain SOI wafers by Soitec. Both companies have hence agreed to dismiss all pending litigations, including the proceedings in front of the US International Trade Commission (ITC).

Soitec says that the agreement reinforces its intellectual property position and allows it to better serve and protect its customers and business partners.

"This settlement is a positive outcome for SiGen and we believe will be beneficial for the SOI industry," comments SiGen's president & CEO Ted Fong. "We can now focus on the development of new product applications with our proprietary layer transfer process technology." SiGen develops substrates using a beam-induced thick-film and thin-film room-temperature controlled cleave layer transfer process.

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AXT resumes substrate production after fire at Beijing manufacturing facility

Some 6" furnace capacity used for 2", 3" and 4" GaAs and Ge after power supply damaged, prior to return to full production in Q2/2017

AXT Inc of Fremont, CA, USA has resumed wafer processing production of all substrate types, including indium phosphide (InP), gallium arsenide (GaAs) and germanium (Ge), at its manufacturing facility in Beijing, China , following the electrical fire on 16 March.

The fire caused no damage to InP crystal growth or wafer production. In addition, the firm's 6-inch GaAs and Ge crystal growth furnaces were not damaged by the fire, and there is no damage to the electrical supply supporting these 6-inch crystal growth furnaces. The electrical power supply supporting 2-, 3- and 4-inch GaAs and Ge crystal growth was damaged. The custom-designed furnaces enable the firm to rotate key furnace hardware between different growth diameters. It therefore plans to use some of the 6-inch furnace capacity for 2-, 3- and 4-inch GaAs and Ge crystal growth production.

In addition to rotating diameter sizes, AXT says that it has sufficient redundancy in furnaces and plans to move furnaces within the plant to an area designated for crystal growth expansion. Power can then be connected and it can restore the smaller-diameter crystals to full production. The firm believes that it can return to full production during second-quarter 2017. Further, to meet immediate customer demand, staged inventory of smaller-diameter crystalline ingots will be moved to wafer processing.

AXT's manufacturing facility in Beijing, China.

AXT notes that its wafer processing production area (including its cleanroom) is housed in a facility across the street from the building in which the electrical short-circuit fire occurred, and was therefore not affected. Further, no structural damage occurred to the building in which the fire took place.

To meet immediate customer demand, staged inventory of smaller-diameter crystalline ingots will be moved to wafer processing

"I am thankful that no injuries occurred and that the damage to our facilities was considerably less than we initially believed," says CEO Morris Young. "I am grateful to local authorities for their timely response and assistance," he adds. "We remain convinced about our business opportunities and are deeply committed to supporting the requirements of our customers through this process."

AXT raises $31.9m in public offering

Proceeds may be used for relocation of GaAs product line

On 7 March, AXT closed an underwritten public offering (announced on 2 March) of 4,615,385 shares of common stock at a price of $6.50 per share.

In addition, on 3 March the underwriters exercised in full their 30-day option to purchase up to an extra 692,307 shares.

After deducting the underwriting discount and estimated offering expenses payable by AXT, the net proceeds to the firm are about $31.9m.

AXT intends to use the proceeds for general corporate purposes, which may include the relocation of its gallium arsenide product line, working capital, capital expenditures and other corporate expenses.

www.axt.com

Riber more than doubles gross margin as losses are slashed in full-year 2016

Year-on-year revenue growth of 29% in 2016 to be exceeded in 2017

For full-year 2016, Riber S.A. of Bezons, France, which manufactures molecular beam epitaxy (MBE) systems as well as evaporation sources and effusion cells, has reported revenue of €16.5m, up 29% on €12.8m in 2015, driven by growth across all product lines accompanied by a significant upturn in various industrial markets.

MBE systems revenue grew by 45% from €6.1m to €8.8m, reflecting an improvement in product mix (with five research systems delivered in 2016 versus nine in 2015 but two production systems delivered in 2016 compared with none in 2015).

Revenue for Services & Accessories has risen by 10% from €4.2m to €4.6m, due to commercial initiatives rolled out in the past few years.

Revenue for Cells & Sources rose by 21% from €2.5m to €3m, due mainly to the resurgence of interest in Riber's solutions for applications in diverse fields, such as screens, organic light-emitting diode (OLED) technology, photovoltaics and other specific industrial applications.

Gross margin has more than doubled from just 14.9% in 2015 to 36.4% in 2016, reflecting the improvement in sales margins, benefiting from a better product mix, which has also led to €0.6m of provisions for inventories being reversed.

Following a reduction in operating expenditure from €8.3m in 2015 to €7.1m in 2016, operating loss has been cut from €6.3m (49.2% of revenue) in 2015 to €1.1m (just 6.7% of revenue) in 2016. This has resulted from a positive change in other operating income and expenses, while sales, administrative and R&D costs remain virtually unchanged. R&D efforts have been maintained to develop Riber's range of products and services.

During 2016, cash (net of financial debt) rose from just €0.1m to €2.5m, including improving by €1.7m during second-half 2016 following the capital increase in August and an order down-payment received at the end of the year.

In addition, Riber repaid all its financial debt for €0.7m, and its shareholders' equity represented €15.5m at the end of 2016.

In view of its order book at the end of 2016, the orders received since the start of 2017 and the outlook for orders to be delivered in 2017, Riber confirms its forecast for year-on-year revenue growth of at least 30% in 2017.

- Riber has received an order for a model MBE49 production MBE system, from a new customer, to manufacture epiwafers for opto-electronic components. Riber did not disclose the name or location of the customer.

www.riber.com

5N Plus makes changes to executive management

Specialty metal and chemical products firm 5N Plus Inc of Montreal, Québec, Canada has announced changes to its executive management structure.

5N provides purified metals such as bismuth, gallium, germanium, indium, selenium and tellurium, and also produces related II-VI semiconducting compounds such as cadmium telluride (CdTe), cadmium sulphide (CdS) and indium antimonide (InSb) as precursors for the growth of crystals for solar, LED and eco-friendly materials applications.

The firm notes that its existing structure has been effective in managing costs and implementing best practices. In 2016, total costs (excluding variable and metal costs) were over 20% lower than just two years ago. While it continues to manage costs, management has adopted a new structure to emphasize growth along business segments and in alignment with the company's 5N21 strategic plan. The following changes have therefore been implemented:

- Responsibilities assumed by the former roles of chief commercial officer and chief operating officer are being reallocated across the existing business segments (Eco-Friendly and Electronic Materials) and will be led by two executive vice presidents.
- Nicholas Audet, formerly chief commercial officer, is now executive VP, Electronic Materials.
- Paul Tancell, formerly the global general manager of the Electro-Optic Materials business unit of Belgium-based materials technology and recycling group Umicore, has joined 5N Plus and has been appointed executive VP, Eco-Friendly Materials.

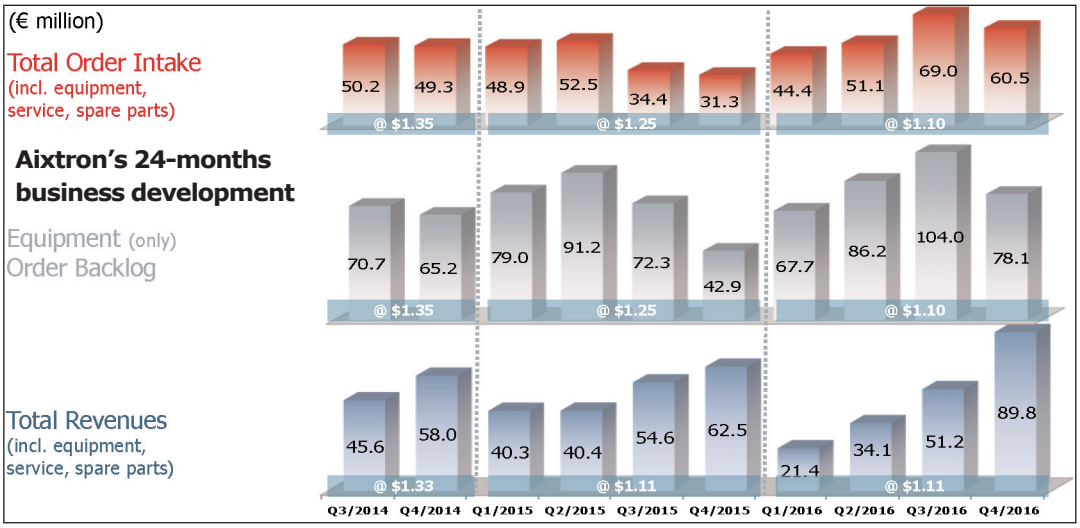
These functions report to president & CEO Arjang (AJ) Roshan. "Having leveraged our functional structure to markedly enhance our organizational efficacy and significantly shrink our cost structure, we see the need for further evolution," says Roshan. "Our new management structure is designed to maintain our discipline around cost management while accentuating growth and emphasizing contribution from emerging opportunities," he adds. "This structure is ideally positioned to deliver the objectives of our 5N21 strategic plan, and provides for better management accountability," Roshan believes.

www.5nplus.com

Aixtron returns profit in Q4, helping full-year 2016 revenue recover to 2015 level

Strategy to seek partners or joint ventures targets sustainable return to profitability and positive EBIT for 2018

Deposition equipment maker Aixtron SE of Herzogenrath, near Aachen, Germany has reported full-year revenue of €196.5m for 2016, near the top of the €170–200m range forecasted at the beginning of the year and almost matching 2015's €197.8m (down just 1%), following a strong second-half 2016. In particular, equipment revenue grew by 3% from €151m to €155.7m (rising from 76% to 79% of total revenue), while sales of spare parts & services shrank by 13% from €46.8m to €40.8m (falling from 24% to 21% of total revenue).



Asian revenue rebounded slightly from 60% of total revenue in 2015 to 65% in 2016 (growing from €118.4% to €128m), while the Americas fell from 22% to 19% (shrinking from €43.6m to €37.7m) and Europe fell from 18% to 16% (shrinking from €35.8m to €30.8m.

Fourth-quarter revenue was €89.8m (the highest quarterly revenue since 2011), up 44% on €62.5m a year ago and up 75% on €51.2m last quarter due to a high volume of planned system shipments. The largest contributions came from production systems for LED, telecom and optoelectronics, as well as for the silicon industry.

"It was important that we continued to press ahead with diversifying our technology and product portfolio last year," says CEO Martin Goetzeler. While the share of full-year 2016 revenue attributable to LED applications — including red-orange-yellow (ROY) LEDs and UV LEDs – remained stable at 26% (rising slightly from €39.7m to €41.1m, including sales of AIX R6 systems from inventory), optoelectronics (excluding LEDs) and power electronics now account for 48% of Aixtron's system revenues, including optoelectronics rising from 31% of revenue in 2015 to 34% in 2016 (rising by 14% from €46.7m to €53.2m, whereas power electronics-related revenue fell from €25.8m to €21.8m, reflecting customer capital expenditure plans prior to expected future growth). Silicon applications rose from 19% of revenue in 2015 to 21% in 2016 (including revenue for logic and memory tools rising by 11% from €29.3m to €32.4m).

"That is also one of the reasons why, based on our own calculations, we were once again the global market leader for MOCVD systems in 2016," Goetzeler reckons.

Gross margin was 33% in Q4, level with 33% last quarter but up on 31% a year ago, enabling full-year gross margin to rise from 25% in 2015 to 29% for 2016.

Due to consistent cost control, full-year operating expenses were almost unchanged from €76.5m (39% of revenue) in 2015 to €77.7m (almost 40% of revenue) in 2016 (within the annual limit of about €80m), including €53.9m of R&D spending (27% of revenue). This was despite quarterly operating expenses rising slightly from €20.4m in Q3 to €21.4m in Q4.

Earnings before interest, tax, depreciation and amortization (EBITDA) improved from –€16.4m in 2015 to –€7.9m in 2016. This was driven by the strong Q4 of +€12.5m, compared with –€0.4m last quarter.

For Q4, Aixtron returned a net profit of €6.4m, compared with a net loss of –€3.8m in Q3. This contributed to the full-year net result improving from a loss of –€29.2m in 2015 to –€24m in 2016.

"Operationally, we made major progress in numerous areas in fiscal year 2016 and met the financial targets communicated at the beginning of the year," notes Goetzeler. "The strong performance in the second half, and especially in the fourth quarter of 2016, enabled us to further improve the company's full-year results, even if we did not yet return to profitability due to ongoing high R&D costs," he adds.

Full-year capital expenditure was cut from €13.3m in 2015 to just €5.3m in 2016. This helped free cash flow to improve by €14.4m from –€57.3m in 2015 to –€42.9m in 2016. Quarterly free cash flow has improved from –€35m a year ago, but dropped back from +€3m in Q3/2016 to –€4.9m in Q4, due mainly to high shipment volumes at the end of the year. A large part of the resultant increase in outstanding receivables has converted into cash in Q1/2017.

During 2016, cash and cash equivalents fell from €209.4m to €160.1m, due mainly to the negative net result, payment of the second installment of the agreed refund of €17.2m in advance payments to Chinese customer San'an Optoelectronics Co Ltd, and an agreed milestone payment of €4.1m for the purchase of PlasmaSi (acquired in 2015) in Q1/2016. Due to high shipment volumes at the end of 2016, receivables rose at the end of 2016. A large part of these receivables was paid in early 2017.

Order intake has grown by 35% from €167.1m in 2015 to €225.1m in 2016 (the highest since 2011, and exceeding both the initial guidance of €180–200m and the revised guidance €200–220m). Q4 order intake of €60.5m was down 12% from Q3's €69m but almost double the €31.3m a year ago, due to consistently high demand for LED, telecom and optoelectronic applications, including the sale of AIX R6 inventories.

Equipment order backlog totaled €78.1m at the end of Q4/2016, down from €104m at the end of Q3 but up 82% on €42.9m at the end of 2015.

The key driver for the development in revenues and the order intake in Q4/2016 was demand for production systems for LED, telecom and optoelectronics, as well as for the silicon industry. This in turn was mainly attributable to technology trends, such as big data, cloud computing, electro-mobility, and the upcoming 5G mobile communication standard, says Aixtron.

"The strong reported equipment order backlog gives us reason to be confident in our outlook for 2017, in particular with regard to opto- and power electronics as well as to the silicon business," says Goetzeler. "We took a decisive step forward by supplying a Beta system with Gen1 (200mm x 200mm) configurations to a major display manufacturer to demonstrate our production processes on site. This way, we have moved significantly closer to obtaining the first order initially targeted for 2016," he adds.

"The dominant topic in fiscal year 2016 was certainly the planned takeover by Grand Chip Investment, which was intended to secure the company's access to the major Chinese market while also ensuring that all of Aixtron's product portfolio could be brought to market maturity," says Goetzeler. "Following the US President's order prohibiting the bidder's acquisition of Aixtron's US business and the investor's subsequent withdrawal, Aixtron acted to realign its corporate strategy," he adds.

"Aixtron is currently pursuing different options in order to successfully reduce required upfront expenses for the development of future technologies," says the firm. "These options include looking for partners, joint ventures or other alternatives. All these measures are targeted to enable a sustainable return to profitability and to report a positive EBIT for full year 2018.

Based on the existing business structure and the assessment of its current order situation (with the equipment order backlog of €78.1m on 1 January joined by an estimated €62–92m of order intake shippable during 2017, plus an estimated €40m of spares & services revenue) with an internal budget rate of US$/€1.10, Aixtron expects for fiscal year 2017 to achieve both revenue and order intake of €180–210m.

Due to planned additional upfront expenses for development of future technologies and based on the existing structure, Aixtron expects to achieve lower EBITDA, EBIT and net result for 2017. However, influenced by the significant reimbursement of an advance payment in Q1/2016 that will not repeat, Aixtron expects a further improvement in free cash flow in 2017.

As in previous years, Aixtron expects that it does not require any external bank debt financing in 2017.

www.aixtron.com

Supervisory board chairman now interim CEO after Goetzeler leaves

CEO Martin Goetzeler left Aixtron for personal reasons (and in agreement with the supervisory board) at the end of his contract on 28 February (having been appointed in March 2013).

Goetzeler's responsibilities included strategy, finances and personnel as industrial relations director. Former executive board member and current supervisory board chairman Kim Schindelhauer has taken on his duties as CEO & chief financial officer in the interim from 1 March until a successor is found.

"During Mr Goetzeler's tenure, Aixtron's technology portfolio was diversified considerably and the company oriented its strategy toward the future markets it identified," says Schindelhauer. "Both the focus on profitability as well as the awareness of costs were successfully internalized in the company and the financial results steadily improved," he adds. "He strengthened the relationships with the Chinese market and consequently initiated the planned China deal."

During Schindelhauer's work as CEO, the supervisory board's deputy chairman professor Dr Wolfgang Blättchen will take over as supervisory board chairman.

Aixtron receives repeat order from Sumitomo for GaN-on-SiC production technology

Deposition equipment maker Aixtron SE of Herzogenrath, Germany has delivered a CRIUS metal-organic chemical vapor deposition (MOCVD) system in 4"-wafer configuration to Japan's Sumitomo Electric Device Innovations Inc (SEDI) to boost its production of gallium nitride on silicon carbide (GaN-on-SiC) devices for RF data transfer applications including for the upcoming 5G wireless mobile network. The system was put into operation in fourth-quarter 2016.

SEDI has long-standing experience with Aixtron's Close Coupled Showerhead technology, which enables easy scalability, says Aixtron. Furthermore, the system's 4" wafer uniformity and precise process control is especially important for device production on cost-intensive silicon carbide wafers. The new reactor is equipped with optional features such as dynamic gap adjustment, ARGUS in-situ temperature control and the LayTec EpiCurve TT metrology system. The ARGUS monitoring device provides full wafer mapping in real time for optimum control of the growth process. Extended flexibility is enabled by allowing the adjustment of the process gap between the showerhead and the substrate.

SEDI already offers a range of GaN high-electron-mobility transistor (HEMT) devices for radar, mobile phone base-stations, and general applications. The GaN-on-SiC HEMT devices enable high-power amplification at operating frequencies of up to 14GHz RF.

www.sedi.co.jp/e
www.aixtron.com

EpiValence voted a top 10 Manufacturing Supplier by NMI

MOCVD and ALD precursor materials maker EpiValence of Redcar, Cleveland, UK was voted a top 10 Manufacturing Supplier of 2016 in a poll by NMI (National Microelectronics Institute), the UK trade association representing electronic systems, microelectronics and semiconductor communities.

Each year NMI asks its manufacturing sites to rate their suppliers on the following areas: Customer Responsiveness; Quality of Products; Criticality of Product to Business; and Continuous Improvement Activities to Improve Products or Services.

http://nmiawards.uk
http://epivalence.com/2017/02/22

Atlas Copco forms new Vacuum Technique business, incorporating Edwards

Mike Allison appointed president of Semiconductor division and Paul Rawlings president of Semiconductor Service division

Integrated vacuum and exhaust-abatement equipment maker Edwards Ltd of Burgess Hill, West Sussex, UK is now part of the newly formed Vacuum Technique business area of Atlas Copco Group (a Sweden-based provider of industrial productivity solutions that acquired Edwards in 2013). Mike Allison has been appointed president of the Semiconductor division and Paul Rawlings is now president of the Semiconductor Service division. Both report to Geert Follens, president of the Vacuum Technique business.

"Mike Allison is a passionate business leader with deep and global experience from the semiconductor industry," comments Follens. "His proven track record in delivering strong business results through high-value solutions for our customers made him the best candidate for the position," he adds. "Paul Rawlings has a long history in the semiconductor industry with established relationships with key customers around the globe. He was an obvious choice to head our Semiconductor Service division."

The new Vacuum Technique organization comprises 13% of Atlas Copco Group's total business, and includes the Semiconductor, Semiconductor Service, Industrial Vacuum, High Vacuum and Vacuum Technique Service divisions. Major brands within the Semiconductor division include Edwards and CSK.

Founded by F.D. Edwards in 1919, Edwards High Vacuum International became part of The BOC Group in 1968, and was named BOC Edwards in 1997. After acquiring The BOC Group in 2006, Linde Group sold the component business (vacuum pumps and semiconductor equipment) of BOC Edwards in 2007 for €685m (£460m) to private equity firm CCMP Capital.

www.edwardsvacuum.com

SUSS MicroTec launches XBS200 automated permanent wafer bonding system

At SEMICON China 2017 in Shanghai (14–16 March), SUSS MicroTec AG of Garching, Germany, which makes photomask aligners, laser processing systems and wafer bonders, is launching the XBS200 automated permanent wafer bonding system, a universal platform designed for aligned wafer bonding of wafer sizes up to 200mm.

SUSS MicroTec says that the versatility and modular design offer maximum process flexibility in all permanent bonding tasks. A novel aligned wafer transfer method eliminates the complexity of traditional systems and offers consistent process results with what is claimed to be excellent system availability. The XBS200 platform provides low cost of ownership for high-volume production of MEMS, LED and 3D stacked devices, adds the firm.

The new bond aligner uses SUSS MicroTec's proprietary Inter-Substrate Alignment (ISA) technology to deliver consistent submicron alignment. Automated calibration and overlay verification ensures optimum repeatability.

Based on the standalone XB8 bonder, the bond chamber offers a wide parameter window with temperatures of up to 550°C and bond forces of up to 100kN. The mechanical and thermal chamber design results in optimal bonding force and temperature distribution across the wafer and therefore ensures high yield, says the firm.

"With the development of the new XBS200 platform, SUSS MicroTec enters the attractive market for automated permanent bonding systems," says Stefan Lutter, general manager of the bonder product line. "The XBS200 is based on our successful temporary bonding equipment platform and was designed according to the needs and demands of our customers," he adds. "The XBS200 offers high throughput along with a small footprint, high alignment accuracy and repeatability as well as excellent temperature and bond force uniformity for maximum yield."

www.suss.com/en/products-solutions/wafer-bonder/xbs200

EVG receives 2017 Austrian Innovation Award

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 received the 2017 Austrian Innovation Award (Staatspreis Innovation 2017) for the development of its SmartNIL nanoimprint lithography technology for micro- and nano-structuring of wafers and other substrates. The award was presented on 28 March by Vice Chancellor & Federal Minister of Science, Research and Economy Dr Reinhold Mitterlehner at a ceremony at the Hall of Sciences in Vienna.

EVG received the award for the project 'SmartNIL process and HERCULES NIL high-volume production system for nanoimprint lithography'. For electronic, micromechanical or optical components and products, existing manufacturing processes are often complex or do not provide the required precision, especially in high-volume production, notes EVG. Nanoimprint lithography can meet these requirements while reducing manufacturing costs by transferring extremely small structures from a stamp to a polymer material. Due to SmartNIL technology, which was specifically developed for this, uniform contact between the substrate and the re-usable imprinting stamp can be achieved even with sub-100nm structures, says EVG. Applications include optical and semiconductor fabrication, medical device manufacturing for DNA and protein analysis, diagnostics and drug discovery, as well as water quality screening.

From left to right, Dr Werner Thallner, Erich Thallner, Paul Lindner, Hermann Waltl and Dr Reinhold Mitterlehner. Source: Austrian Federal Ministry for Science, Research and Economy/APA-Fotoservice/Schedl.

In total, 485 companies competed for the 37th Austrian Innovation Awards, which were organized by the Austria Wirtschaftsservice GmbH (aws) on behalf of the Ministry of Science, Research and Economy. A jury of experts chose the winner based on its assessment of the nominated companies' products, processes or services, relevant entrepreneurial data as well as the innovation's impact on the market, environment and society.

www.EVGroup.com
www.staatspreis.at

Desert Silicon appoints former AXT CEO & chairman Phil Yin as general manager & board director

Desert Silicon Inc of Tempe, AZ, USA (which supplies spin-on glasses and other materials and services such as wafer bonding used in manufacturing integrated circuit and discrete component including LEDs) says that its board of directors has appointed Philip C.S. Yin Ph.D. as executive VP & general manager, as well as board director.

Dr Yin was most recently VP & general manager — China Operations for ARC Energy Inc, a manufacturer of equipment for growing sapphire crystals/aluminum oxide used in light-emitting diode bulbs and displays.

From 2005–2009, Yin was CEO & chairman of the board of AXT Inc of Fremont, CA, USA — which makes gallium arsenide (GaAs), indium phosphide (InP) and germanium (Ge) substrates and raw materials.

Phil Yin.

From 2003–2005, Yin was general manager for North America at deposition equipment maker Aixtron Inc. From 1999–2002, he was president of ATMI Epitaxial Services.

Prior to that, Yin held positions as senior VP of sales/marketing for Crysteco Inc, director of sales for Mitsubishi Silicon America, district sales manager for Monsanto Electronics Materials Corp (MEMC) and senior research engineer at IBM Thomas J Watson Research Center.

Yin received his undergraduate degree in Physics from Villanova University and his Ph.D. in Materials Science from Brooklyn Polytechnic Institute. He is a member of the Electrochemical Society and the American Association for Crystal Growth, and has authored five IBM Technical Disclosures, three trade journal publications, and holds three US patents.

"Phil's knowledge of our customers and technology — coupled with his prior leadership success, sales experience and technical expertise in semiconductors — makes him a valued addition to Desert Silicon," comments Desert Silicon's CEO Kent Ridgeway. "His record of success in increasing revenue, expanding market share and bringing shareholder value, driven by a results-focused leadership style, places Desert Silicon in a prime opportunity for exponential growth," he reckons.

www.desertsilicon.com

Monocrystal introduces first 350kg KY sapphire crystal

Extra Large Stress Free initiative responding to LED makers' requirements for 6-inch wafers

Monocrystal Inc of Stavropol, Russia (part of diversified industrial holding Energomera), which manufactures large-diameter synthetic sapphire substrates and cores for LED, optical product and RFIC applications (as well as screen printing metallization pastes for solar cells) has demonstrated what it claims is the first 350kg Kyropoulos (KY) sapphire crystal.

The 350kg crystal is a part of Monocrystal's technological roadmap, aimed at enabling higher crystal uniformity, more efficient large-diameter ingot throughput for LED, and size-sensitive optical applications. Low bubble content, which is crucial for ultra-large sapphire products, has been achieved with the 350kg crystal. Another objective of the roadmap is to move Monocrystal's sapphire supply reliability to a new level, which is now of paramount importance since major LED makers are increasing their capacities, says Monocrystal.

Monocrystal's 350kg KY sapphire crystal (left), next to its 300kg and 140kg crystals.

"Our ongoing 'Extra Large Stress Free' initiative is in response to challenging conditions on our main market: sapphire for LEDs," says CEO Oleg Kachalov. "Extra-large crystals enable high crystal uniformity across a 6" wafer surface and guarantee uniform wavelength distribution. Our LED customers are able to ramp up their production securely, having Monocrystal as a reliable source," he adds.

"We also have received a very positive feedback from the non-LED market since the introduction of our extra-large crystals in 2015," says VP sales Mikhail Berest. "Working closely with our partners, we have already enabled several promising large-size applications. We are confident that our new 350kg crystals will allow greater flexibility of our customers' designs and further expand the scope of sapphire use."

www.monocrystal.com

Rubicon names director Timothy E. Brog as CEO

Rubicon Technology Inc of Bensenville, IL, USA (which makes monocrystalline sapphire substrates and products for the LED, semiconductor and optical industries) has concluded its search for a new chief executive officer by appointing Timothy E. Brog (a director of Rubicon since May 2016). He replaces Bill Weissman, who has resigned as CEO & president, and as a member of the board of directors. Weissman will serve as a consultant to Rubicon under terms to be agreed upon.

The board will working with Brog on "his ideas relating to the core sapphire business, the sale of real estate and excess assets and our previously stated desire to explore various alternatives to enhance stockholder value, including potentially through acquiring an existing business, establishing a new venture, or other investment opportunities in order to utilize our substantial net operating losses," says chairman Don Aquilano. "He is an accomplished executive, with extensive investment, legal, management and financial experience," he adds.

"I also want to thank Bill for his tireless effort on behalf of Rubicon during a very challenging period where global excess capacity of sapphire drove prices to record low levels, particularly in two high-volume markets, LED and mobile devices," says Aquilano.

In addition, Rubicon has appointed Susan M. Westphal as a new independent director. Westphal has been chief counsel at Melissa & Doug LLC, a designer and manufacturer of educational toys and children's products, since February 2016, and is responsible for legal, strategic, and organizational matters. From January 2012 to January 2016, Westphal was an attorney with Brody and Associates LLC. Prior to 2012, she was an attorney at several law firms, including Epstein, Becker & Green p.c. Westphal's legal practice has included representing corporate clients in litigations and negotiations in commercial, real estate, and employment matters.

"I look forward to working with the board and Timothy Brog, Rubicon's new chief executive officer, on the company's efforts to implement change and maximize stockholder value," says Westphal. "We seek to strengthen the company's existing sapphire business, capitalize on new opportunities and position Rubicon for the future," she concludes.

www.rubicon-es2.com

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Everlight opens $300m automotive LED factory

Introduction of automation satisfies automotive standards while achieving production capacity of 200 million units per month

Taiwan-based Everlight Electronics Co Ltd has opened its Miaoli Tongluo New Factory, which is dedicated to automotive LED products, following the investment of over US$300m in construction.

Everlight began to expand its automotive-related activities in 2014, and the firm now owns a comprehensive portfolio of automotive LED products for all interior/exterior vehicle applications. All products are sulfur-resistant and have passed the corrosive gases test for H_2S, SO_2, Cl_2 and NO_2 etc.

Beginning in 2015 much investment has been made in constructing the new factory in order to satisfy the specific quality requirements for automotive products. As well as using automated optical inspection (AOI), radio-frequency identification (RFID) has been introduced to aid the manufacturing execution system (MES) in process control. All products will hence have a laser code engraved before die bonding, in order to facilitate tracking the in-process and post-process status of the product.

The new Tongluo factory for automotive LED components.

Due to the automation, the new factory reduces the manpower required, effectively reducing the logistic processes, maximizing the production efficiency, and achieving a production capacity up to 200 million units per month, reckons Everlight.

www.everlight.com

Seoul Semiconductor launches Acrich COB line-up

At the Lighting Fair in Tokyo, Japan (7–10 March), South Korea's Seoul Semiconductor presented its new Acrich chip-on-board (COB) family of products targeting the high-quality and high efficiency lighting market.

"Seoul Semiconductor's Acrich COB family is an entirely new LED concept, adopting its proprietary Acrich MJT multi-junction LED technology and direct AC technology on a COB platform," says chief technology officer Nam Ki-Bum.

Based on Acrich (the firm's core technology for high-efficiency direct AC-driven LEDs), Acrich COB has two line-ups: MJT COB and AC COB. MJT COBs use integrated multi-junction technology chips and have what is said to be the world's highest luminous efficacy of up to 168lm/W. They come in standard form factors with a single power connection. AC COBs use direct AC driving technology, which combines four groups of LEDs in a unique, solderable design. This dramatically improves the simplicity in design and the lifetime of the product by eliminating the external AC–DC converter.

The line-up includes 11 different MJT COB products ranging from 6W to 180W and 6 Acrich COB products that operate off 120V and 230V AC supplies. Seoul Semiconductor also provides various solutions such as optics and holders to aid manufacturing of lighting fixtures.

Also, Seoul Semiconductor has developed a high-CRI (color rendering index) COB for spot lighting for broadcasting studios. The firm has applied its MJT COB technology, yielding what is claimed to be the best performance in the industry.

MJT COB combines multi-junction technology and chip-on-board technology, for which Seoul Semiconductor owns the corresponding patents. It uses integrated multi-junction technology, and is characterized by high light quality and reliability, says the firm.

The luminous efficacy of 168lm/W, together with a correlated color temperature (CCT) of 5000K, a CRI of 80, a junction temperature of 85°C and 40W of power, is about 6% higher than that of existing products, the firm says. The high performance is achieved with an MJT COB that uses only 54 chips, compared with competing COB products requiring 144 chips, Seoul Semiconductor says. Also, MJT COB is claimed to be more reliable due to a significant reduction in wire bonds (a leading cause of defects in COB products).

The AC COB product line is driven by an AC source of either 120V or 230V. As it does not require a bulky and short-lived converter, the circuit cost can be reduced by about 25%, and it features good space utilization and a long lifetime, says the firm.

Both product lines are suitable for a wide range of general lighting applications requiring high-quality and high-efficiency indoor and exterior lighting applications including shop lighting streetlights, industrial and commercial lighting.

"In addition to the MJT COB and AC COB line-ups, we will also be launching two enhanced COB products this year, and we are going to market them worldwide together with all our high-quality LED solutions," says Nam Ki-Bum.

www.seoulsemicon.com

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Cree signs patent cross-license agreement with Ledvance

Cree to receive royalty payments and royalty-free license to Ledvance's patents in exchange for license to Cree's LED light bulb & LED patents

LED chip, lamp and lighting fixture maker Cree Inc of Durham, NC, USA has signed a cross-license agreement under which it will receive ongoing royalty payments and a royalty-free license to the patent portfolio of lighting firm Ledvance Inc. In exchange, Ledvance will receive a license to Cree's portfolio of patents related to LED light bulbs and LED luminaires.

The licensed patents address various aspects of forming an LED light including optics, heat management, LED power and control, LED light efficiency and light color and uniformity. Certain patents that cover Cree's networked lighting technology (SmartCast) and color mixing technology (TrueWhite) were excluded from the license.

"With intellectual property developed over the past 29 years, Cree has a deep portfolio of technologies that are elemental to the design and manufacture of high-performing LED bulbs and LED luminaires," says Brad Kohn, VP legal and general counsel for Cree. "This recent licensing agreement with Ledvance is yet another example that demonstrates the value of Cree's R&D investments, as well as the breadth and strength of Cree's lighting technologies."

www.ledvance.com

XLamp XP-G3 Royal Blue LED launched for horticulture applications

Cree has launched the XLamp XP-G3 Royal Blue LED, which is claimed to be the industry's highest-performing Royal Blue LED, doubling the maximum light output of similar-size competing LEDs and delivering wall-plug efficiency of up to 81%.

The new Royal Blue LED expands Cree's high-power portfolio for applications such as horticulture, architectural and entertainment lighting. Using the XP-G3 Royal Blue LED and the XP-E High Efficiency Photo Red LED (launched in October 2016), Cree says that it has created a new horticulture reference design that achieves a photosynthetic photon flux (PPF) efficiency of up to 3.2µmol/J at steady-state, which is over 50% more efficient than the traditional high-pressure sodium solutions currently in use. The XP-G3 Royal Blue LED delivers up to 3402mW radiant flux (equal to 13µmol/s PPF) at its 2A maximum current and 85°C junction temperature.

"Our newest horticulture-optimized products help lighting manufacturers push LED horticulture systems into mainstream use," says Dave Emerson, Cree LEDs senior VP & general manager. "Cree's high-power LED technology provides the best combination of photon output, efficiency and reliability to drive the replacement of outdated high-pressure sodium lights with LED lighting solutions that minimize power consumption and maximize crop yield," he reckons.

The XP-G3 Royal Blue LED is based on Cree's ceramic high-power technology, which can deliver what are claimed to be excellent lifetimes even at the extreme temperature of 105°C. Additionally, horticulture lighting manufacturers can immediately take advantage of the existing ecosystem of drivers and optics proven to work with Cree's other 3.45mm-footprint XP products to shorten their time to market.

Product samples of the new XP-G3 Royal Blue LEDs are available now. Production quantities are available with standard lead times.

www.cree.com/xlamp/horticulture

Cree expands ZR series LED troffer family to higher efficiencies

Cree has expanded its ZR Series LED troffer family by launching the ZR-C Commercial troffer in addition to the ZR-FD High Efficiency and updated ZR-T TrueWhite products. The series will feature Cree SmartCast Technology to provide advanced controls.

Cree says that, by expanding the range, it is making it easier to select the appropriate solution for each application by providing multiple options for affordability, efficiency, color quality and controls.

"Expanding our ZR Series troffer portfolio to address the unique requirements of each application or project, whether it is superior color quality or maximum savings, ensures that our customers always have a high-performance option," says David Elien, Cree senior VP & general manager, lighting.

The ZR-C Commercial line is said to provide affordable performance with premium rebate eligibility, capturing maximum energy savings and rebates for the most competitive projects. The line provides luminous efficiency of 125 lumens per watt (LPW), making it up to 10% more efficient than other products, it is claimed.

For those seeking enhanced energy savings, the ZR-FD High Efficiency troffer offers 130 lumens per watt and optional SmartCast Technology to boost energy savings by up to 70%. For applications requiring color accuracy, the ZR-T TrueWhite troffer delivers 90+ CRI (color rendering index), lifetime color consistency and an 11% boost in efficacy, from 90 to 100LPW.

www.cree.com/lighting/ZRSeries

Cree's second-generation Extreme High Power LED boosts lumen output by 9% and efficacy by 18%

LED chip, lamp and lighting fixture maker Cree Inc of Durham, NC, USA has introduced the XLamp XHP70.2 LED, the second generation of the highest-output Extreme High Power LED, which delivers up to 9% more lumens and 18% higher lumens-per-watt (LPW) than the first-generation XHP70 LED. The XHP70.2 LED provides up to 58% higher lumen density than the closest competitor LED of the same size, it is reckoned, enabling smaller luminaires and better optical control for high-lumen lighting applications than ever before.

"We selected Cree's first-generation XHP70 LED as the best light source for large areas, including sporting and industrial facilities, because it enabled us to create smaller and more innovative LED lighting systems with unprecedented output and efficacy," comments Ing. Flavio Sangiorgio, R&D director at lighting firm Fael Luce SpA. "The improved efficacy of the next-generation XHP70.2 LED lets us easily upgrade our products to maintain performance leadership without any major redesign," he adds.

The XHP70.2 LED features the same 7.0mm x 7.0mm footprint as the previous generation and provides an easy drop-in upgrade for customers with existing XHP70 designs. In addition to light output and efficacy enhancements, the XHP70.2 LED improves optical uniformity through secondary optics, enabling lighting manufacturers to deliver better lighting performance. Also, LM-80 data is available immediately, reducing the time required to receive ENERGY STAR and DesignLights Consortium qualifications.

"Unlike some companies, Cree continues to invest in improving light output, efficacy and reliability of our Extreme High Power LEDs to enable our customers to quickly improve their existing designs and create innovative new products," says Dave Emerson, Cree LEDs senior VP & general manager. "Our XHP LEDs highlight the unique advantages of Cree's ceramic high-power LED technology in reducing the cost and improving the performance of systems where extreme light output is required."

Featuring Cree's EasyWhite technology (which is claimed to provide the industry's best color consistency), XHP70.2 LEDs are available in correlated color temperatures (CCTs) of 2700-6500K with high-CRI (color rendering index) options. Product samples are available now, and production quantities are available with standard lead times.

www.cree.com/xlamp/xhp70_2

Cree boosts XLamp CXA2 LED output by 10% and adds premium color options

Cree Inc of Durham, NC, USA has enhanced its XLamp CXA2 family of chip-on-board (COB) LEDs, including new premium color options, higher light output levels and what are claimed to be the longest lifetimes published for this type of LED.

The premium color quality options include high fidelity (98 color rendering index) and specialty color points for the 9–19mm LES (light-emitting surface) sizes with up to 50% higher efficacy than LEDs of similar sizes and light quality. The enhancements enable users to upgrade the performance of existing designs and to sell their products into lighting applications where color quality is important, such as museum, retail and medical lighting, says Cree.

"The leading efficacy and excellent reliability of Cree's CXA2 LEDs allow us to create a complete portfolio of high-quality, energy-efficient LED track lights," comments Eric Lin, general manager of Westport International. "With the new premium colors, the CXA2 family will allow us to bring these same advantages to more customers and applications while still leveraging the same, easy-to-use platform."

Cree's XLamp CXA2 chip-on-board LED.

Enhancements enable users to upgrade the performance of existing designs

The CXA2 Standard Density LEDs now deliver up to 10% higher light output levels across all CRIs and LES sizes, providing the highest chip-on-board (COB) LED efficacy for all applications. The CXA2 LEDs are claimed to be the only COB LEDs to have more than 11,000 hours of LM-80 data available. Based on this data, they provide L90 lifetimes well beyond 60,000 hours, even under extreme 105°C test conditions.

Product samples are available now and production quantities are available with standard lead times.

www.cree.com/cxa2premium

Osram launches 810nm IR LED to increase image contrast in license plate recognition

Osram Opto Semiconductors GmbH of Regensburg, Germany is expanding its Oslon product family of high-power infrared LEDs for illumination solutions to include a new wavelength (810nm), benefiting camera systems such as those used to read license plates.

The additional wavelength of the SFH 4703AS can be used to improve image contrast, making it easier to read patterns from recorded images. Also, camera sensors have higher sensitivity at 810nm. At the same optical output, the new device hence extends the range of camera systems compared with 850nm.

Greater image contrast

The new wavelength is advantageous for applications requiring superior image contrast. The 850nm and 940nm typically used currently have difficulty creating high-contrast images of certain color combinations.

For camera systems supporting automatic license plate recognition at toll stations or entrances to parking garages, the SFH 4703AS yields higher-contrast images for many types of license plates, making it easier to retrieve the numbers. Hence, automated barriers function more smoothly, reducing waiting times for drivers. Other camera applications can also benefit, such as traffic monitoring and closed-circuit television (CCTV) systems.

Increased range

The new wavelength has the bonus that the spectral sensitivity of typical camera sensors is higher at 810nm than it is for 850nm and 940nm. Using a light source with the same optical output, an 810nm system will achieve a greater detection distance than was previously possible. Alternatively, this also allows designers to reduce the number of components if they wish to maintain the same range. However, Osram says that designers should bear in mind that humans do perceive infrared light as a mild red glow, and this is stronger at 810nm than at 850nm.

Optical performance from proven package

Osram currently provides 810nm emitters for iris scanners in mobile devices. For the SFH 4703AS, developers mounted the highly efficient chip manufactured in nanostack technology in the tried-and-tested Oslon package for illumination applications. At 1A current, the emitter generates 1W optical power. The beam angle of ±45° allows for broad illumination, with a resulting radiant intensity of 630mW/sr at 1A. The component measures 3.85mm by 3.85mm, and is 2.29mm high including the lens.

The firm says that, with the new device, designers can now choose from mutually compatible emitters in three different wavelengths. These can be combined within a single illumination unit or used to convert existing systems to another spectral range without the need for layout changes.

www.osram.com

New Oslux IRED yields high-quality images for facial recognition

Osram has expanded its Oslux product family for biometric security with a special variant for facial recognition. Exhibited at the 2017 Mobile World Congress (MWC) in Barcelona, Spain, the compact infrared SFH 4796S LED (IRED) ensures uniform illumination of facial features for high image quality, says the firm.

For secure biometric identification, facial recognition records a user's face and detects typical features independent of facial expressions. To identify features accurately and reliably, high-quality images are needed, by illuminating the face brightly and evenly, without shadows. To safeguard laptops and tablets, it must also work in varied lighting conditions. The solution lies in additional illumination of the face with infrared light.

Boosting system efficiency

Based on its proven Oslux family, the new IRED package's low-profile design enables a narrow emission angle. This ensures that the generated light hits exactly the point where illumination is required, so the overall system operates very efficiently. Also, Oslux IREDs are based on an internal reflector and a specially adapted, integrated lens, and the flat component surface is a particular advantage.

Facial illumination

The SFH 4796S's emission angle (±40°) suits the field of view needed for facial recognition. Due to specially adjusted internal reflectors and lenses, the IRED achieves very even illumination of the face. "We can build on our in-depth knowledge around the interplay between chip, package, reflector and optical elements," says marketing manager Bianka Schnabel. "Adding this new device to the family allows us to offer a broad portfolio specifically for the Oslux package, now also encompassing dedicated solutions for facial recognition."

The SFH 4796S is based on a highly efficient chip featuring nanostack technology. At 1A current, it outputs 800mW, ensuring ample illumination for identification applications. Radiant intensity is 550mW/sr. The IRED is just 1.4mm high, with a footprint of 3.5mm x 3.5mm. At a 850nm, the emitted light does not dazzle users and is simply perceived as a weak red glow, giving an indication that the facial recognition function is currently active. The sensitivity of camera sensors in this spectral range remains good.

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FerroTec

AIM Photonics gains process modeling firm Coventor as new member

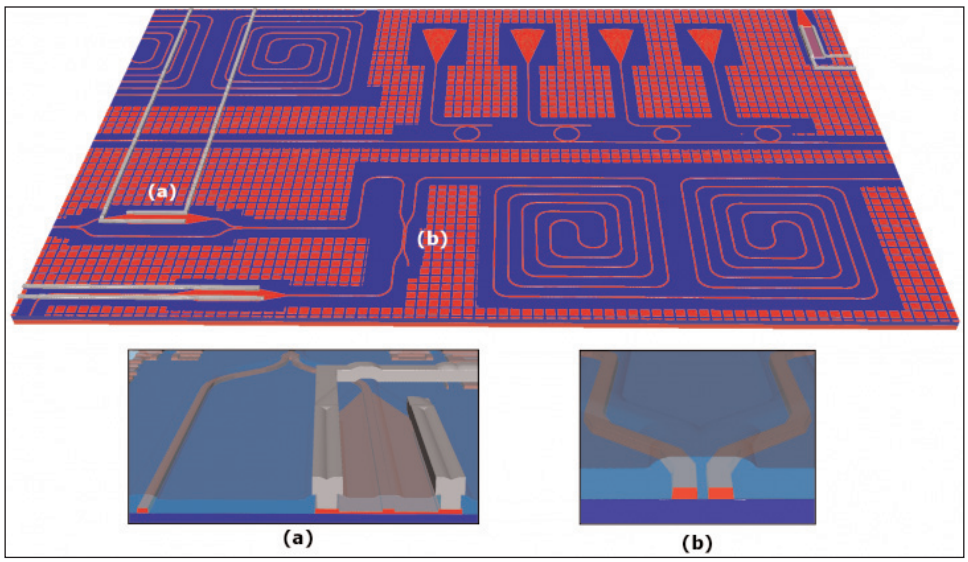
3D modeling technology to improve manufacturing of high-yield, complex integrated photonic designs

The Rochester-based consortium AIM Photonics (American Institute for Manufacturing Photonics), an industry-driven public–private partnership advancing the USA's photonics manufacturing capabilities, has announced Coventor Inc of Cary, NC, USA, which provides automated design software tools for developing semiconductor process technology and micro-electromechanical systems (MEMS), as its newest member. Coventor will provide access to its unique, physics-driven 3D modeling technology to improve the performance and manufacturability of complex integrated photonic designs.

"AIM Photonics partnership with Coventor is another key building block in expanding this vital ecosystem," says John Maggiore, New York State photonics board of officers chairman. "We are creating nothing short of a revolution in integrated photonics for our members, companies in NY's Photonic Valley, and across the USA," he reckons.

"Tasked with fostering advanced research in integrated photonics to enable the United States to achieve global manufacturing leadership, AIM Photonics is building a membership that includes the country's most innovative technology companies," says Robert Duffy, chairman of the AIM Photonics Leadership Council. "Coventor's process modeling capabilities are strategic to our success and will help ensure the manufacturability of photonic designs produced in the USA."

Managed by SUNY Polytechnic Institute, AIM Photonics was established in 2015 as part of the National Network for Manufacturing Innovation, a federal initiative designed to foster innovation and deliver new capabilities that can ultimately create a nationwide manufacturing infrastructure for integrated photonics.



Silicon photonics test die with top cladding removed to show structures, with close-ups of (a) a Mach–Zehnder modulator and (b) a directional coupler.

Coventor's SEMulator3D modeling and analysis platform provides a complete virtual fabrication environment that models actual semiconductor processes and parallels the capabilities of actual fabs. It enables photonic device designers to perform fast 'virtual' fabrication of their devices and accurately predict downstream ramifications of process changes that would otherwise require build-and-test cycles in the fab.

SEMulator3D modeling and analysis platform provides a complete virtual fabrication environment that models actual semiconductor processes and parallels the capabilities of actual fabs. It enables photonic device designers to perform fast 'virtual' fabrication of their devices and accurately predict downstream ramifications of process changes

"Building upon our commercial experience in the semiconductor industry, we see our membership in AIM Photonics as essential to our mission in supporting the design and manufacturing of next-generation photonic integrated components," says Coventor's president & CEO Michael Jamiolkowski.

"Coventor's expertise in process modeling brings value to AIM Photonics and its membership and is key to scaling and integrating photonic design into commercial applications," comments Dr Michael Liehr, CEO of AIM and executive VP of technology and innovation for SUNY Poly. "We look forward to working with Coventor on next-generation electronic-photonic design platforms that support first-pass, high-yield manufacturing of advanced silicon photonic devices."

www.aimphotonics.com
www.manufacturing.gov/nnmi
www.coventor.com/semiconductor-solutions/semulator3d

MRSI delivers 3µm die bonder to AIM Photonics Academy's Education & Practice Factory at MIT

MRSI Systems of North Billerica, MA, USA, which manufactures fully automated, high-precision die bonding and epoxy dispensing systems, has installed its flagship MRSI-M3 3µm die bonder in AIM Photonics Academy's Education and Practice Factory at the Massachusetts Institute of Technology (MIT) in Cambridge, MA, USA. MRSI reckons that this is the beginning of a relationship that will lead to further collaboration in research and education of integrated photonics.

The American Institute of Manufacturing (AIM) Photonics Academy built the Education and Practice Factory at MIT to enhance its education and training programs in integrated photonics manufacturing for the next generation of engineers. MRSI says that AIM Academy chose it as a partner because of its 33 years of experience as a leading supplier in the industry, its strategic vision, and its fast, accurate, and flexible systems that research and high-volume manufacturing of integrated photonics require. The MRSI-M3 will be an integral part of the Factory's education and training program in chip packaging, board integration and assembly, and inspection and testing.

"MRSI Systems has been serving optoelectronics and microelectronics customers for the past 33 years," notes president Michael Chalsen. The AIM Photonics Academy's Education and Practice Factory at AIM Academy has created "a unique environment for engineering students and researchers to learn automation and to develop advanced prototypes at the same time," he adds.

"We chose MRSI Systems and the MRSI-M3 because we value MRSI's state-of-the-art automation technology, strong process knowledge, and its products' flexibility for research and volume manufacturing," comments Brian W. Anthony PhD, associate director, AIM Photonics Academy. "MRSI Systems offered the best package for our requirements," he adds. "We look forward to further collaboration with MRSI Systems in training programs and prototype development," Anthony concludes.

www.mrsisystems.com
www.aimphotonics.com

VCSEL maker Princeton Optronics to be acquired by Austria's ams

Adding illumination source extends ams' optical sensor portfolio

ams of Premstaetten, Austria, which designs and manufactures high-performance sensor and analog solutions, has agreed to acquire Princeton Optronics Inc of Mercerville, NJ, USA in an all-cash transaction comprising $53.3m upfront and a cash earn-out related to realized 2017 and 2018 revenues, with a potential maximum earn-out value of $75m.

With a total of 37 staff, Princeton Optronics develops high-power single-mode and multi-mode vertical-cavity surface-emitting lasers (VCSELs) and VCSEL arrays for mobile, consumer, automotive and industrial applications. The firm operates an outsourced high-volume supply chain with partners in Taiwan, the USA, and the UK. Annual revenue is about $10m and the firm is profitable.

In the mobile and consumer markets, Princeton Optronics says it realizes benchmark power efficiency and accurate control of beam divergence. In automotive and industrial applications, the firm's technology enables high-temperature operation and delivers high-power pulsed lasers and laser arrays that support future applications. The use of VCSELs is expected to gain momentum in optical sensor solutions for the human-machine interface (HMI). Broader adoption of 3D sensing in mobile applications could accelerate market growth for VCSEL light sources in the coming years.

"Adding the illumination source expands ams' optical sensor solutions offering, with the light path optics covered by Heptagon and the light sensor including filters by ams," says ams' CEO Alexander Everke. "Leveraging this portfolio, ams can now design and manufacture the most complete and differentiated optical solutions for future growth areas like mobile 3D sensing and imaging or automotive autonomous driving," he adds. "Princeton Optronics is a strategic partner to ams/Heptagon for optical sensing products already, so we see a range of potential future synergies."

The acquisition is expected to close within six months (subject to certain approvals and conditions defined in agreements with the sellers).

www.ams.com
www.princetonoptronics.com

Excelitas launches 1x4 pulsed laser diode array for LiDAR in autonomous vehicles

Excelitas Technologies Corp of Waltham, MA, USA (which provides customized photonic solutions to OEMs) has launched the 1x4 Pulsed Laser Diode Array for LiDAR applications.

The new laser array combines the firm's field-proven high-efficiency, multi-cavity laser chip technology with small-form-factor surface-mount device (SMD) packaging for applications requiring high reliability such as autonomous vehicles and drones.

The 1x4 Pulsed Laser Diode Array constitutes a key building block of LiDAR systems, which have become an indispensable detection technology for autonomous vehicles. Unlike single-pixel lasers, the 1x4 linear configuration enables each pixel to be situated in close proximity to its neighbour, minimizing space requirements in the assembly and enabling the use of smaller, less costly optical components. It is fully compatible with SMD pick & place and reflow soldering equipment, allowing it to integrate into high-volume, low-cost assembly lines.

New 1x4 Pulsed Laser Diode Array.

Each laser pixel can have up to four emitting stripes, enabling per-channel optical power levels in excess of 85W for long-range detection with minimal power consumption. The lasers can sustain large reverse voltage levels, with rise times of less than 5ns that can be achieved with appropriate drive electronics (which can also be provided by Excelitas).

The standard 1x4 Pulsed Laser Diode Array can be customized to meet each customer's optical system requirements. Variables such as the number of elements, element spacing, stripe width, channel power output and package footprint can be adjusted to enable minimized losses, longer-range detection and reduced power consumption.

"Excelitas is actively involved in LiDAR for autonomous vehicles," says product leader Denis Boudreau. "This new laser array combines multi-cavity lasers and SMD packaging capabilities to address OEM design engineers' need for a high-performance, customizable solution that enables the development of next-generation LiDAR systems."

The 1x4 Pulsed Laser Diode Array debuted at SPIE Photonics West 2017 in San Francisco (31 January – 2 February).

www.excelitas.com

Daylight to be acquired by Leonardo DRS for $150m

US subsidiary of Italian defense firm gaining QCL-based IR technology

Daylight Solutions Inc of San Diego, CA, USA — which makes molecular detection, imaging and illumination systems based on mid-infrared quantum cascade lasers (QCLs) for scientific research, life science, industrial process control and defense applications — has signed a definitive agreement for its acquisition for $150m by Leonardo DRS of Arlington, VA (the US subsidiary of Italy's Leonardo S.p.A., formerly Leonardo-Finmeccanica S.p.A.).

Leonardo DRS (formerly DRS Technologies Inc) is a supplier of integrated products, services and support to military forces, intelligence agencies, and prime contractors worldwide. The firm specializes in naval and maritime systems, ground combat mission command and network computing, global satellite communications and network infrastructure, aviation support and avionics systems, and intelligence and security solutions. DRS also builds power systems and electro-optical/infrared systems for commercial customers.

Daylight will operate as one of eight Leonardo DRS lines of business, and will maintain its current management and location in San Diego. The transaction has been devised to be essentially transparent to Daylight's current customers and supply chain partners. All of Daylight's current contracts will continue to be executed without change.

"With this acquisition, Leonardo DRS reinforces its commitment to remain at the forefront of infrared technology to not only protect our men and women in uniform but also to perform critical tasks across a range of industries, including medical and industrial applications," says Leonardo DRS' CEO Bill Lynn.

"Daylight has established itself as a market leader in scientific lasers, infrared microscopy and lasers for aircraft survivability utilizing QCL technology," says Daylight Solutions' chairman & CEO Dr Timothy Day. "Together with the added strength of the people and resources of Leonardo DRS, the mission of Daylight Solutions 'To Protect with Light' will be more fully realized and will enhance our proven ability to transition new technologies into commercial products for a wide range of industries."

All three co-founders, Timothy Day, Paul Larson and Sam Crivello, will remain with Leonardo DRS. The acquisition is subject to a number of closing conditions, including the receipt of regulatory approvals, review by US anti-trust authorities, and by the Committee on Foreign Investment in the United States (CFIUS).

www.daylightsolutions.com
www.drs.com

Ushio America and Necsel IP announce integration

Ushio America Inc of Cypress, CA, USA (a subsidiary of Ushio Inc of Tokyo, Japan that manufactures specialty and general illumination lighting solutions) and Necsel Intellectual Property Inc of Milpitas, CA, USA (which manufactures visible lasers and laser systems for the projection, endoscope, bio instrumentation, industrial and life sciences markets, and which became a fully owned Ushio company in December 2010) have announced the integration of both companies to offer a full spectrum of light sources including lamps, LEDs, lasers, drivers, systems and services. Ushio America will operate as a matrix organization consisting of four individual business units: Solid State Solutions, Semiconductor and Industrial Solutions, Specialty Lighting Solutions, and General Lighting Solutions.

William F. Mackenzie (who was most recently founder, chairman, president and CEO of Necsel IP, and later group executive officer of Ushio Inc) will lead Ushio America Inc as president & CEO. Shinji Kameda will serve as chief operating officer, running the four business units of the new matrix organization.

"I look forward to working with them to create this new solution-driven and one-stop shop for all types of light source solutions," says Mackenzie about Ushio. "I have been working closely with Ushio Inc in Tokyo and other Ushio group companies for the last eight years," he adds.

"I have been working with William for the last several months, but I have known him for several years, and watched the successful and profitable growth of Necsel," comments Kameda. "Our ideas are in alignment, so this is an exciting opportunity for both Ushio America and Necsel," he believes.

Mackenzie has over 30 years of international business experience in executive management, marketing, engineering and operations, since beginning his career in 1987 in engineering at Motorola Semiconductors in the UK. He has since served as CEO and in various executive management roles in both public and private companies ranging from small, innovative startups to Fortune 100 companies. Mackenzie has also helped to start one of the fastest-growing semiconductor firms, which went public in 2001 with a market capitalization of >$3bn, just four years after inception.

In over 25 years with Ushio in sales and business development, Kameda directed Ushio's Excimer lamp business (capturing market share, with revenue of >$50m). He became CEO & president of Ushio America in October 2014, only 18 months after serving as general manager, Business Development, and Emerging Technologies.

www.ushio.co.jp/en

POET's losses rise after lower-than-expected revenue in second-half 2016

Prototype low-loss micro-multiplexer and demultiplexer in Q2/2017 to lead to customer sampling in Q3

For full-year 2016, 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$1.86m (compared with none in 2015). This reflects about seven months of contribution from Singapore-based subsidiary DenseLight Semiconductor Pte Ltd (acquired in May) — mainly from photonic sensors for test & measurement applications — plus non-recurring engineering (NRE) revenue of US$154,000.

For second-half 2016, revenue was US$1.29m, below the prior guidance of US$1.6–1.8m (which had previously, in December, been lowered from US$2m) due to previously disclosed operational inefficiencies.

Gross margin for full-year 2016 was 26%, impacted by fair value of inventory adjustments related to a prior acquisition. Net loss was US$13.2m ($0.06 per share), up from US$12.1m ($0.07 per share) in 2015. Cash and short-term investments totalled US$14.9m at the end of 2016.

Beginning in late 2016, POET conducted a strategic review of DenseLight, while simultaneously taking steps to improve operational efficiencies. These and other actions taken to streamline the consolidated company and realign management responsibilities were completed during first-quarter 2017. POET has hence also strengthened its management team by adding several key personnel, including appointing Rajan Rajgopal as president & general manager of DenseLight.

"Since our last earnings release [in late November, for Q3/2016], POET has made notable progress with the development of our integrated photonics engine," says CEO Dr Suresh Venkatesan. "We have achieved a very significant milestone for the company — successfully demonstrating the functionality of our vertical-cavity surface-emitting laser (VCSEL) for the integrated GaAs [gallium arsenide] optoelectronic platform," he adds. After establishing a second supplier for the proprietary epitaxial stack, POET completed the first phase of epitaxial design optimization in January, followed by VCSEL fabrication and validation of its functionality and performance. "The pace of progress has rapidly increased with the resumed development cycles at our epitaxial wafer vendor and our foundry partner in Taiwan, helping to further advance the development of our fully integrated optical engine," notes Venkatesan. "The development program for the POET photonic engine continues to be focused on single-chip transceivers for the active optical cable (AOC) market."

Results from the recent validation process indicated that VCSEL threshold currents were near expectations and with good process yields, demonstrating what are claimed to be excellent material properties and surpassing the previous results. POET is now focused on additional performance optimization and is addressing that, along with the rest of its planned ongoing development activities towards a single-chip transceiver optical engine.

Strategic update

POET says it has also substantiated a complementary opportunity to further leverage DenseLight's indium phosphide (InP) technology and dielectric waveguide devices developed at BB Photonics Inc (a designer of integrated photonic solutions for the datacoms market, acquired in May 2016).

This new dielectric photonics approach consists of integrating InP-based chips together with dielectric waveguide devices, eliminating the need for active alignment and expensive packaging. In addition to POET targeting the short-reach AOC market, dielectric photonics-based hybrid integration enables the potential for much lower-cost solutions in medium-reach data-center applications, greatly expanding the addressable market across multiple higher-volume opportunities, POET reckons.

The firm also expects to increase its addressable market for sensing products with unique low-cost solutions by incorporating BB Photonics' designs for waveguide multiplexers and filters together with the DenseLight InP product portfolio.

Collectively, POET's strategy to pursue new solutions that combine both monolithic and hybrid integration approaches will enable it to target the fast-growing 100G-and-beyond transceiver market, reckons the firm, offering both fully integrated optical engines as well as individual active and passive components.

"Since my appointment earlier this year, I have worked extensively with the board and management team to formalize a strategy that we believe can fully leverage the company's GaAs and InP technology platforms," says executive chairman David Lazovsky. "The acquisitions of DenseLight and BB Photonics provided the company with critical capabilities to pursue additional high-volume markets within data communications in order to expand and diversify our business. Moreover, by broadening our integrated photonics platform capabilities, we are significantly expanding the size of the company's addressable

market and business opportunities in data communications with the addition of medium-reach applications," he adds. "Although it will take additional time to realize these opportunities, I believe our strategy will ultimately drive higher unit volumes and revenue across a broader target market."

The firm expects that the product development phase for the POET monolithic integration technology, and the integration of BB Photonics technology into the DenseLight product portfolio as part of new hybrid approaches, will be the primary focus of its development activities throughout 2017. Initial commercial revenue contribution from new DenseLight sensing products is also anticipated in 2017.

New products

Also, subsequent to year-end, the firm announced that, leveraging passive dielectric waveguide technology from BB Photonics, low-loss micro-multiplexer and demultiplexer solutions for 100G-and-above transceivers are currently under development. POET Technologies highlighted this technology at the Photonic Integrated Circuits International (PIC) conference in Brussels, Belgium (7–8 February), and also discussed the first target application as being local-area network (LAN) WDM filters for high-speed transceivers. The firm expects prototypes to be available in second-quarter 2017, followed by initial sampling with customers during Q3.

In February, DenseLight demonstrated the newest generation of its Constellation series of narrow-linewidth lasers (NLWLs) for Wind LiDAR and distributed acoustic sensing (DAS) applications. The NWL lasers were designed specifically to meet the increasing requirement across multiple end-markets for superior relative intensity noise (RIN) performance and ultra-narrow linewidths, says POET. The new family of products simplifies the overall design process for OEMs, while shortening development time and accelerating time-to-market, it adds. The firm plans to make engineering samples available in second-quarter 2017 and expects to begin commercial production in the second half of the year.

Business outlook

Preliminary financial results for first-quarter 2017 are expected to reflect a sequential improvement in revenue. Additionally, while management continues to emphasize efforts aimed at minimizing the net cash used from operations, the timing of reaching cash-flow breakeven will largely depend on the future revenue performance of its DenseLight subsidiary as well as continued expense management.

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

ColorChip raises an extra $17m, boosting latest financing round to $37m

Optical transceiver firm to expand manufacturing capabilities and extend PAM4-enabled product range to 200G and 400G

Privately held optical transceiver firm ColorChip Ltd of Yokne'am, Israel has secured an additional $17m, boosting the total for its most recent round of financing to $37m (including the $20m raised last August). The latest financing was led by venture capital firm CIRTech fund, joined by Scale-Up fund.

Founded in 2001 by Dr Shimon Eckhouse and professor Shlomo Rushin of the School of Engineering at Tel Aviv University, ColorChip provides dense, hyper-scale high-speed optical transceivers for telecom/datacom markets as well as planar lightwave circuit (PLC) optical splitters for FTTx markets, after developing its patented 'SystemOnGlass' hybrid optical integrated circuit technology.

SystemOnGlass comprises multi-lane waveguide-in-glass photonic integrated circuits (PICs) that include both active optoelectronic components (indium phosphide-based lasers and photo-detectors) and passive optical components (PLCs). The firm uses glass wafers to industrialize its optical devices, allowing for what is claimed to be cost-effective, rapid and highly scalable production, and bringing efficiencies commonly only seen in semiconductor fabrication to optical communications.

The new capital will be used to accelerate go-to-market initiatives, expand ColorChip's manufacturing capabilities and fuel R&D. The firm hired 100 extra team members in the past 12 months, and during 2017 it will add 50 more to its operations and engineering groups as well as to R&D. Several products will be launched over the next two years.

"The space of web 2.0 and cloud providers is growing at an unprecedented rate, and ColorChip solutions and roadmap are in high demand," says CEO Yigal Ezra. "The company is building capabilities to support mega data centers in the US and Asia, while developing next-generation 400G solutions," he adds.

"ColorChip's optical transceiver solutions have been recognized for exceptional efficiency and reliability and are being deployed and trusted by leading mega data centers worldwide," comments Alex Lazovsky (managing partner at CIRTech Fund and Scale-Up), who has joined ColorChip's board of directors.

http://color-chip.com

Kaiam expanding UK manufacturing capacity by acquiring Compound Photonics' facility

Silica-on-silicon and transceiver manufacturing to be supplemented by integrated indium phosphide photonic integrated circuits

Kaiam Corp of Newark, CA, USA — a private company founded in 2009 commercializing hybrid photonic integrated circuit (PIC) technology for pluggable optical transceivers in data-centers — intends to acquire the manufacturing facilities of Compound Photonics Group Ltd (CP) in Newton Aycliffe in the UK. The deal includes investment by CP into Kaiam to further develop the facility. The agreement should be finalized in second-quarter 2017.

The large (300,000ft^2) manufacturing space enables expansion of Kaiam's datacom transceiver manufacturing capacity, and includes an extensive cleanroom for processing III-V devices, including pHEMTs, HBTs, photodetectors, and lasers. Originally built as a silicon fab for DRAM memory chips, the plant was converted to III-V materials by subsequent acquirers and now has both a 3" and 6" line for III-V devices.

Kaiam says that the addition of the Newton Aycliffe facility continues its trajectory of vertical integration. It acquired Gemfire, its strategic photonic lightwave circuit (PLC) supplier, in 2013, and operates an 8" silica-on-silicon line for the fabrication of integrated optical components in Gemfire's large-scale manufacturing facility in Livingston, Scotland, UK, where it also operates 40Gb/s and 100Gb/s optical packaging lines that are close to capacity due to increased demand. The Newton Aycliffe plant, with the fully operational wafer fab, allows Kaiam to expand its silica-on-silicon and transceiver manufacturing, and provides a long-term roadmap to add integrated indium phosphide (InP) photonic integrated circuits (PICs) for advanced transceivers.

"Our optical integration technology is based on MEMS-assisted assembly of different materials and components," says CEO Bardia Pezeshki. "We already have advanced integration in silica-on-silicon for manipulating light. In the future, with new modulation formats and increased speed, one also needs integration in the InP for generating, modulating and detecting light. By using our unique hybrid integrated technology for combining silica-on-silicon PICs and InP PICs, we get the best of all worlds," he adds. "The Newton Aycliffe site is a world-class facility in both capabilities and scale for producing III-V devices. This acquisition not only allows us to ramp product in the short term, but gives us access to advanced integrated InP PICs at low cost that we will need in the long term."

"CP no longer needed an in-house laser facility at Newton Aycliffe, and is very pleased that its Newton Aycliffe team is joining a fast-growing company in Kaiam," comments CP's chief financial officer Brian Bolger. "As part of the transaction, CP is investing in Kaiam to become a significant shareholder."

www.compoundphotonics.com
www.kaiam.com

Luna's Picometrix enters into vendor-managed inventory agreement with Chinese telecoms equipment provider

Luna Innovations Inc of Roanoke, VA, USA (which makes fiber-optic sensing and test & measurement products for telecoms, automotive, aerospace and defense markets) says its Picometrix division has entered into a vendor-managed inventory (VMI) agreement with a leading Chinese telecoms equipment and network provider that will integrate Picometrix more closely into its supply chain and manufacturing processes. Picometrix will maintain in Hong Kong a dedicated inventory of 100G integrated coherent receivers and other future approved products, which its customer can draw into manufacturing on a 'just in time' basis.

"Being pulled closer into the sourcing and manufacturing processes of this significant customer demonstrates a strengthening strategic relationship between our two companies," believes Luna's president & CEO My Chung. "This relationship is a major success factor in our corporate key strategic initiative for growth in the high-speed optical receiver markets."

After the VMI agreement, Picometrix received a new $1.4m order to supply coherent receivers for 100G optical transport network equipment (for delivery through June. Luna expects to supply both its first-generation CR-100D product and its next-generation (Gen 2) CR-100F coherent receivers. Compliant with the Optical Internetworking Forum (OIF) standard 'Implementation Agreement for Integrated Dual Polarization Micro-Intradyne Coherent Receivers', the CR-100F is about quarter the size of the first-generation CR-100D, with additional features including signal detect and a variable optical attenuator (VOA). It will be deployed in both the long-haul and metro applications to support the continued increase in global bandwidth demand.

www.advancedphotonix.com
www.lunainc.com

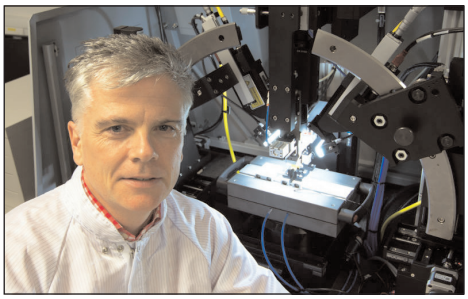
Tyndall to lead €15.5m EU-funded consortium PIXAPP

First open-access photonic integrated circuit packaging pilot line aims to drive EU growth and competitiveness in global photonics

The photonics market is expected to grow to more than €615bn by 2020. With Europe's share of the production technology market currently at 55%, the European Union — in partnership with Europe's photonics industry body Photonics21 — has identified photonics as a Key Enabling Technology (KET), critical for the future economic development of Europe. To provide Europe with a state-of-the-art infrastructure that supports the industrial development and manufacture of photonic integrated circuits (PICs), the EU is therefore investing €15.5m in the new international consortium PIXAPP, which will be led by Ireland's Tyndall National Institute (based at University College Cork).

Spanning high-speed fiber-optic communications, medical diagnostic sensors, the control of self-driving cars and emerging mass markets in the Internet of Things (IoT), the need for photonics (to generate, control and detect light) is driven by the fact that the speed and usage of day-to-day technology is almost at capacity, whereas photonics can address mass market requirements in communications, healthcare and security.

"The consortium involved in PIXAPP, led by Tyndall, has an unmatched record of excellence in delivering many world 'firsts' in PICs," said professor Peter O'Brien, PIXAPP pilot line director & head of Photonics Packaging Research at Tyndall National Institute, speaking at the Photonics21 annual general meeting (AGM) in Brussels. "We will establish 'best in class' PIC packaging technologies that are cost-effective and scalable to high-volume manufacture," he adds. "We will offer these technologies through a single easy access point, which we call the Pilot Line Gateway, which is located at Tyndall. Furthermore we plan to train and educate the photonics workforce of the future by creating a unique laboratory-based training program. This program is a game-changer not only for the European photonics industry but also global photonics."



Professor Peter O'Brien, PIXAPP Pilot Line Director and Head of Photonics Packaging Research at Tyndall National Institute.

Packaging PICs can represent up to 80% of the cost of photonics components, so it is a critical area for the industry. PIXAPP is claimed to be the world's first open-access PIC assembly and packaging pilot line, combining a highly interdisciplinary team of Europe's leading industrial and research organizations. Partners in the UK, Germany, France, Belgium, The Netherlands, Finland, Italy and Czech Republic each bring their own particular expertise to provide small- and medium-sized enterprises (SMEs) with a unique infrastructure to help them exploit the advantages of PIC technologies.

"In the past, it has been very expensive to manufacture high volumes of PICs, and more expensive and challenging again to package them," says Jose Pozo, director of the European Photonics Industry Consortium (EPIC). "This is creating a bottleneck for production, which is impacting the potential for growth in the photonics industry," he adds. "I am confident that Tyndall National Institute's leadership will deliver market success for Europe and drive our competitiveness across the communications, medical, automotive, energy, safety and defence sectors globally."

www.pixapp.eu
www.tyndall.ie

Hamamatsu completes new building to increase optoelectronic production capacity

Assembly & inspection facility targets demand for IR sensors and emitters in automotive, x-ray inspection and industrial equipment

Japan's Hamamatsu Photonics K.K. has held a completion ceremony on the site of its new building no. 1 at Shingai Factory, which will increase its manufacturing capacity for optoelectronic devices.

Dedicated to the assembly and inspection stages of the manufacturing process, the new building will enable the firm to meet the growing demand for infrared photo sensors and light emitters in automotive, x-ray non-destructive inspection systems, industrial equipment, and other applications.

Operations at the new building are scheduled to begin in May.

www.hamamatsu.com

Spec released for QSFP-DD MSA form factor

Quad Small Form Factor Pluggable Double Density module enables up to 400G solutions, quadrupling bandwidth in network applications

The Quad Small Form Factor Pluggable Double Density multi-source agreement (MSA) group has released a specification for the new QSFP-DD form factor. In total, 52 companies are supporting the QSFP-DD MSA to address the need for high-density, high-speed networking solutions.

Established in March 2016, the QSFP-DD MSA group aims to meet the market demand for a next-generation high-density, high-speed pluggable module form factor. It has now released a specification with broad market support that overcomes the technical challenges of specifying a QSFP28-compatible double-density interface. The QSFP-DD specification defines mechanical, electrical and thermal management requirements to enable multi-vendor interoperability.

QSFP-DD pluggable modules can quadruple the bandwidth of networking equipment to keep pace with advances in ASIC technology. Systems designed for QSFP-DD modules will be backwards compatible with existing QSFP form factors and provide maximum flexibility for end users, network platform designers and integrators.

The QSFP-DD specification defines a module and both a stacked height integrated cage/connector system and a single height cage/connector system. These expand on the QSFP form factor (the leading multi-lane pluggable form factor used across Ethernet, Fibre Channel and InfiniBand for 40Gbps and 100Gbps network applications).

The new QSFP-DD form factor expands the standard QSFP four-lane interface by adding a row of contacts providing for an eight-lane electrical interface, each operating up to 25Gbps with non-return-to-zero (NRZ) modulation or 50Gbps with pulse amplitude modulation (PAM4). This adaptation allows the QSFP-DD form factor to address solutions up to 400Gbps aggregate per QSFP-DD port, while providing backward compatibility to 40Gbps and 100Gbps. A single switch slot can support up to 36 QSFP-DD modules providing up to 14.4Tbps aggregate capacity. With an advanced thermal design, the new QSFP-DD solution can support modules up to 12W, providing significant system design flexibility.

QSFP-DD MSA founder-promoters include Broadcom, Brocade, Cisco, Corning, Finisar, Foxconn Interconnect Technology, Huawei, Intel, Juniper Networks, Lumentum, Luxtera, Mellanox Technologies, Molex, Oclaro, and TE Connectivity.

Contributors include Amphenol, Applied Optoelectronics, APRESIA Systems, Celestica, Ciena, ColorChip, Dell EMC, Delta, Fujitsu Optical Components, Genesis, H3C, Innovium, Inphi, Ixia, Kaiam, LEONI, Lorom, Luxshare, MACOM, MaxLinear, MultiLane, NeoPhotonics, Nokia, Panduit, PHY-SI, Ranovus, Samtec, Senko, Semtech, Sicoya, Siemon, Skorpios Technologies, Source Photonics, Spirent, Sumitomo Electric, Xilinx, and Yamaichi Electronics.

www.qsfp-dd.com/qsfp-dd-msa-group-announces-form-factor-specification

MSA formed for shortwave WDM over duplex MMF

Specs published defining 40 and 100G transceivers for enterprise and cloud data-center applications

The SWDM MSA (shortwave wavelength division multiplexed multi-source agreement) Group has announced its formation as an industry consortium to define optical specifications and promote adoption of shortwave WDM standards for use in data-center and enterprise campus applications that deploy duplex multi-mode fiber (MMF). The SWDM MSA has also published its first two standards, defining optical specifications for four-wavelength SWDM to transmit 40Gb/s and 100Gb/s Ethernet signals (40 GE SWDM4 and 100 GE SWDM4, respectively).

MMF is by far the most common type of fiber deployed in data centers because it allows the use of low-cost, vertical-cavity surface-emitting laser (VCSEL)-based transceivers. Most data centers originally deployed 10Gb/s optics with duplex MMF, and this paradigm is now being continued with 40Gb/s and 100Gb/s signals. Use of SWDM allows the same type of duplex MMF infrastructure to be used for higher data rates, greatly simplifying the upgrade of data rates at enterprise and cloud data centers.

The new SWDM specs support transmission over duplex OM3, OM4 and OM5 MMF. Maximum reach varies from 75m to 440m, depending on data rate and fiber type. In future, SWDM could be leveraged to enable 200, 400 and 800Gb/s Ethernet traffic on MMF cabling as well.

SWDM MSA founding members of are CommScope, Finisar, Lumentum, Hisense, OFS and Prysmian. The MSA is affiliated with the SWDM Alliance, an industry group (formed in September 2015) dedicated to the adoption of SWDM technology in data centers. The alliance also includes Anritsu, Corning, Dell EMC, H3C, Huawei, Juniper Networks, Panduit, Suruga Seiki, and YOFC.

www.swdm.org/msa

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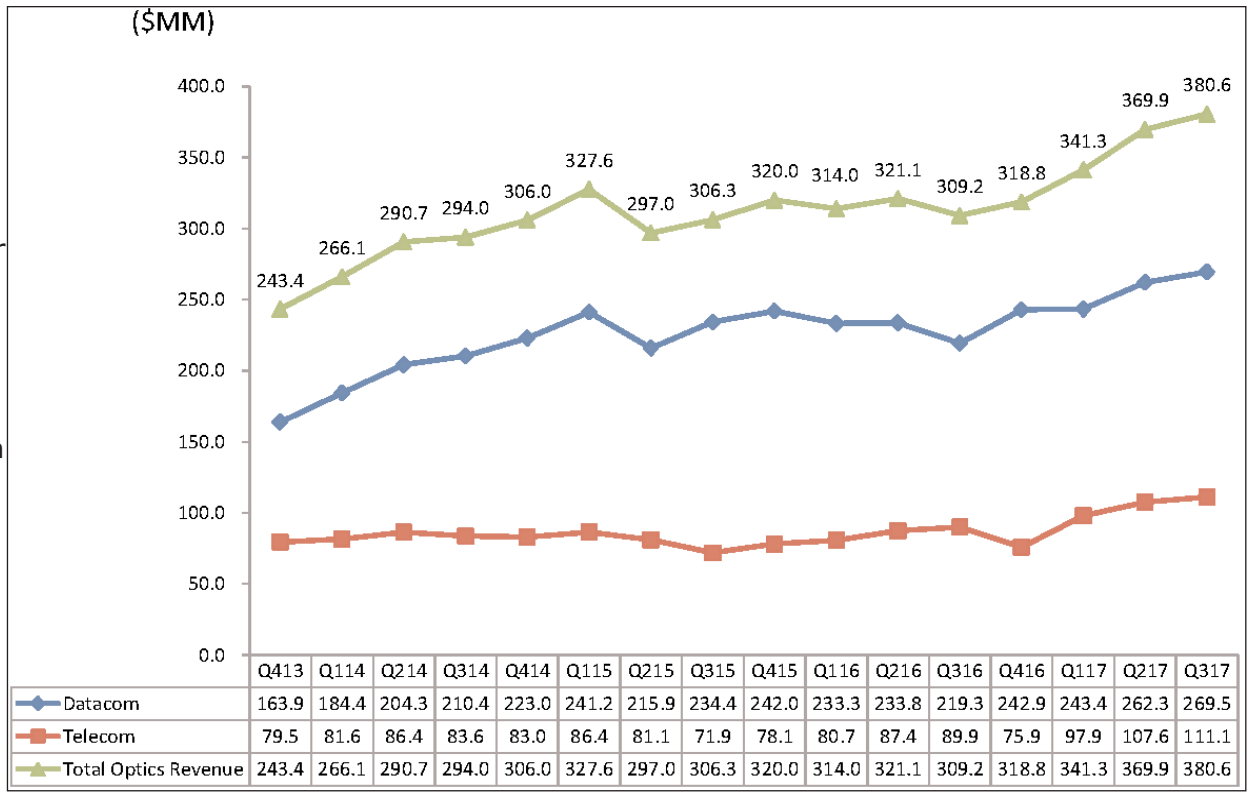
Finisar reports another quarterly revenue record, but up only 2.9%

Dip in revenue in January quarter to precede return to growth in June quarter

For its fiscal third-quarter 2017 (ended 29 January), fiber-optic communications component and subsystem maker Finisar Corp of Sunnyvale, CA, USA has reported record revenue of $380.6m, up 2.9% on $369.9m last quarter and 23.1% on $309.2m a year ago. However, this was towards the low end of the expected $378–398m, mainly because of lower-than-expected sales of 100G CFP transceiver modules into China. "We thought there were going to be some orders in the last week just prior to Chinese New Year that didn't happen," notes chief financial officer Kurt Adzema.



	Q413	Q114	Q214	Q314	Q414	Q115	Q215	Q315	Q415	Q116	Q216	Q316	Q416	Q117	Q217	Q317
Datacom	163.9	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
Telecom	79.5	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
Total Optics Revenue	243.4	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

Finisar's quarterly revenue trends.

Datacom product sales were $269.5m, up just 2.8% on $262.3m last quarter but up 18.6% on $219.3m a year ago, due mainly to growth in demand for 100G transceivers (up 9% on last quarter and 110% on a year ago).

Telecom product sales were $111.1m, up 3.2% on $107.6m last quarter and 23.6% on $89.9m a year ago, due to higher sales of wavelength-selective switch (WSS) and reconfigurable optical add-drop multiplexer (ROADM) line-card products (for Chinese OEMs).

There were again two 10%-or-greater customers. The top 10 customers represented 57.4% of total revenue.

On a non-GAAP basis, gross margin was 37%, down slightly from 37.2% last quarter (and at the bottom end of the expected range of 37–38%) but still up on 30.3% a year ago.

Operating expenses have risen further from $67.3m a year ago and $69.4m last quarter to $70.5m, but this is below the expected $72m, and OpEx has nevertheless been cut as a percentage of revenue further from 21.8% a year ago and 18.8% last quarter to 18.5%.

Operating income was $70.4m (18.5% of revenue, at the bottom end of the expected 18.5–19.5% range), but this is up from $68.3m last quarter and just $26.3m (8.5% of revenue) a year ago. Net income also rose further, from just $26.6m ($0.25 per diluted share) a year ago and $65.2m ($0.58 per diluted share) last quarter to $67.2m ($0.59 per diluted share, towards the low end of the $0.58–0.64 guidance range).

Capital expenditure has been increased from $30m last quarter to $42m (above the planned $40m).

During the quarter, cash, cash equivalents and short-term investments rose by $588m from $626.3m to about $1.2bn. This was due mainly to the issuance of $575m of 0.50% convertible notes (due in December 2036), which yielded net proceeds of $569.3m. Excluding those net proceeds, cash would have risen by $18.7m.

For fiscal fourth-quarter 2017, Finisar expects revenue to fall slightly to $360–380m (lower than previously expected). Datacom revenue should grow by $5m, due mostly to continued growth for 100G QSFP28 transceivers, partially offset by lower sales of 10G-and-below short-wavelength transceivers. However, Telecom revenue will fall by $15m, mostly from three factors: annual telecom

price reductions, seasonality associated with Chinese New Year, and continuing lower revenue from 100G CFP transceivers in China.

Due mainly to the impact of the telecom price reductions and lower levels of revenue, gross margin will fall to about 36%. OpEx should be steady at about $70m. Operating margin is expected to be 17%. Earnings per fully diluted share should be $0.50–0.56.

Capital expenditure will be raised further to $50m, driven by capacity expansion in the vertical-cavity surface-emitting laser (VCSEL) fab in Allen, Texas, targeting new 3D sensing opportunities for consumer applications.

During fiscal Q3, Finisar shipped many thousands of its high-powered VCSEL arrays for 3D sensing. "We are continuing to add manufacturing capacity in anticipation of strong demand from this application in the second half of calendar year 2017," says chairman & CEO Jerry Rawls.

At the beginning of fiscal Q4, Finisar acquired the rights to a manufacturing facility in China. The firm expects to complete building construction on this site in calendar second-half 2018, which will be used primarily for manufacturing. Capital expenditures for full-year fiscal 2018 is expected to be $35–40m per quarter.

"We are optimistic about fiscal year 2018. We believe our revenues will grow again, starting from the first quarter," says Rawls. "We expect continued growth from the sales of 100G QSFP28 transceivers, mostly for hyperscale data centers. We are currently sold out on this product and, despite our continuing to add capacity, we expect that sold-out situation to last at least through the end of calendar year 2017," he adds.

CFP sales themselves are probably going to be flat. CFP is migrating to CFP2 and we've got CFP4, and all of those eventually are going to go to QSFP28

In addition, Finisar expects to finally achieve qualification in fiscal first-quarter 2018 for both its 100G coherent CFP2 ACO transceiver and its ROADM line-card for use in the Verizon metro upgrade. "We have already completed qualification of our CFP2 ACO at multiple customers and are in the qualification process with several others," says Rawls. "Chinese service providers will begin domestic deployments of ROADMs in the second half of calendar 2017," he believes.

"As we go into the next fiscal year [fiscal 2018], I would expect that CFP sales themselves are probably going to be flat," continues Rawls. "CFP is migrating to CFP2 and we've got CFP4, and all of those eventually are going to go to QSFP28. CFP has been a good product for a long time for us, but we're not expecting a lot of growth out of it in the future."

Finisar appoints former Coherent CFO as new director

Finisar has appointed Helene Simonet to its board of directors, which now consists of seven directors who are elected to staggered three-year terms. Simonet will serve as a Class II director with a term running until the annual meeting of stockholders in 2019.

Simonet served as executive VP & chief financial officer of Coherent Inc (a provider of photonics-based solutions to the commercial and scientific research markets) from April 2002 to February 2016. From December 1999 to April 2002, she was VP of finance of Coherent's former Medical Group and VP of finance of its Photonics Division. Prior to joining Coherent, Simonet spent over 20 years in senior finance positions at Raychem Corp. She has been a director of Rogers Corp since October of 2014.

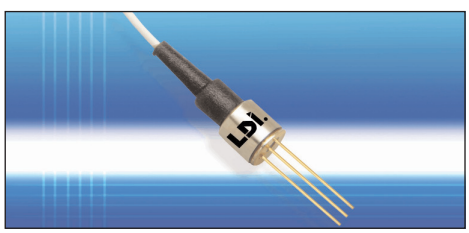
"Her experience in both executive and financial management of global technology manufacturing companies makes her an excellent addition to the board," comments CEO & chairman Jerry Rawls.

www.finisar.com

OSI Laser Diode launches 1550nm InGaAs APD module

OSI Laser Diode Inc (LDI) of Edison, NJ, USA (an OSI Systems Company) has launched the LAPD 3050, an indium gallium arsenide (InGaAs) avalanche photodiode (APD) module designed for light level detection and/or signal transmission applications.

The new 50µm active-area device features low dark current, low back reflection, and high speed (2.5GHz) in a miniature package. With spectral response from 1000nm to 1650nm at 25°C, the typical operational wavelength is 1550nm.



OSI's new LAPD 3050 InGaAs APD.

The APD is housed in a hermetically sealed 3-pin coaxial package and is coupled to a single-mode fiber pigtail. The overload-tolerant LAPD 3050 device is suitable for optical time-domain reflectometers (OTDRs), line receivers, and long-haul applications. Breakdown voltage is from 50V (minimum) to 70V (maximum) and operating and storage temperatures range from –40°C to +85°C.

www.laserdiode.com

NeoPhotonics reports record revenue of $109.8m for Q4, driven by High Speed Products sales up 52% year-on-year

Q1 to see dip due to delays in next 100G deployment phase in China

For fourth-quarter 2016, NeoPhotonics Corp of San Jose, CA, USA (a vertically integrated designer and manufacturer of hybrid photonic integrated opto-electronic modules and subsystems for high-speed communications networks) has again reported record revenue, of $109.8m, up 6% on $103.3m last quarter and up 23% on $89.1m a year ago.

Sales of High Speed Products (for 100G-and-beyond) were $78.5m (72% of total revenue), up on $69.2m (67% of revenue) last quarter and up 52% on $51.7m (58% of revenue) a year ago.

Sales of Network Products and Solutions were $31.3m (28% of total revenue), down on $34.1m (33% of revenue) last quarter and down 16% on $37.4m (42% of revenue) a year ago. Of this, Low Speed Transceiver Products contributed just $12.8m (11.7% of total revenue), down 2% on $13.1m (12.7% of revenue) last quarter and down 49% on $25.2m (28% of revenue) a year ago.

Shortly after the end of fourth-quarter 2016 (on 14 January 2017), NeoPhotonics completed the sale of its Low-Speed Transceiver product business to APAT Optoelectronics Components Co Ltd (APAT OE) of Shenzhen, China, a designer and manufacturer of optical sub-assemblies for telecom and datacom markets, primarily fiber-to-the-home (FTTH). Excluding the Low Speed Transceiver product business, NeoPhotonics' total revenue in Q4/2016 was $97m, up just 8% on last quarter but up 52% on a year ago.

Of total Q4 revenue (compared with last quarter), 65% came from China (up further, from 61%) and 18% from the Americas (down further, from 19%), while Japan was 4% (down from 5%) and the rest of the world was 13% (down from 15%).

There were again two 10%-or-greater customers, with Huawei Technologies (including Huawei affiliate Hi-Silicon Technologies) at 53% (up further, from 48% last quarter) and Ciena at 14% of total revenue (down further, from 15%).

Full-year 2016 revenue was $411.4m, up 21.2% on 2015's $339.4m. This was driven by High Speed product revenue rising 42% year-on-year, as Low Speed Transceiver Product revenue fell by 31.6% from 2015's $93m to $63.6m in 2016.

"End-market demand for our 100G-and-beyond products remained robust throughout 2016, with China deployments kicking off a wave of growth beginning back in the fourth quarter of 2015, followed by acceleration in metro and DCI [data-center interconnect] deployments that continued through the year and including a strong fourth quarter," says chairman & CEO Tim Jenks.

On a non-GAAP basis, Q4 gross margin was 29.9%, up from 27.6% last quarter but down from 32.4% a year ago (and below the expected 30–33%). Full-year gross margin fell from 31.5% in 2015 to 29.9% in 2016.

Operating expenses have risen further, from $22.6m a year ago and $24.7m last quarter to $26.6m. Full-year OpEx has risen from $84.7m in 2015 to $96.1m in 2016, although this has fallen from 24.9% of revenue to 23.4% of revenue.

The reduction in outlook is mostly due to delays in the next 100G deployment phase in China (exacerbated by inventories at some customers). NeoPhotonics is working through a lingering yield reduction in one of its fabs as well as some supply constraints in certain product lines

Net income was $6.3m ($0.13 per diluted share), down from $6.9m ($0.16 per diluted share) a year ago but up from $2.9m ($0.06 per diluted share) last quarter. Full-year net income has risen from $21.1m in 2015 to another record of $23m in 2016.

Adjusted EBITDA was $12.5m, up from $11.8m a year ago and $8.3m last quarter. Full-year adjusted EBITDA has risen from $43.2m in 2015 to another record of $45.1m in 2016.

Cash flow from operations was a record $27.1m (up from just $4m last quarter). Capital expenditure was $21.7m in Q4 (up from $15m last quarter), making $51.7m for full-year 2016 (up from just $16.8m in 2015).

During the quarter, cash and cash equivalents, short-term investments and restricted cash rose from $102.9m to $105.6m.

For first-quarter 2017, NeoPhotonics expects revenue of just $67–73m (well below Q4, even after accounting for a $13m drop from Low Speed Transceiver Product revenue following the sale of those product lines on 14 January).

The reduction in outlook is mostly due to delays in the next 100G deployment phase ('Phase 12') in China (exacerbated by inventories at some customers).

Also, NeoPhotonics is still working through a lingering yield reduction in one of its fabs as well as some supply constraints in certain product lines caused by the rapid ramp of production volumes.

"We are rapidly mitigating both of these issues, but expect some residual impact on revenues in the first and also the second quarter," says chief financial officer Raymond

Wallin, adding that these issues (which affect all customers) equate to less than half that of the drop in demand from China. Smaller affects are the Chinese New Year holidays and the typical seasonal low due to annual price reductions.

Gross margin should be 28–31%. Operating expenses are expected to rise further to $29–31m. NeoPhotonics expects to make a net loss of $0.20–0.30 per share.

"The softness in our first quarter outlook directly reflects the views we have from customers on the quarter and their needs," notes Jenks. "We feel confident this is simply a delay in the timing of deployments, with demand returning once tenders are announced. We see the demand conditions of the first quarter as temporary, and we expect to see a return to sequential growth with further acceleration later in the year through a combination of the next phase of deployments in China as well as new revenue streams from our new product introductions," he adds.

"Further, we have several key new product introductions which will expand our market opportunity, and position us to benefit from accelerating deployments both in the west and in China in 2017," Jenks continues. "Demand for 100G-and-beyond products will be stronger in 2017 than in 2016, though later in calendar 2017," he believes. "We have been expanding capacity and investing in our new product developments and technology in line with this view. Our capacity additions and new product introductions position us well to serve the 100G-and-beyond market as it continues to grow over the next several years."

"While our performance in 2016 was good, it was constrained by our capacity versus demand," notes Jenks. "Actions taken during the year to expand production capacities, reduce supply chain bottlenecks and increase manufacturing yields will set the stage for a more robust year in 2017 that will result from anticipated tenders moving to deployment," he believes.

"The mid- and long-term market drivers for our business remain compelling. China remains committed, through the China Broadband 2020 initiative, to continue build out of the national backbone network and expanded buildouts of 100G provincial and metro networks. Our OEM customers in China tell us they expect these actions to markedly increase the number of 100G ports in China in 2017 over 2016, but now with the preponderance of the deployments in the second half of the year," says Jenks. "In North America, we continue to see strong demand, with continued metro strength at Verizon, growing DCI deployments and new announcements for AT&T to begin initial 400G installations."

"Despite near-term volatility in our largest served market, we believe the macro trends of the industry favor our core capabilities of delivering the highest-performance products for the most demanding applications," Jenks concludes.

www.neophotonics.com

NeoPhotonics' chief financial officer resigns

NeoPhotonics' chief financial officer Ray Wallin is to resign, effective 15 May, but remain as a consultant to the firm for a three-month transition period. Wallin has served as CFO since December 2013.

"We thank Ray for the contributions he made to NeoPhotonics over the last three years," comments president & CEO Tim Jenks. "Leveraging his expertise, Ray played an important role in building a strong finance organization and has added to the strength of the company's financial position," he concludes.

"I am proud of the accomplishments the team has made over the last three years, including the build-out of our global finance organization," says Wallin.

NeoPhotonics has retained an executive search firm to identify a successor CFO.

First Solar begins operation of 250MW Moapa Southern Paiute Solar Project

First Solar Inc of Tempe, AZ, USA — which makes thin-film photovoltaic modules based on cadmium telluride (CdTe) as well as providing engineering, procurement & construction (EPC) services — and the Moapa Band of Paiutes joined Senator Dean Heller, Senator Catherine Cortez Masto, Nevada State Energy Office Director Angela Dykema, Clark County Commissioner Marilyn Kirkpatrick, executives from the Los Angeles Department of Water and Power (LADWP) and other community and energy industry leaders to celebrate the commissioning of the Moapa Southern Paiute Solar Project. Officials from the United States Department of Energy, the Bureau of Land Management and the Bureau of Indian Affairs also participated.

Located on the Moapa River Indian reservation in Clark County about 30 miles north of Las Vegas and capable of generating 250MW$_{AC}$ (enough energy to power an estimated 111,000 homes), the Moapa Southern Paiute Solar Project is the first utility-scale solar power plant to be built on tribal land and has a 25-year power purchase agreement (PPA) with LADWP.

"Nevada has the unparalleled natural resources to be a national leader in investment and development of clean energy technology and job creation," commented Senator Catherine Cortez Masto. "I will continue to fight for commonsense policies and projects like this one to reduce our dependence on fossil fuels, invest in clean energy, and create good paying jobs."

For the Moapa Band of Paiutes, the solar facility is providing lease revenues over the lifetime of the project and about 115 construction jobs for tribal members and other Native Americans, while also preserving their land and cultural heritage.

"As a first-of-its-kind project, the Moapa Southern Paiute Solar Project signifies our role as a leader in Indian Country, creating a template for other tribes to follow," says Darren Daboda, chairman of the Moapa Band of Paiutes Tribal Council. "Tribes across the nation have the perfect areas in which to build utility-scale projects."

Constructed and operated by First Solar, the project features over 3.2 million CdTe solar panels covering more than 25 million square feet (enough to cover more than 450 NFL football fields). The project will avoid about 341,000 metric tons per year of CO_2 emissions (equivalent to taking nearly 73,000 cars off the road).

The project will help the City of Los Angeles to achieve 33% of all energy from renewable resources by 2020 and 50% by 2025, states Reiko A. Kerr, senior assistant general manager, of LADWP Power System.

First Solar sells Moapa Solar Project to Capital Dynamics

First Solar has completed the sale of the cash equity interests in the 250MW$_{AC}$ Moapa Southern Paiute Solar Project in Nevada to global private asset manager Capital Dynamics.

Minority tax equity interests in the project are shared by GE unit GE Energy Financial Services and an affiliate of the Goldman Sachs Group.

"The Moapa project is an important step in the Clean Energy and Infrastructure strategy of Capital Dynamics," comments John Breckenridge, Capital Dynamics' head of Clean Energy and Infrastructure (CEI). "We continue to be long-term owners of high-quality power generation assets in North America and Europe," he adds. "With Moapa, we expand our strong relationship with First Solar."

Benoit Allenhaut (left), Capital Dynamics' Director of Clean Energy and Infrastructure, talking with First Solar's chief commercial officer Georges Antoun (center) and Laura Abram (right), director of Government and Public Affairs, at the formal commissioning of the Moapa Southern Paiute Solar Project on 17 March in Moapa, Nevada.

First Solar Energy Services will operate and maintain the power plant for Capital Dynamics.

Featuring over 3.2 million CdTe solar panels covering more than 25 million square feet (enough to cover more than 450 NFL football fields), the Moapa Southern Paiute Solar Project will avoid about 341,000 metric tons per year of carbon dioxide emissions (equivalent to taking nearly 73,000 cars off the road).

www.firstsolar.com

First Solar mulls sale of stake in 8point3

Resources and capital to be focused on transition to Series 6 CdTe PV module production

First Solar Inc of Tempe, AZ, USA — which makes thin-film photovoltaic modules based on cadmium telluride (CdTe) as well as providing engineering, procurement & construction (EPC) services — says that, working together with its financial and legal advisors, it is reviewing alternatives for the sale of its interests in 8point3 Energy Partners LP (a limited partnership formed in March 2015 by First Solar and solar panel & system maker SunPower Corp of San Jose, CA, USA to own and operate a portfolio of selected solar energy generation assets). First Solar will coordinate the review with its partner SunPower.

In recent months, First Solar has taken actions to strategically align its resources and capital in support of its transition to its new Series 6 CdTe PV modules.

Last November, First Solar announced an acceleration of its roadmap for Series 6 production into 2018, with about 3GW of production expected in 2019. Over the course of 2017 and 2018, the existing production facilities are being converted to Series 6 production and the current Series 4 product is being phased out. As a result of the change in roadmap, the firm has cancelled its Series 5 product.

As a continuation of these efforts, First Solar is exploring options for selling its stake in 8point3 in order to refocus resources on Series 6 objectives and to allow faster recycling of systems business capital. This capital would support the planned transition to Series 6 production and provide additional funding for the expected deployment of multiple gigawatts of Series 6 capacity over the next several years.

This capital would support the planned transition to Series 6 production and provide additional funding for the expected deployment of multiple gigawatts of Series 6 capacity over the next several years

First Solar also intends to accelerate the return of capital from its systems business by selling projects earlier in the construction phase. This includes the California Flats and Cuyama projects, which have been formally offered to 8point3. If 8point3 is unable to acquire these projects, First Solar expects to sell these projects to third parties.

"We remain committed to developing, constructing and selling utility-scale solar power plants," says CEO Mark Widmar. "Series 6 has the potential to be a transformational product and provide attractive returns to our shareholders. As we accelerate the cash conversion cycle from our systems business, we will further enable this important transition in our business," he adds.

"We want to thank SunPower for their partnership in forming 8point3, which has a portfolio of high-quality solar assets and proven operating performance," Widmar continues. "We look forward to working cooperatively with them through this process."

www.firstsolar.com

First Solar secures loan for utility-scale solar project in Ishikawa, Japan

First Solar Inc of Tempe, AZ, USA — which makes thin-film photovoltaic modules based on cadmium telluride (CdTe) as well as providing engineering, procurement & construction (EPC) services — has obtained non-recourse project debt financing of about ¥27bn ($240m) in a syndicated loan arranged by Mizuho Bank Ltd for a utility-scale solar project in Ishikawa prefecture, Japan. First Solar says that the financing arrangement demonstrates its technology, project development, operations and maintenance, and project financing capabilities for utility-scale solar projects in Japan.

With a generation capacity of 59.5MW_{AC}, the Ishikawa Sogo Solar Power Plant will be one of the largest mega solar projects in the Hokuriku region. Scheduled to begin operation in late 2018, it is expected to provide enough electricity to serve the needs of around 17,500 average Japanese homes (displacing about 35,000 metric tons of carbon dioxide annually).

Together with the existing construction loan of up to 4bn yen ($33m) financed by Mizuho Bank, First Solar reckons that it is well positioned to develop, construct and operate utility-scale solar projects and to provide integrated energy solutions that contribute to a safe and reliable energy mix in Japan.

Solar power is playing a significant role in Japan's renewable energy strategy, says First Solar, and the availability of project debt financing will further bolster utility-scale solar development to meet the country's unique energy needs.

Stion's CIGS PV modules outperform c-Si by 5–6%

Stion Corp says that results from a multi-year performance comparison by the USA's Sandia National Laboratories reveal that its copper indium gallium diselenide (CIGS) technology outperformed monocrystalline silicon (c-Si) by as much as 6%. Testing was completed at three climatically distinct US Department of Energy (DOE) Regional Test Centers (RTCs) in New Mexico, Florida and Vermont.

In the test, Stion's modules outperformed expectations by 1% based on their nameplate power ratings. In contrast, the c-Si reference arrays at the RTCs underperformed by 5% relative to their rated power. The study, which is based on the 'relative efficiency' (performance relative to the nameplate rating of the modules) began in January 2014 and was lasted two years.

Not only do Stion's modules slightly outperform their rated capacity but, as irradiance (the amount of sunlight hitting the panels) increases, the efficiency of the modules also increases, which is not generally true of c-Si modules.

Stion says that its modules also offer an advantage in northern regions. In Vermont, Sandia observed that the frameless modules shed snow faster than the adjacent monocrystalline framed modules. Stion has observed the same phenomenon in other snowy regions. The accelerated shedding is due to the frameless configuration, which allows snow to slide off the panel without obstruction and also to the panels' black aesthetics, which result in snow melting faster once the sun reappears after a storm. This translates into an increase in energy production and therefore a higher return-on-investment, adds the firm.

"It's important for companies to have a good understanding of how weather will impact their products over time," says Joshua Stein, a Sandia photovoltaics researcher and director of the RTC program. "The RTC collects and analyzes high-quality data to give US companies such as Stion the information they need to ensure their products perform well in a variety of climates," he adds.

The US DOE Regional Test Center program, which is funded though the DOE's SunShot Initiative and managed by Sandia for the DOE, aims to increase innovation in the US solar sector by rigorously evaluating the performance and reliability of new solar technologies across multiple climates.

Stion was accepted into the program in 2014 and agreed to install systems in New Mexico, which represents a hot, arid climate; Florida, which is hot and humid; and Vermont, which has harsh snowy winters. The Stion systems installed at each site had identical data-monitoring systems, which were designed by Sandia, and rigorously monitored.

US manufacturers that wish to have their equipment validated at one or more RTCs are selected via a competitive process and work closely with Sandia and/or the National Renewable Energy Laboratory (NREL) on an installation and validation plan, which the Regional Test Centers then execute.

www.rtc.sandia.gov

Midsummer's Asian client manufacturing CIGS solar modules with 14% efficiency

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 — says that its Asian client is now manufacturing lightweight flexible solar modules with an energy conversion efficiency of 14%.

Midsummer previously announced that it had sold its compact DUO solar cell manufacturing system to an Asian client. The system is in production and is producing flexible solar modules at record levels, it is claimed. The flexible solar module is made of cells from the client's factory in Asia.

Midsummer's client has now surpassed 14% in efficiency (corresponding to 15.4% aperture-area efficiency), as tested at the independent research institute Chemitox Inc in Yamanashi, Japan. The modules were made in the client's mass-production line in normal production conditions and with standard process settings with a CIGS layer less than 1μm thick.

Designed for operational stability and superior material utilization, the DUO is a compact, fully automatic deposition system for CIGS solar cell manufacturing.

With Midsummer's production system, the solar cells are manufactured individually and then strung together into modules (just like crystalline solar cells). So, lightweight flexible modules can easily be made in any size and shape. A dry, all-vacuum process has less stringent requirements for cleanrooms. Avoiding cadmium in the manufacturing process is desirable for the sake of production staff and also makes it easier to commence low-cost manufacturing of CIGS solar cells, says the firm.

"Lightweight, flexible solar modules are the future of solar energy since they fit in to the 'distributed energy' trend and can be fitted on buildings, vehicles etc," notes CEO Sven Lindström.

www.midsummer.se

Solliance sets record stabilized efficiency of 12.6% for roll-to-roll produced perovskite-based solar cells

Technology demonstrated on industrially applicable roll-to-roll processes

Solliance, a cross-border Dutch–Flemish–German thin-film photovoltaic (TFPV) solar energy R&D consortium in the ELAT (Eindhoven-Leuven-Aachen) region, has demonstrated an industrially applicable roll-to-roll process for the production of solar cells, achieving a record 12.6% conversion efficiency at the cell level (paving the way towards accelerated market introduction of the technology).

Solliance partners include ECN, imec, TNO, Holst Centre, TU/e, Forschungszentrum Jülich, University Hasselt and Delft University of Technology. The consortium conducts research on the development of perovskite-based PV modules and its applications with its industrial partners Solartek, Dyesol and Panasonic. Solliance reckons that, with these results, it has demonstrated the effectiveness of their collaboration in the development of perovskite based PV modules.

Perovskite microcrystals are promising materials for making high-yielding, thin-film solar cells. They can be processed into thin, light-weight and potentially semi-transparent modules that could eventually be integrated into building materials such as windows or curved construction elements. Solliance and its research partners focus on using scalable, industrial processes towards the fabrication of large-area modules, eventually suitable for seamless integration in a broad variety of PV systems.

The roll-to-roll (R2R) process was developed for both the electron transport and the perovskite layers on the new Solliance dual R2R coating line, as developed by Solliance with its partners VDL Enabling Technologies Group (VDL ETG), Smit Thermal Solutions and Bosch-Rexroth. The in-line roll-to-roll coating, drying and annealing processes were executed at a linear speed of 5m/min on a 30cm-wide commercial PET/ITO foil and under ambient conditions. After applying a newly developed off-line single device finishing step, individual solar cells of 0.1cm^2 achieved efficiencies of up to 12.6%, measured under maximum power point tracking conditions during 5 minutes. All process steps on this roll-to-roll line were performed using low-cost materials while keeping the process temperatures below 120ºC. Solliance reckons that this shows the high-volume production potential of the emerging thin-film PV technology.

"The demonstration of R2R processing at 5m/min of perovskite layers for solar cells indicates that high-volume production, and hence with an expected very low cost, will be possible in the future", says Pim Groen, professor of SMART materials at the Technical University of Delft and program manager at Holst Centre/Solliance. "These results show that the Solliance research partners, with their in-depth know-how on processing of thin-film PV devices and their extensive sheet-to-sheet and roll-to-roll pilot production infrastructure, are excellently placed to realize this upscaling."

VDL ETG has been leading the consortium of equipment makers that designed and built the R2R coating line. "It shows that combining process know-how at Solliance with capabilities of high-tech equipment companies in this region can deliver very powerful results that potentially open up completely new business opportunities," says VDL's CEO Willem van der Leegte.

"We are committed to developing the industry standard for R2R perovskite solar cell (PSC) PV manufacturing in conjunction with Solliance, and this result is an important step along this route," comments Dyesol's managing director Richard Caldwell. "This pioneering work confirms that Dyesol and its partners retain a global leadership position in the industrialization of PSC technology, and in particular its continuous R2R processing for flexible BIPV applications — a core element of its commercialization strategy."

The existing record efficiency for a small lab-scale perovskite-based PV cell is 22.1%. "The challenge is to upscale perovskite cells to larger-size, industrially manufacturable modules with high efficiency and long lifetime at low cost," says Solliance program director Ronn Andriessen. "These 12.6% R2R upscaled perovskite-based solar cells are a first and important step in this development," he adds. "With this result, we are confident to quickly boost the up-scaled perovskite-based PV module efficiency above 15% by using low-cost materials and processes. Furthermore, we are working hard to improve the stability of these devices under real-life operational conditions."

Due to its high power conversion efficiency and flexible and light-weight nature, thin-film perovskite PV technology is considered to be a future key technology for building-integrated photovoltaics (BIPV), says Solliance. It can be seamlessly integrated into building elements, on curved surfaces and can be made semi-transparent. Combining the industrially applicable manufacturing processes with Solliance's proprietary back-end interconnection process allows the creation of perovskite-based PV modules with any form and shape and any desired current-voltage output. These properties will enable customized and aesthetic integration of solar modules for infrastructure-, building- and vehicle-integrated PV products, reckons Solliance.

www.solliance.eu

Improving indium arsenide antimonide nanowire optical quality on silicon

Researchers use droplet-assisted MBE to increase antimony content and extend peak photoluminescence wavelength from 4μm to 5.1μm.

Researchers from UK and China have used optimized droplet-assisted molecular beam epitaxy (MBE) to improve the optical quality of indium arsenide antimonide (InAsSb) nanowires (NWs) on silicon with up to 19% Sb content [Q D Zhuang et al, Nanotechnology, vol28, p105710, 2017]. The peak wavelength of the resulting NWs ranged from 3.0μm to 5.1μm.

The 5.1μm wavelength represents the longest to date for InAsSb NWs, according to the team from Lancaster University (UK), Shanghai Institute of Technical Physics (China), University of Warwick (UK), Jianghan University (China), University of Liverpool (UK) and Sun Yat-Sen University (China).

The team believes that the NWs could enable highly efficient silicon-based mid-wave infrared (MWIR, 3–5μm) and even long-wave infrared (LWIR, 8–12μm) photodetectors, operating at room temperature, along with infrared-emitting devices, highly sensitive phototransistors, and renewable electricity generators. They see InAsSb NWs as "an ideal and versatile candidate for a variety of device applications, for instance, in optoelectronics in the infrared and terahertz spectral ranges, high-speed electronics, thermophotovoltaic and thermoelectric devices, and cost-effective biosensors."

As usual, realizing the possibilities requires improved material. The researchers used a technique where the deposition of indium (In) droplets under pre-optimized conditions nucleates NW growth, avoiding the use of catalysts such as gold or nickel. Antimony has a strong surfactant effect that creates problems for incorporation into InAsSb.

The samples were grown on (111) Si with the composition mainly determined by flux ratios. The researchers found that reducing the V/III ratio favored a higher growth rate of NWs and enhanced Sb incorporation. The researchers comment: "We believe that a faster growth rate reduces the Sb surfactant effect. Meanwhile, the higher growth rate favors Sb incorporation, which is the same as that observed in the epitaxy of InAsSb thin film."

The areal density of NWs reduced from ~$5x10^9$/cm^2 at 16% Sb content to ~$3x10^7$/cm^2 at 19% Sb content.

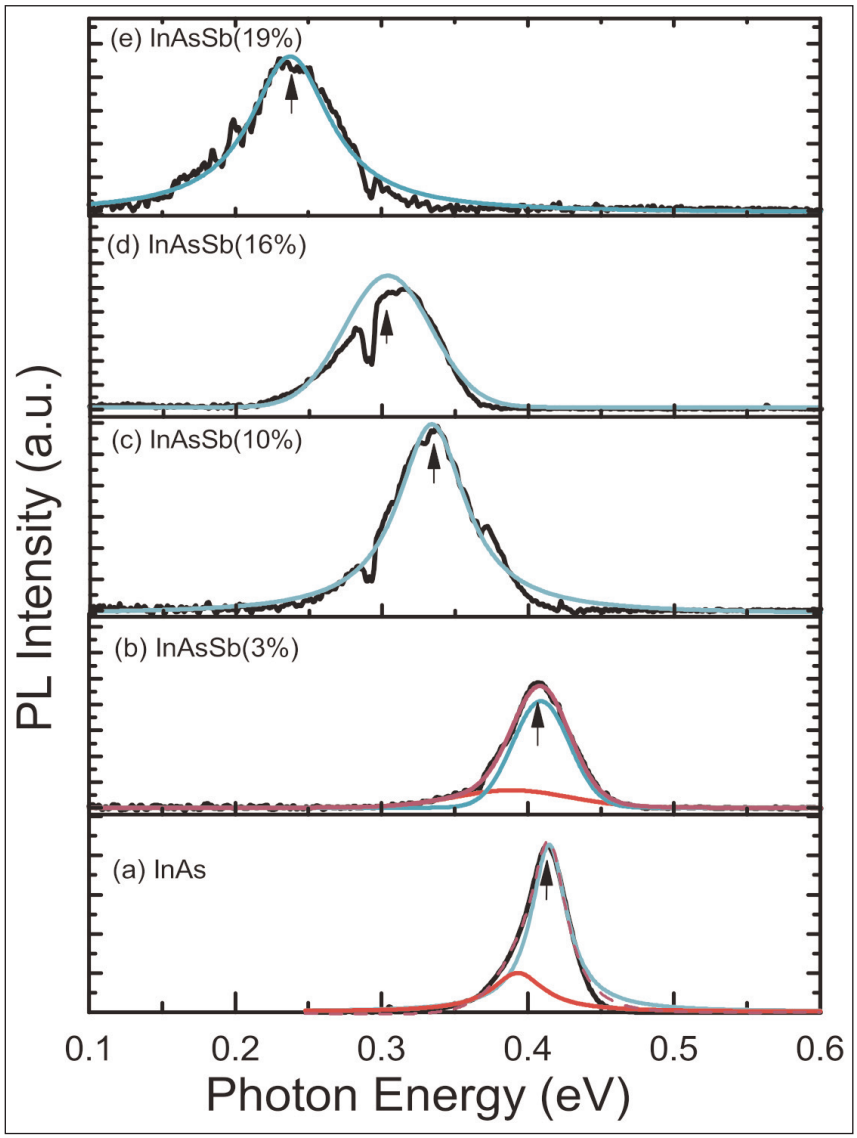


Figure 1. Evolution of 10K photoluminescence of InAs NWs (a) and InAsSb NWs with Sb composition of 3% (b), 10% (c), 16% (d) and 19% (e). Peaks in colors show decomposed emissions.

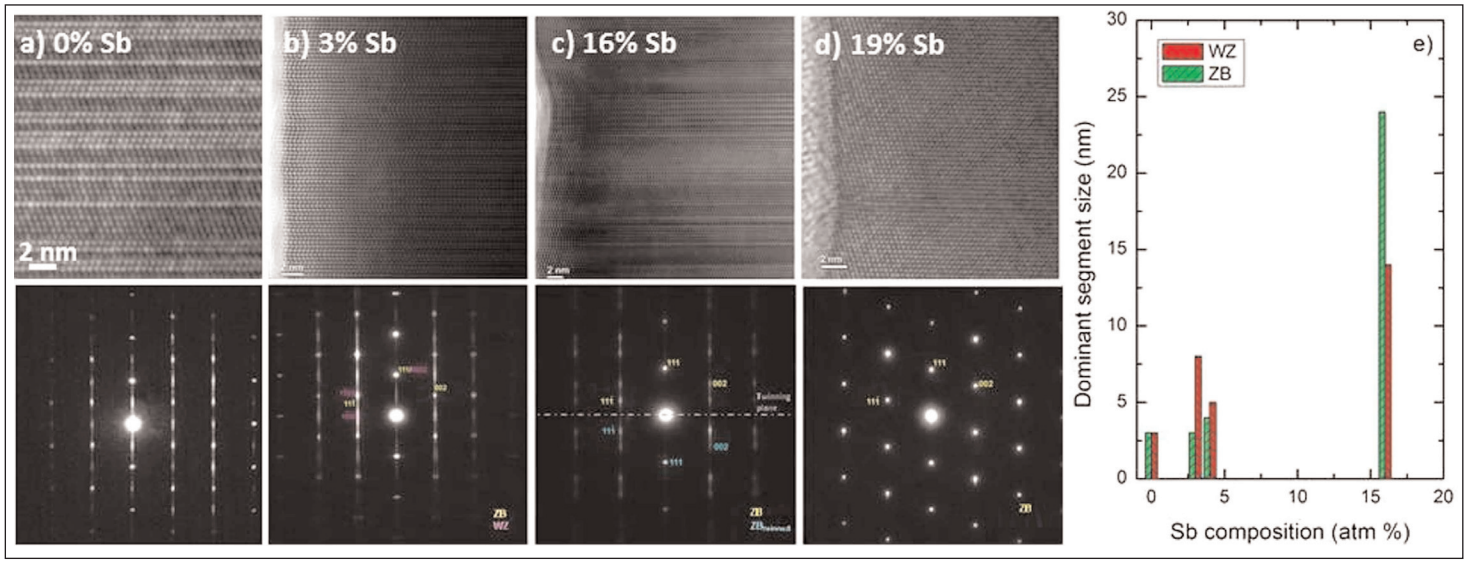


Figure 2. High-resolution TEM images with corresponding fast Fourier electron diffraction patterns of InAs NWs (a) and InAsSb NWs with Sb content of 3% (b), 16% (c), 19% (d), and average size of ZB and WZ segments in InAsSb NWs as a function of Sb content (e).

Table 1. Sb content determined through energy-dispersive x-ray analysis and corresponding theoretical bandgap energy for series of InAsSb NWs with 10K band-to-band photoluminescence peaks and full-width at half maximum (FWHM). Estimated uncertainties for peak and FWHM energies 1.0meV and 1.4meV, respectively.

Measured Sb content and variation (atm.%)	Peak energy (eV)	FWHM (meV)	Theoretical bandgap (eV)
0	0.427	30.0	0.417
3±1	0.405	47.4	0.394±0.008
16±3	0.304	66.8	0.297±0.017
19±4	0.242	71.8	0.279±0.022

Photoluminescence studies were carried out at 10K (Table 1), with all samples exhibiting "strong emission" (Figure 1), according to the researchers. Increasing Sb content resulted in lower-energy longer-wavelength photons. The longest wavelength was 5.1μm with 19% Sb. The researchers comment: "To the best of our knowledge, we have reported the longest emission wavelength of InAsSb NWs so far: 27.5% longer than the previously reported longest emission wavelength (i.e. 4.0μm)." At increased temperature, the photoluminescence peak underwent red-shift.

Low-Sb-content NWs were a mixture of zincblende (ZB) and wurtzite (WZ) crystal structure segments, according to high-resolution transmission electron microscope (TEM) analysis (Figure 2). For 16% Sb content the NWs were predominantly ZB and the 19% NW was pure-ZB.

The researchers believe that increased Sb incorporation could lead to further improved optical properties. They also think that suppressing surface states should also be beneficial. According to the team, surface states are "the major factor impeding the development of NW optoelectronic devices".

https://doi.org/10.1088/1361-6528/aa59c5

Author: Mike Cooke

Increasing light output power from gallium nitride LEDs with p-trenches

Trench structure improves injection of holes into quantum wells and reduces strain-induced electric fields, boosting recombination into photons.

Seoul National University and Samsung Electronics Co Ltd in South Korea have used trenches filled with p-type gallium nitride to increase the output power of indium gallium nitride (InGaN) light-emitting diodes (LEDs) [Garam Kim et al, Appl. Phys. Lett., vol110, p021115, 2017].

The aim of the trenches was to allow holes to enter multiple quantum well (MQW) structures more effectively. In conventional LEDs, holes from the top p-GaN contact layers tend to only get as far as the top well, meaning that not much light is emitted from the lower wells. With trenches, the researchers hoped to increase the numbers of holes injected into the deeper parts of the device (Figure 1a).

It was also hoped that splitting up the strained material with trenches would reduce piezoelectric fields in MQW structures arising from charge polarization of the III-nitride bonds. The strain is due to lattice mismatching between the GaN and InGaN crystal structures.

The (piezo-)electric field tends to pull electrons and holes apart, reducing wavefunction overlap and conversion into photons (Figure 1b). This is commonly referred to as the quantum-confined Stark effect (QCSE). The effect can be avoided by growing material in semi-polar or non-polar crystal orientations, but that often requires the use of prohibitively expensive free-standing or bulk GaN substrates.

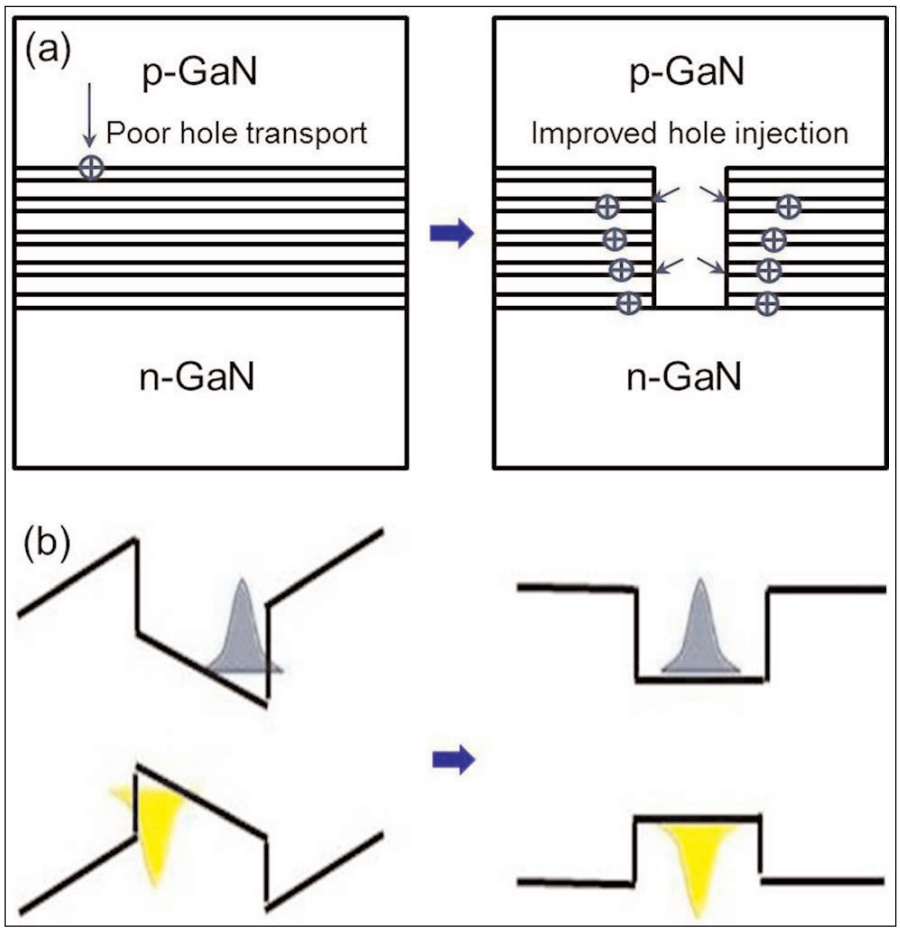


Figure 1. (a) Hole distribution in MQW of conventional LED and p-type trench LED. (b) Energy band structure in MQW when strain is present or eliminated.

Poor hole transport is among the many issues that are thought to contribute to efficiency droop at high current injection. With most electron-hole recombination occurring in one or two wells, the onset current for non-radiative 'Auger'-like processes is reduced. Further, the probability for electron overflow into the p-GaN contact layer is increased.

Trenches were defined by electron-beam lithography on 3nm/12nm InGaN/GaN multiple quantum wells grown by metal-organic chemical vapor deposition (MOCVD) on c-plane sapphire. The active region emitted blue light. The lithography was carried out on a 100nm coating of polymethyl methacrylate (PMMA) resist. The patterning into trenches was transferred into the MQW structure by inductively coupled plasma etch. The p-type GaN filling the trenches was laterally grown at 950°C temperature and 200Torr pressure.

The researchers also tried a selective wet etch

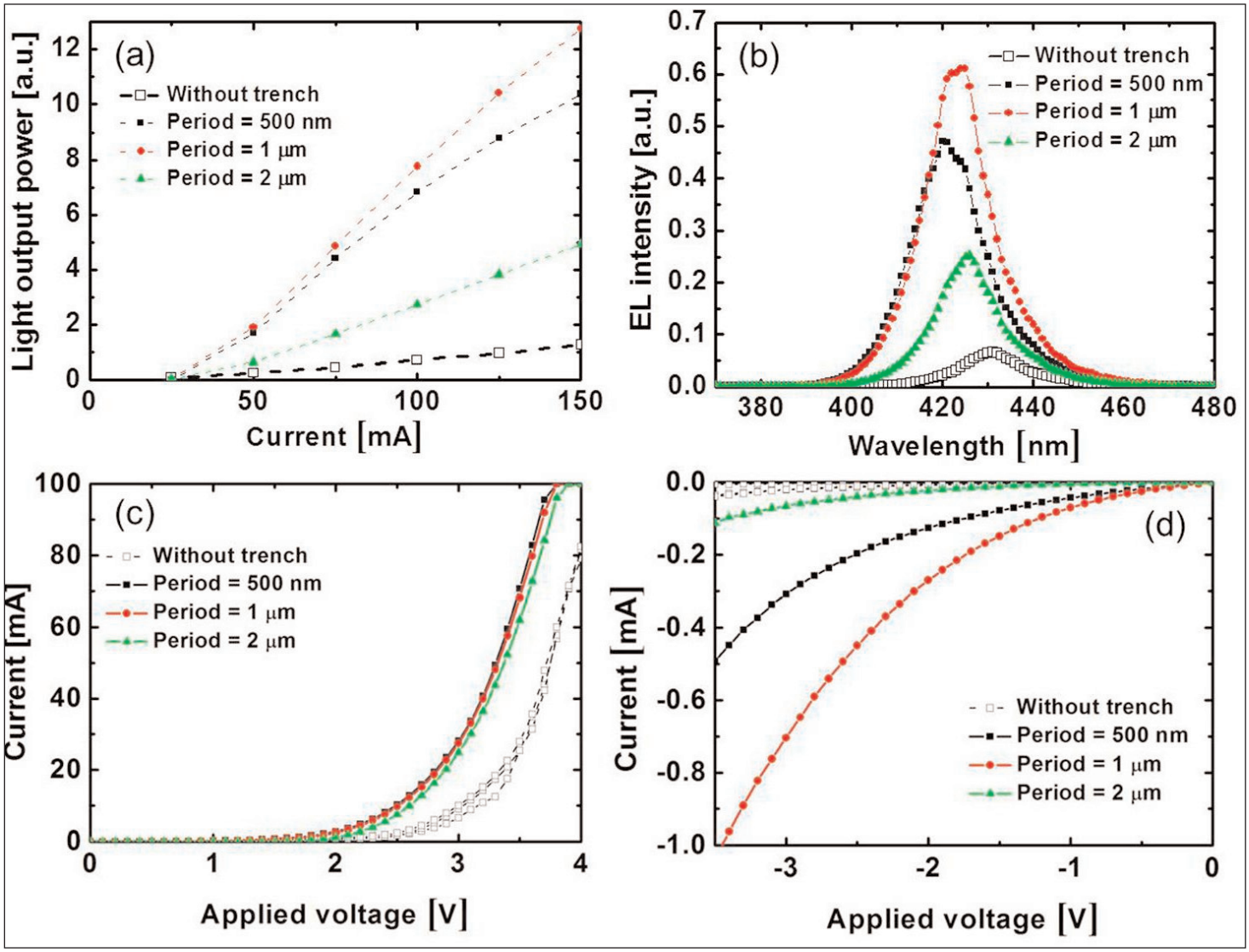


Figure 2. (a) Light output power of p-type trench structure using electron-beam lithography and conventional structure; (b) electroluminescence (EL); and (c) forward and (d) reverse current characteristics.

method to create the trenches, using potassium hydroxide in ethylene glycol at 165°C. The selection was on threading dislocations, rather than being defined by lithography.

The electroluminescence of the structures was tested by applying an indium tin oxide (ITO) current-spreading layer. The metal contact was chromium/nickel.

The researchers estimate that their devices without trenches emit about 5% of the light output power of commercial LEDs with similar active region area. Creating trenches by dry etch increases light output and blue-shifts the emission to shorter wavelengths (Figure 2).

The p-type trench structures also reduce the volume of the MQW while reducing the strain and the QCSE. Therefore, in order to maximize the light output power, it is important to optimize the ratio between the trench structure volume and the remaining MQW volume

The light output was greatest for 1μm period trenches. The researchers comment: "This is because the p-type trench structures also reduce the volume of the MQW while reducing the strain and the QCSE. Therefore, in order to maximize the light output power, it is important to optimize the ratio between the trench structure volume and the remaining MQW volume."

The wavelength shift was greatest with a 500nm period – from 431nm without trenches to 420nm. The effective bandgap was thus increased from 2.76eV to 2.85eV. This is attributed to strain relaxation.

The p-trenches increased forward current for a given voltage, but also increased leakage under reverse bias.

Wet etching of trenches also increased light output power, but not as dramatically. Further the technique was not as effective in relaxing strain, as evidenced by a minimal shift in emission wavelength. The current–voltage behavior was also less affected by the wet etch trenches. ■

http://dx.doi.org/10.1063/1.4973995

Author: Mike Cooke

Aluminium indium gallium nitride electron-blocking layers

Quaternary III-nitride improves light output power, droop, forward voltage, and wall-plug efficiency in blue LEDs.

South China University of Technology and Taiyuan University of Technology in China have used quaternary aluminium indium gallium nitride (AlInGaN) semiconductor alloys to improve the performance of electron-blocking layers (EBLs) in blue light-emitting diodes (LEDs) [Zhiting Lin et al, IEEE Transactions on Electron Devices, vol64, p472, 2017].

Conventional AlGaN EBLs aim to stop electrons overshooting the active light-emitting region and recombining non-radiatively in the p-type GaN contact layers. However, AlGaN EBLs also reduce hole injection and suffer from strain-induced piezoelectric fields from charge-polarization effects of the III-nitride chemical bond. The piezoelectric field acts to reduce the barrier to electron flow.

The researchers used AlInGaN to reduce the strain and hole blocking effects of the EBL (Figure 1) both in simulations and experimental work. Test vehicles of simulations were grown on 2-inch c-plane sapphire by metal-organic chemical vapor deposition (MOCVD). The AlInGaN was grown at 760°C at 200hPa (20kPa) pressure. The composition was varied through altering the trimethyl-indium flow. The material was divided into standard 750μmx220μm LED chips.

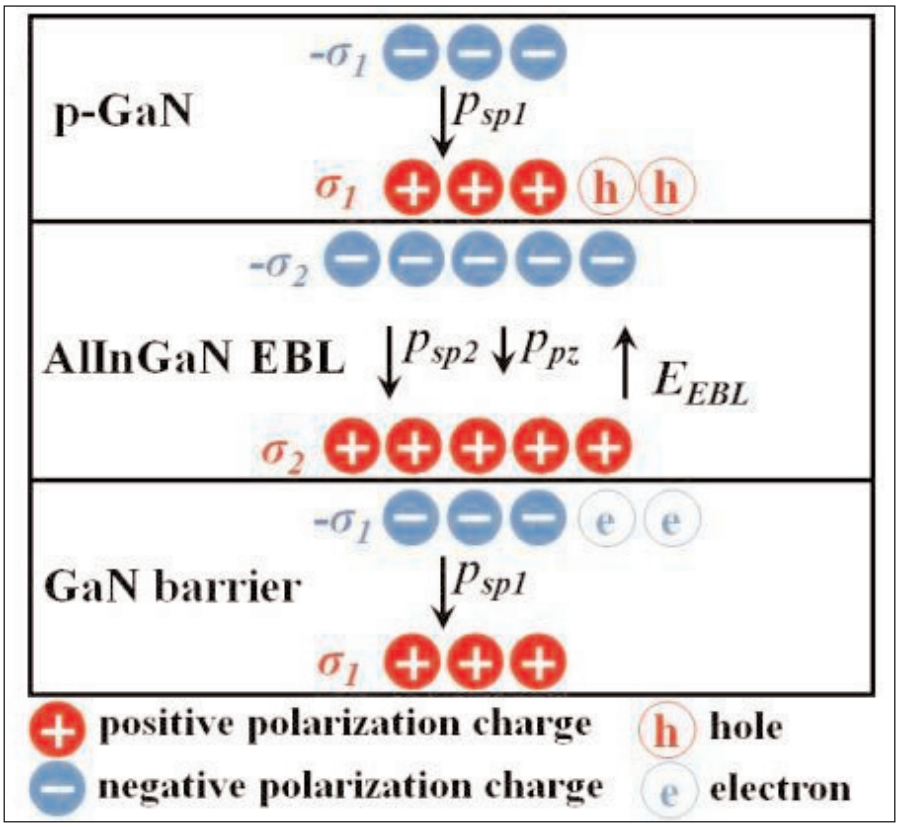


Figure 1. Illustration of polarization charge distribution for sandwich structure composed of p-GaN, AlInGaN EBL, and GaN barrier.

A reference EBL (LED A) had $Al0_{.15}Ga_{0.85}N$ composition. Four $Al_xInyGa_{1-x-y}N$ quaternary EBL structures were also produced with 0.35 Al-content, and 0.04, 0.11, 0.18, 0.21 In-content for LEDs B-E in order, spanning In/Al ratios of 0.1 to 0.6.

The light output power (LOP) from the devices A–E at 43A/cm^2 was 65.90mW, 75.99mW, 81.26mW, 86.58mW and 90.07mW, respectively (Figure 2). In particular, the improvements of LEDs D and E over that of LED A were 31.38% and 36.68%, respectively.

However, LED D had better performance in terms of lower forward voltage for a given current, which indicates greater power efficiency. At 14.4A/cm^2 (20mA) injection, the forward voltages for LEDs A-E were 3.45V, 3.77V, 3.62V, 3.31V and 3.72V, respectively.

The improved overall performance of LED D was reflected in it having the best peak wall-plug efficiency (WPE) of 60.99% and lowest efficiency droop of 31.12% at 43A/cm^2. The corresponding WPEs for LEDs A–C and E were 51.58%, 54.78%, 57.58% and 58.84%; the respective droops were 40.12%, 40.33%, 36.83% and 35.02%.

The 0.5 In/Al ratio of LED D giving the best performance supported the results of the researchers' simulations. The team explains that, according to their simulations, increasing the In/Al ratio enhances carrier injection efficiency, increasing internal quantum efficiency (IQE) and hence WPE. However, beyond 0.35 In/Al ratio, carrier injection efficiency approaches saturation at 100%. High In/Al fractions also increase series resistance of the EBL layer, increasing forward voltage and hitting WPE, as seen in LED E.

The researchers admit that the experimental work does not exactly match the performance expected from the simulation – this is attributed to relatively poor AlInGaN material due to the large difference in optimal growth temperature of the AlGaN (~1000°C)

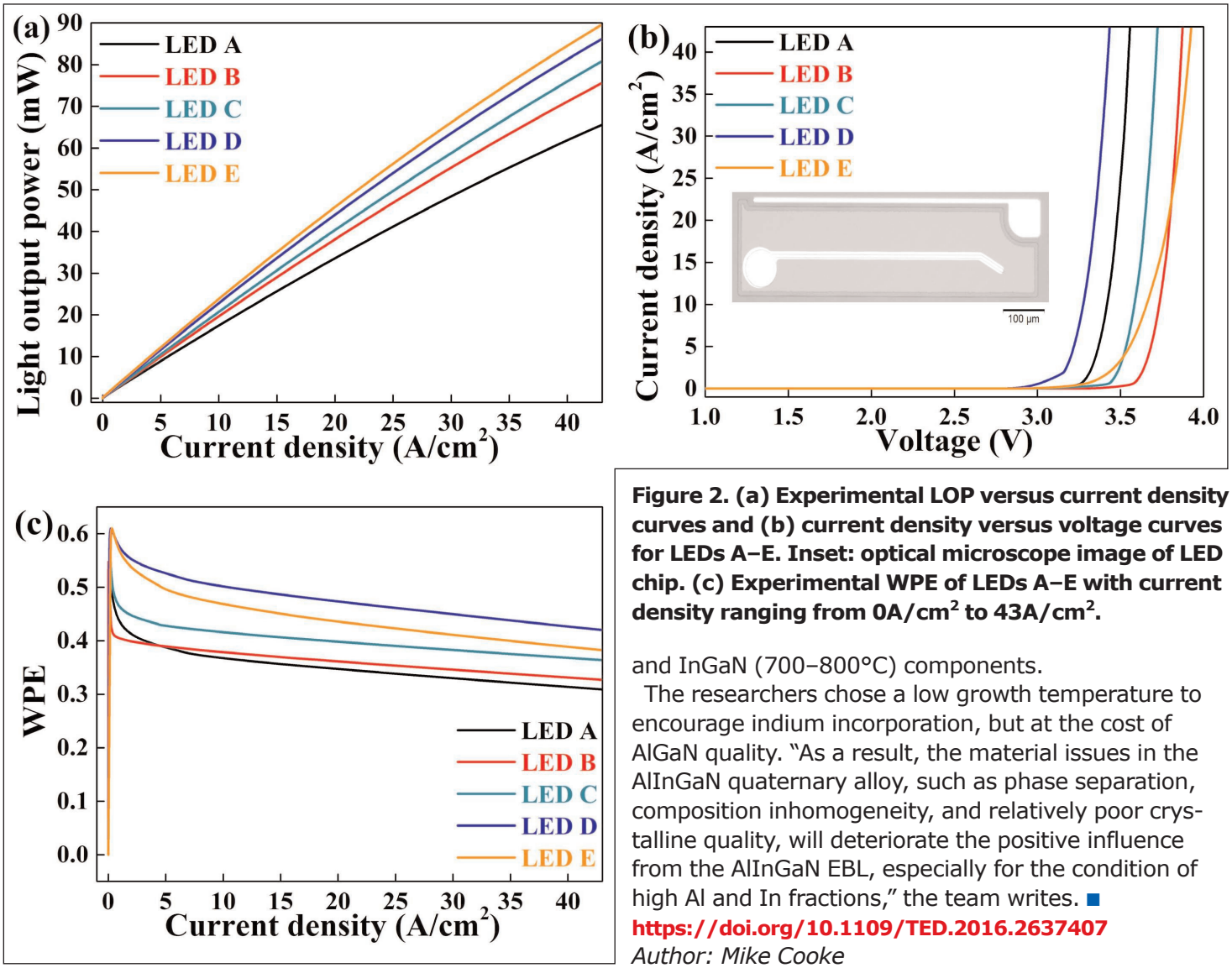


Figure 2. (a) Experimental LOP versus current density curves and (b) current density versus voltage curves for LEDs A–E. Inset: optical microscope image of LED chip. (c) Experimental WPE of LEDs A–E with current density ranging from 0A/cm² to 43A/cm².

and InGaN (700–800°C) components.

The researchers chose a low growth temperature to encourage indium incorporation, but at the cost of AlGaN quality. "As a result, the material issues in the AlInGaN quaternary alloy, such as phase separation, composition inhomogeneity, and relatively poor crystalline quality, will deteriorate the positive influence from the AlInGaN EBL, especially for the condition of high Al and In fractions," the team writes. ■

https://doi.org/10.1109/TED.2016.2637407

Author: Mike Cooke

Gallium nitride quantum dot emission at 232nm deep ultraviolet

Cornell University and University of Notre Dame claim the shortest-wavelength electroluminescence so far in the deep ultraviolet for GaN active material .

Cornell University and University of Notre Dame in the USA have claimed the shortest-wavelength electroluminescence so far using gallium nitride (GaN) active material [S. M. Islam et al, Appl. Phys. Lett., vol110, p041108, 2017]. The use of quantum dot (QD) structures and charge polarization effects to improve doping effectiveness allowed the team to achieve wavelengths as short as 232nm in the deep ultraviolet (UV in the 100–280nm C-band).

Efficient short-wavelength light-emitting diodes (LEDs) would lead to environmentally friendly, compact/portable alternatives to mercury lamps. Such UV LEDs are proposed for use in water purification, medical diagnostics, and security.

However, efficiency in UV LEDs based on III-nitride materials such as wide bandgap aluminium gallium nitride (AlGaN) falls steeply when wavelengths are reduced below 240nm. The Cornell/ Notre Dame approach combined the confinement of electrons and holes in 'zero-dimension' QDs, increasing the bandgap from GaN's bulk value of 3.4eV, and boosting carrier injection into the active light-emitting region.

The team comments: "The reduced dimensionality of the active region can also be suitable for amplified spontaneous emission for LEDs and perhaps lower the threshold for realizing electrically injected deep-UV Lasers, which remains an unsolved problem in semiconductor physics."

Hole injection is a particular problem in III-nitrides. Already in GaN the activation energy for magnesium doping is ~200meV, while room temperature thermal effects are around 26meV. This means that the ionization rate is very low and hole densities are poor. The activation energy increases as aluminium is added to widen the bandgap of AlGaN for shorter-wavelength emission. The Cornell/Notre Dame team improved ionization rates by using the differing charge polarization of the III-nitride bond with graded-Al-content AlGaN.

Plasma molecular beam epitaxy (MBE) created deep UV heterostructures on metal-polar AlN/sapphire templates (Figure 1). The active region consisted of layers of GaN QDs of 1 to 4 monolayers (MLs) thickness in AlN barrier material. The AlN barrier layers were created by depositing 8 monolayers of Al without nitrogen, followed by nitrogen without Al, in a migration-enhanced epitaxy (MEE) process.

Lateral 200μmx200μm LEDs were produced using chlorine-based reactive ion etch of the mesa. The n-type and p-type metal electrodes were titanium/aluminium/nickel/gold and titanium/gold, respectively. A thin nickel/gold current-spreading layer

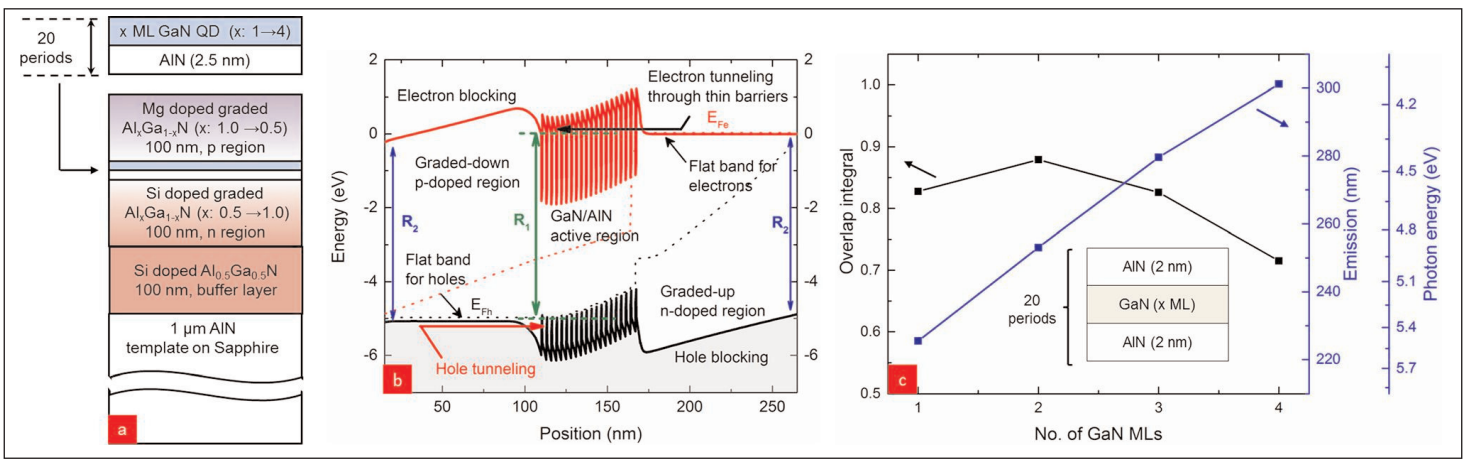


Figure 1. (a) Heterostructure layer design of deep-UV LED, (b) simulated energy band diagram at 5V forward bias, and (c) calculated evolution of UV emission wavelength and wavefunction overlap integral with GaN ML thickness.

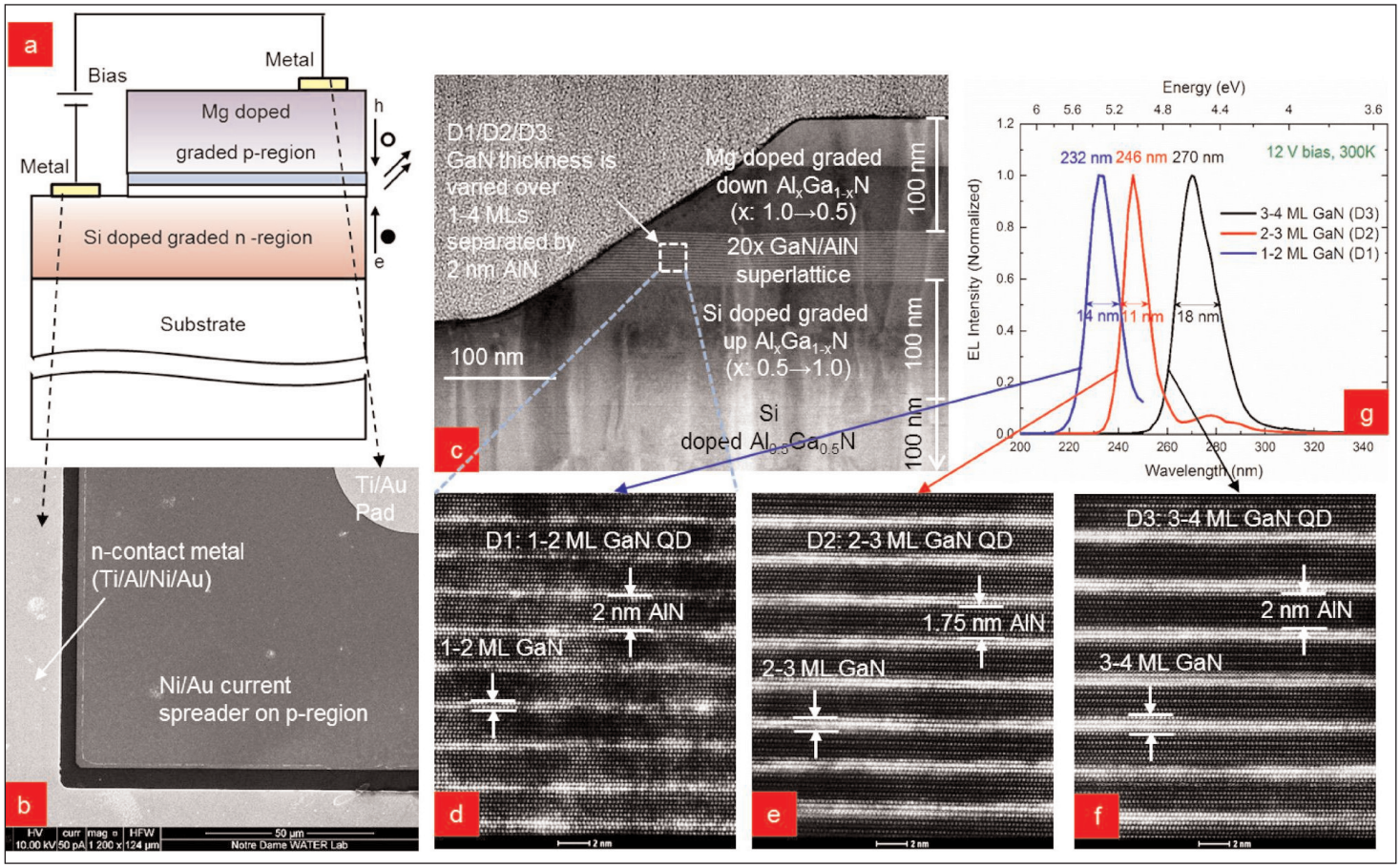


Figure 2. (a) Schematic of processed device and (b) scanning electron micrograph (top view quadrant) of processed device showing n and p metal contacts. (c) High-angle annular dark-field (HAADF) scanning transmission electron microscopy (STEM) image showing different layers for typical sample (D1/D2/D3), and zoomed in active region for (d) D1, (e) D2, (f) D3, along with (g) electroluminescence spectra taken at 12V forward bias for D1–D3 at 300K.

was applied to the p-contact before the p-electrode.

Electroluminescence peaks were observed at 270nm (4.59eV), 246nm (5.04eV) and 232nm (5.34eV)) under 10kHz/5% duty cycle pulsed 12V operation (Figure 2). The shortest wavelength was for 1–2ML QDs (D1). The other devices were based on 2–3ML (D2) and 3–4ML (D3) QDs.

The current densities were 165A/cm^2, 90A/cm^2 and 290A/cm^2 for the 270nm, 246nm and 232nm peak-wavelength devices, respectively. The turn-on voltage for the devices was around 7.5V. The higher-than-expected turn-on voltage was blamed on poor p-contacts and a non-optimum number of 20 active region layers.

The team reports: "Based on some recent simulation and experimental work, 8 periods of the active region seem to be the optimum in terms of the light output and forward voltage drop across the device. Reducing the number of periods and further improvements in the p-layer design using tunnel-contacts can potentially help improve the hole injection problem for deep-UV LEDs."

There was some discrepancy with simulated emission peaks that the researchers attribute to inhomogeneous quantum dot distributions and quantum well and barrier thickness variations, along with uncertainties in the conduction and valence band structure. In particular, the linewidth was broader in reality, compared with simulations.

The researchers comment: "The shortest EL wavelength reported so far using the GaN active region is 239nm by metal-organic chemical vapor deposition (MOCVD) and 243nm by MBE. This work demonstrates that, by changing the thickness of the GaN layer with a ML precision, it is possible to achieve tunable deep UV LEDs emitting as short as 232nm."

Logarithmic plots of the emissions were used to study secondary peaks due to absorption and re-emission at longer wavelength of photons by lower-Al-content AlGaN in the magnesium-doped p-contact region. The Al-content was graded between 100% and 50% in order to increase hole carrier injection into the active region through charge polarization doping enhancement. Both the 1–2ML and 2–3ML had secondary peaks around 4.6eV photon energy, corresponding to the bandgap of $Al_{0.5}Ga_{0.5}N$. By contrast, there is no secondary peak for 3–4ML QD emissions since $Al_{0.5}Ga_{0.5}N$ is transparent to 270nm UV. ■

http://dx.doi.org/10.1063/1.4975068

Author: Mike Cooke

Bulk GaN substrate market growing at 10% CAGR to $100m in 2022, from 60,000 wafers in 2016

Three Japanese players hold 85% of market driven by laser diodes and HB-LEDs.

Optoelectronics applications, particularly GaN-based laser diodes and GaN-on-GaN LEDs, will drive the bulk gallium nitride (GaN) substrate market from 2016–2022, according to a new report from Yole Développement.

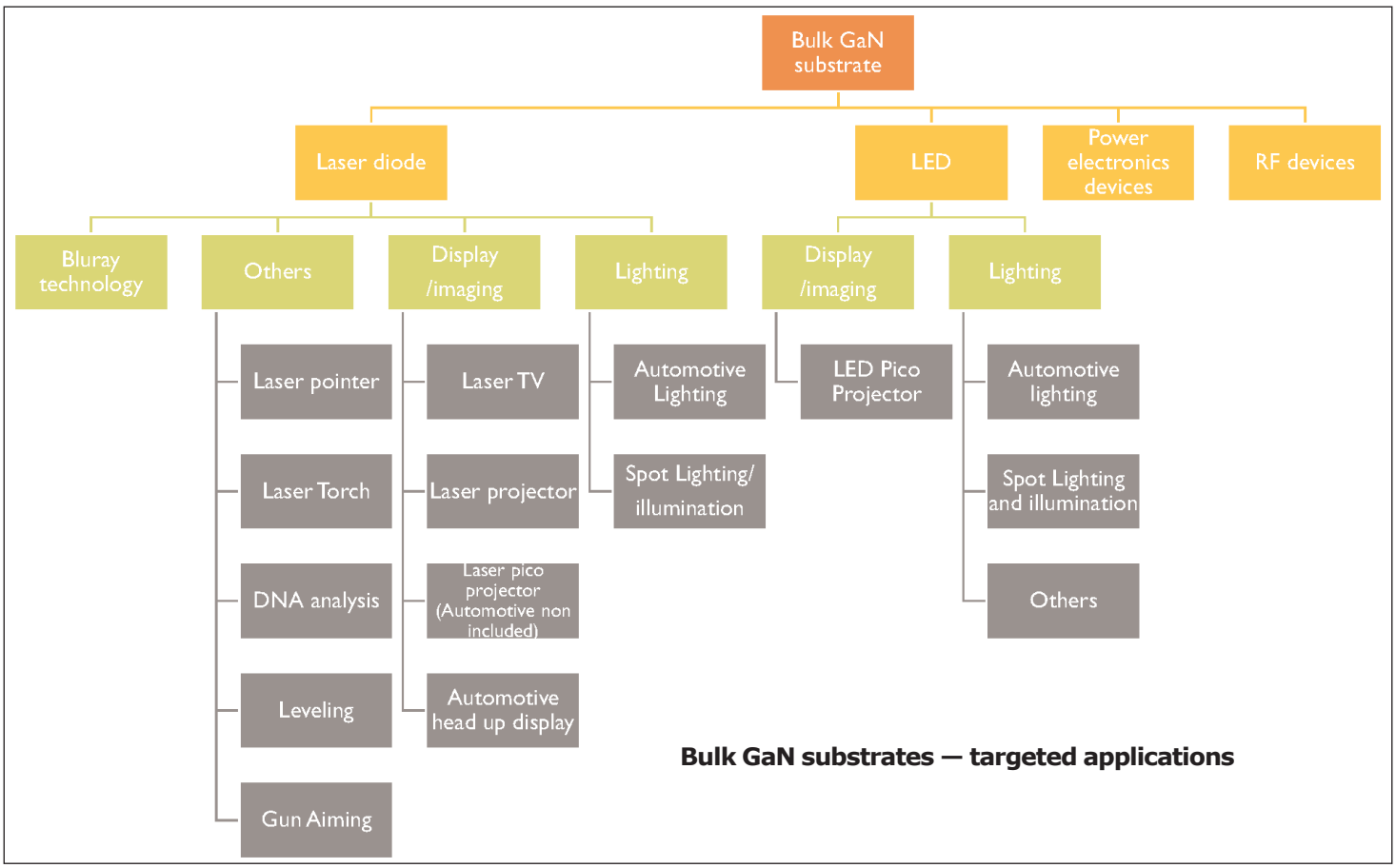
Specific to the laser diode market, the Blu-ray segment, which in the past was the GaN-based laser industry's main driver, continues to decline. In recent years, a much greater percentage of movies were viewed via streaming than on optical discs, and in many cases flash memory is replacing optical discs and magnetic storage. The current crop of mobile phones, netbooks, tablets, and even laptops lack a Blu-ray/DVD/CD drive. UHD Blu-ray's recent development is expected to have only a novelty effect on sales — not enough to reverse the general downward trend to be seen in the coming years. However, decreasing Blu-ray demand is expected to be offset by nascent, growing segments like projectors — office projector, mobile pico projector, head-up display (HUD), etc — and automotive lighting, leading to new growth opportunities for bulk GaN.

In the LED market, improvements in GaN substrate manufacturing have lowered substrate prices enough for various niche LED applications. In addition to Soraa in the USA and Panasonic in Japan, this has revived the interest of other LED makers that are starting to seriously consider using GaN substrates for either spotlighting or automotive lighting. New GaN-on-GaN LED players are expected in the market in the coming years.

In this context, Yole expects laser diodes and LEDs to drive continuous growth of bulk GaN substrate demand.

Japanese players dominating market

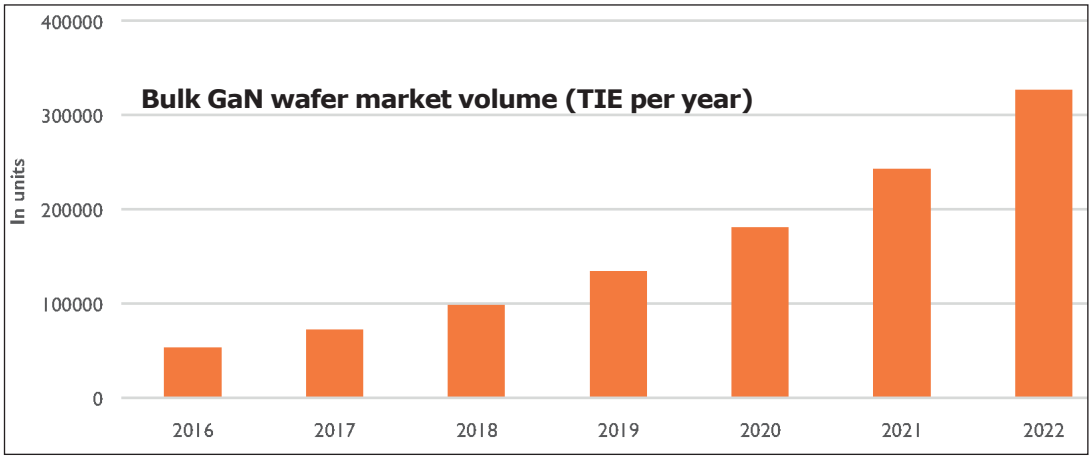
In 2016 the bulk GaN substrate market was estimated to be about 60,000 wafers (two-inch equivalent (TIE)). Essentially all commercial GaN wafers are produced by hydride vapor-phase epitaxy (HVPE) technology, but details of the growth process and separation techniques vary by company. Other techniques, such as Na-flux or



Bulk GaN substrates — targeted applications

Ammonothermal, are still under development. We still don't see large volume of these wafers on the market. The market is expected to rise at a compound annual growth rate (CAGR) of 10% to more than $100m in 2022.

The GaN substrate market is heavily concentrated. More than 85% share is held by three Japanese firms: Sumitomo Electric Industries (SEI), Mitsubishi Chemical Corp (MCC), and Sciocs. Other Japanese and non-Japanese players are still in small-volume production or in R&D, and it is too early for them to challenge these market leaders, says Yole.



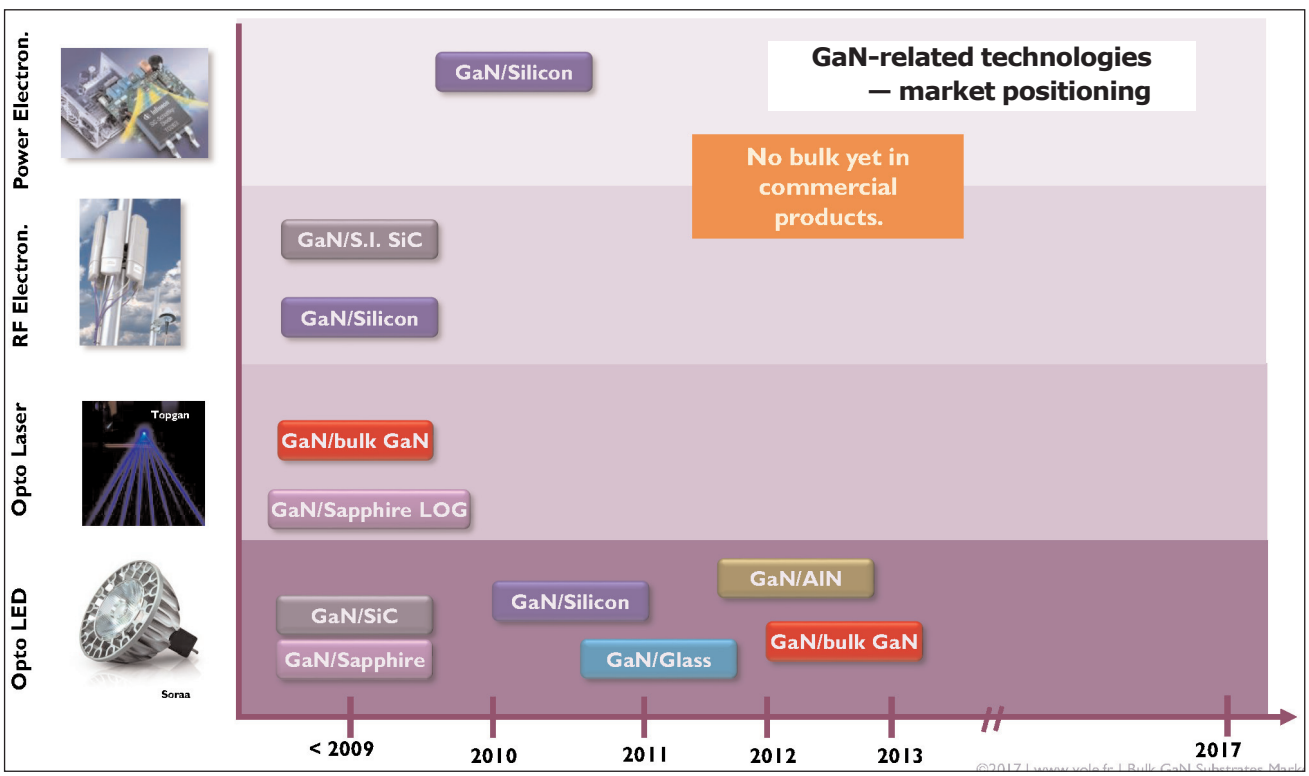
GaN-on-GaN among various GaN-related technologies

In the past, due to technical complexities, limited availability and the high cost of native bulk GaN substrates for homoepitaxial growth, different foreign substrates were used to develop GaN-based devices for diverse applications:

- GaN-on-sapphire was widely developed, benefiting from the LED industry's growth over the past 25 years (the first GaN-on-sapphire LEDs hit the market in the 1990s). Sapphire wafer pricing has eroded significantly in the same period, and GaN-on-sapphire remains the dominant technology for LED applications.
- GaN-on-SiC was among the first to be studied. Today the technology is widely used for GaN RF device manufacturing and LED manufacturing.
- GaN-on-silicon arrived naturally, breaking the cost-point and making GaN an affordable technology. However, it faced a host of technical challenges, i.e. high lattice mismatch and high thermal expansion coefficient (TEC) mismatch. Academia and industry have invested heavily to resolve these technical issues, and today GaN-on-silicon is gradually being commercialized, particularly for power electronics applications.
- Many other materials, i.e. polycrystalline AlN substrates, have been proposed as an attractive alternative due to a more closely matched coefficient of thermal expansion (CTE) with GaN. Other more foreign materials (diamond, Ge, and ZnO) have also been studied, but these remain mostly in the R&D stage.

On the other hand, development of bulk GaN substrates was happening in parallel with other substrates. The progress of GaN substrates — specifically, wafer size/quality increase and wafer cost reduction — sees GaN-on-GaN technology entering more and more optoelectronic applications, and possibly electronics applications in the future., reckons Yole.

www.i-micronews.com/compound-semi-report/product/bulk-gan-substrate-market-2017.html



Silicon and III-nitride high-voltage monolithic cascode diode

Combining pn diode and metal-insulator-semiconductor high-electron-mobility transistor gives two-orders-of-magnitude lower reverse bias leakage.

Hong Kong University of Science and Technology (HKUST) has developed a high-voltage monolithic cascode diode combination (Figure 1) of silicon (Si) pn diode and normally-on aluminium gallium nitride (AlGaN) barrier metal-insulator-semiconductor high-electron-mobility transistor (MIS-HEMT) [Jie Ren et al, IEEE Electron Device Letters, published online 8 February 2017].

"Compared with conventional AlGaN/GaN [Schottky barrier diodes (SBDs)], the cascoded diode can provide much lower reverse leakage current due to the superior voltage blocking capability of the MIS-HEMT and the low leakage of the Si diode," the researchers comment.

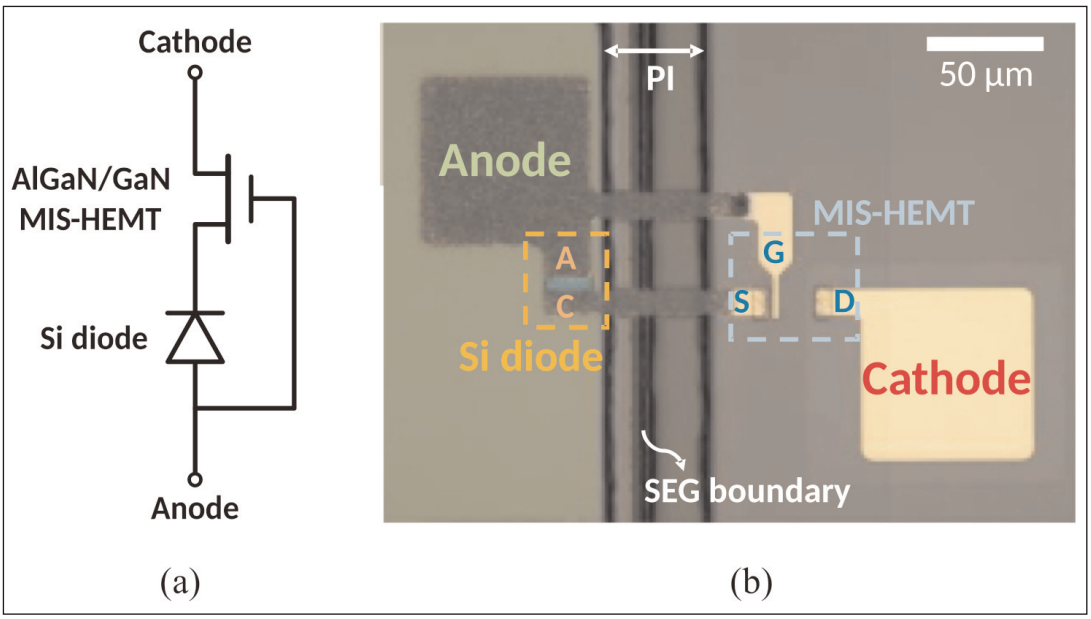


Figure 1. (a) Circuit schematic and (b) top-view image of cascoded diode.

The researchers also see the monolithic integration work as leading to smaller effects from parasitic inductance, resistance, or capacitance, compared with systems assembled from a number of discrete parts. "Large parasitics will cause circuit ringing during fast switching, resulting in system instability," they add. Further potential advantages include reduced system size and production cost.

The devices were fabricated on 4-inch (111) silicon substrates (Figure 2). A 300nm layer of silicon dioxide was formed, which was etched to form a mask for the recessed window. Further etching created a 4µm-deep region for selective epitaxial growth (SEG). More silicon dioxide was deposited as a sacrificial layer that was then removed to smooth the bottom silicon surface in the recessed windows.

A new 1.5µm SiO_2 SEG mask was applied before metal-organic chemical vapor deposition (MOCVD) of 280nm AlN nucleation, 1.1µm step-graded AlGaN buffer, 2.7µm GaN buffer, 100nm GaN channel, 1nm AlN spacer, 20nm $Al_{0.3}Ga_{0.7}N$ barriers, and 8nm in-situ silicon nitride cap.

Polycrystalline GaN on the SiO_2 mask was removed with dry etching that stopped at the SiO_2. Removing the SEG mask then resulted in a near-planar surface, which enabled fine-pattern lithography.

The p- and n-type regions of the silicon pn diode were formed by implantation of boron/boron difluoride (BF_2) and phosphorus, respectively. Plasma-enhanced chemical vapor deposition (PECVD) was used to create a 350nm SiO_2 passivation layer for the diode.

The AlGaN/GaN HEMT was fabricated by argon implantation defining the active region, selective etch of source–drain windows in the silicon nitride cap, titanium/aluminium/nickel/gold source–drain metal deposition, 830°C annealing to activate the silicon diode doping and to alloy the HEMT source–drain metal stacks, atomic layer deposition (ALD) of aluminium oxide as part of the gate insulator with the silicon nitride cap, and nickel/gold evaporation of the

gate electrode.

The devices were connected using sputtered aluminium. A 2.5μm imide layer at the periphery of the SEG window improved the step coverage of the aluminium interconnect. The sputtered aluminium was also used to create the silicon pn diode contacts.

The silicon pn diode had a 50μm^2 active region with a drift region 2.5μm long and 20μm wide. The active MIS-HEMT area was 190μm^2 with a 2μm-long 10μm-wide gate. The gate–source and gate–drain distances were 2μm and 15μm, respectively.

The interconnect distance of 70μm reduces the parasitic inductance to around 0.03nH, compared with the ~2nH typical for conventional ~2mm wire bonding.

Individual characterization of the silicon diode gave a forward voltage of 0.8V at 500A/cm^2 current density. Breakdown occurred at 22V. Meanwhile, the MIS-HEMT had an on/off current ratio of 10^8 and 613mA/mm drive current at 2V gate potential and 10V drain bias. The threshold voltage was –5.2V. Breakdown with 1mA/mm current density was 550V.

The cascode circuit had a turn-on voltage of 0.6V for a current density of 1A/cm^2, normalized by the sum of the active areas (240μm^2 = 50μm^2 + 190μm^2) of the component parts. At 500A/cm^2, the specific on-resistance was 5.4mΩ-cm^2 (differential, 2.8mΩ-cm^2).

A conventional AlGaN/GaN Schottky barrier diode on the same wafer had a 0.7V turn-on and 3.7mΩ-cm^2 specific on-resistance (1.8mΩ-cm^2, differential). The higher on-resistance of the cascode diode is blamed on "series resistance and the additional device area needed for the silicon diode".

By contrast, the reverse bias leakage was two orders of magnitude lower for the cascode diode than for the SBD. In fact, the large reverse leakage of the SBD makes it impractical for applications, according to the researchers. In numbers, the cascode diode reverse leakage was 5.6x10^{-5}mA/mm (1.9x10^{-4}mA/cm^2) at 300V. The 300V reverse bias is a typical bus voltage for applications using 500–600V class diodes, according to the team.

The cascode diode reverse leakage performance was "smaller than most of the state-of-the-art AlGaN/GaN SBDs," the researchers say. They attribute the small leakage to "the superior voltage-blocking capability of the MIS-HEMT and the low leakage current of the silicon diode".

Another area where the cascode diode improves on the AlGaN/GaN SBD is in having a low ideality factor of 1.4, compared with 2.7, indicating a sharper turn-on behavior. Varying the temperature between 25°C and 200°C, the reverse leakage of the cascode diode increased by two orders of magnitude

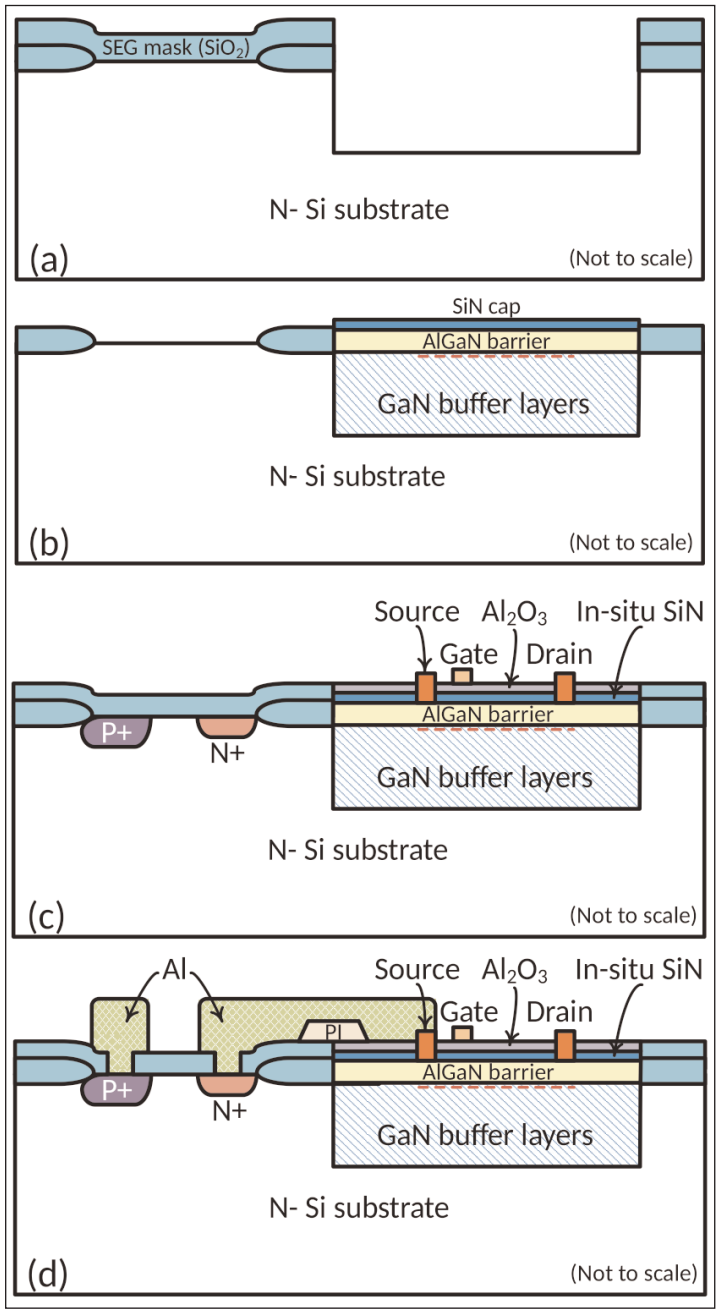


Figure 2. Schematic cross sections: (a) after recessed window formation, (b) after AlGaN/GaN epitaxial structure growth, (c) after silicon and GaN fabrication, (d) after metal-line interconnection deposition.

The cascode diode on/off current ratio was 3x10^6 with 1A/cm^2 breakdown of 557V, which the researchers claim is 62V greater than that of the conventional AlGaN/GaN SBD.

Another area where the cascode diode improves on the AlGaN/GaN SBD is in having a low ideality factor of 1.4, compared with 2.7, indicating a sharper turn-on behavior.

Varying the temperature between 25°C and 200°C, the reverse leakage of the cascode diode increased by two orders of magnitude, but this change was smaller than that of the AlGaN/GaN SBDs. ■

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Author: Mike Cooke

Bulk aluminium nitride platform for gallium nitride high voltage and power

Researchers claim first measurements on quantum well field-effect transistors achieve record high drain current of 2A/mm.

The USA's University of Notre Dame and Cornell University have claimed the first measurements on aluminium nitride/ gallium nitride (AlN/GaN/AlN) quantum well (QW) field-effect transistors (FETs) on bulk AlN substrates with re-grown ohmic contacts [Meng Qi et al, Appl. Phys. Lett., vol110, p063501, 2017]. A device with 65nm gate length achieved a record-high drain current of 2A/mm, it is claimed. The researchers see potential for future high-voltage and high-power microwave electronics.

The use of AlN increases the bandgap to 6.2eV, while a large conduction band offset increases the electron confinement in GaN QWs. The GaN/AlN charge polarization contrast should also increase carrier densities and drive currents.

Another attractive feature of AlN is a high thermal conductivity of 340W/m-K, close to that of silicon carbide substrates (370W/m-K), which are often used for state-of-the-art AlGaN/GaN devices. High thermal conductivity relieves heat dissipation in high-power operation.

The AlN/GaN/AlN quantum well structures (Figure 1) were grown by radio frequency plasma molecular beam epitaxy (MBE) on semi-insulating aluminium-polar bulk AlN substrates. The wafers were 400μm thick. The structure also included a 1.5nm GaN cap to prevent oxidation of the 6nm AlN top barrier.

The conductivity of the two-dimensional electron gas (2DEG) that forms near the AlN/GaN QW interface through charge polarization effects was characterized by Hall measurements, giving a sheet carrier density (n_s) of $2.8x10^{13}/cm^2$, a mobility (μ) of $260cm^2/V\text{-}s$, and sheet resistance (R_{sh}) of 835Ω/square.

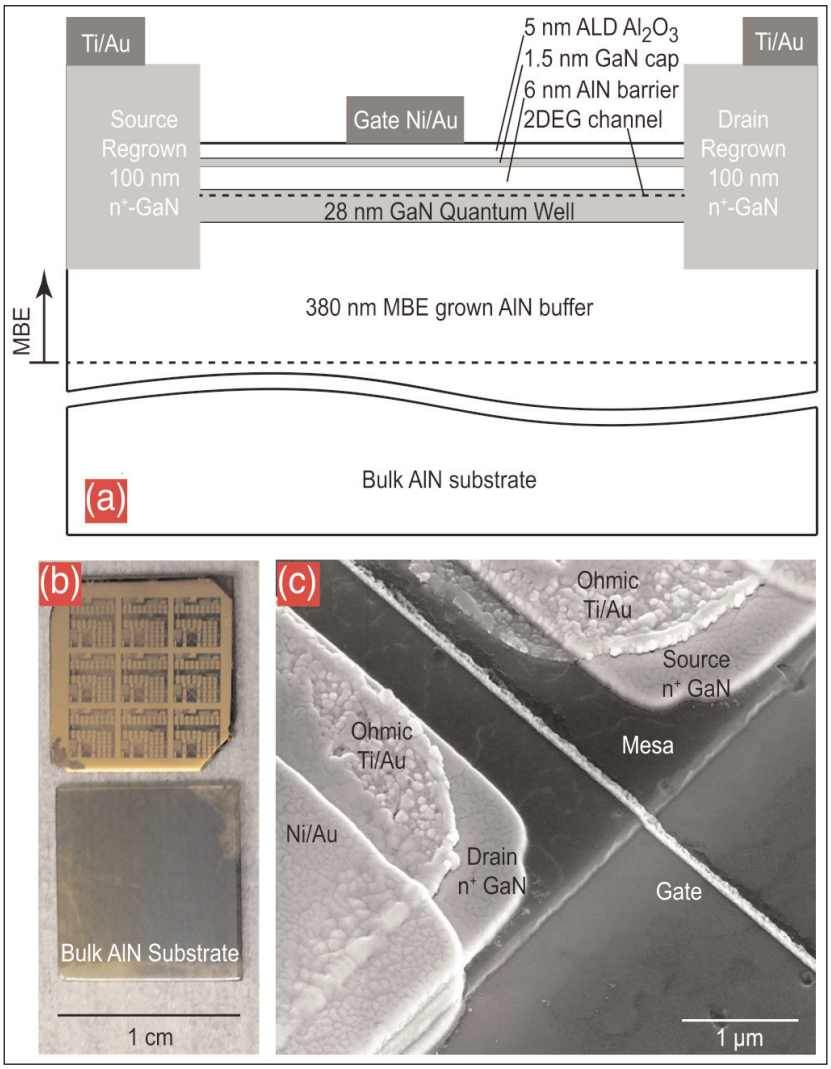

Figure 1. (a) Schematic cross-section layer structure of AlN/GaN/GaN heterostructure FETs on bulk AlN substrates (not to scale). (b) Images of grown and processed sample (top), and unprocessed bulk AlN substrate (bottom). (c) SEM image of finished short-gate-length GaN quantum well FET.

The researchers did produce a structure with $601cm^2/V\text{-}s$ μ, $3.2x10^{13}/cm^2$ n_s, and 327Ω/square R_{sh}. In that case the GaN layer was 21nm, and the AlN top barrier was 3nm. The improved performance is attributed to modified nucleation conditions in the epitaxy process. Referring to these figures, and measurements carried out at 77K, the researchers comment: "These are the highest measured mobility and lowest sheet resistance for the AlN/GaN/AlN strained quantum well heterostructures on the AlN platform till date."

Unfortunately, the team was unable to capitalize on the structure due to fabrication difficulties and limited supply of substrate material. In particular, there was a

lithography alignment problem. The team is presently attempting to more fully understand the transport properties of the AlN/GaN/AlN structure and the reason why the mobility is lower than for structures on GaN substrates.

Short-channel FET fabrication consisted of 40nm reactive-ion etch and MBE re-growth of n^+-GaN as the source–drain contacts with titanium/gold electrodes, atomic layer deposition (ALD) of 5nm aluminium oxide (Al_2O_3) and deposition of nickel/gold gates.

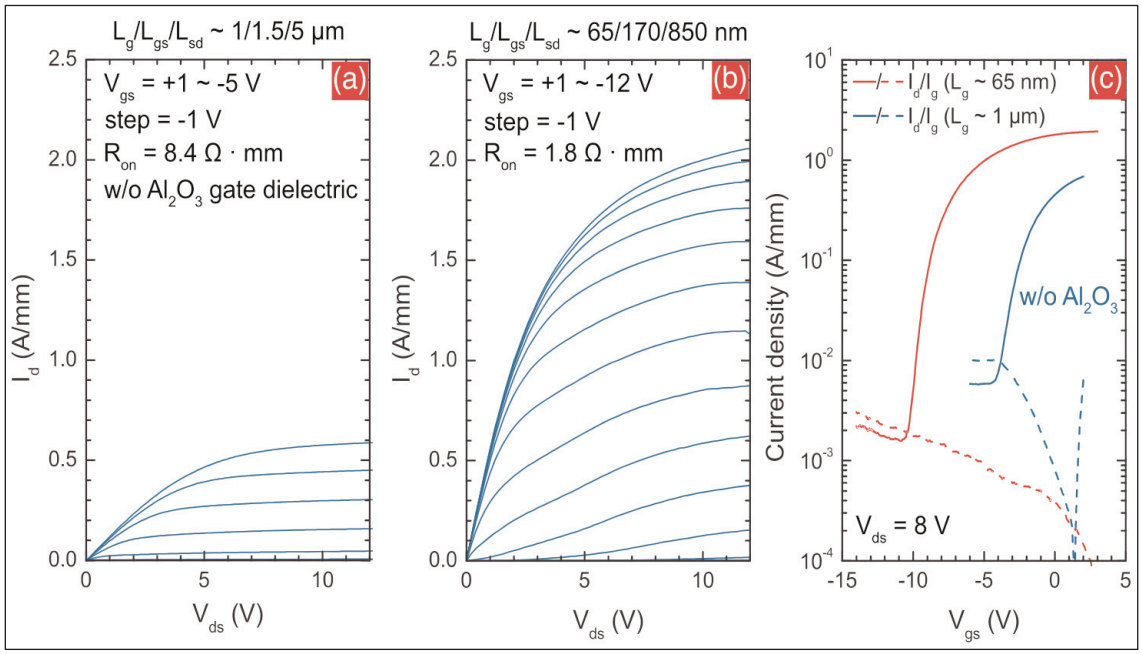

Figure 2. DC common-source family of current-voltage characteristics for (a)1µm and (b) 65nm gate AlN/GaN/AlN FETs. (c) Transfer characteristics of both (semi-log scale).

Nickel/gold was also added to the source–drain electrodes. The researchers also produced long-channel devices where the gate metals were deposited on the GaN cap, followed by 5nm ALD of Al_2O_3.

Raman spectroscopy indicated that the compressive strain of the channel was almost completely relaxed in the re-grown GaN of the source-drain contacts. Hall measurements on the FET structure gave $3.4x10^{13}/cm^2$ n_s, $180cm^2/V\text{-}s$ µ, and 1020Ω/square R_{sh}. The researchers comment that the reduced µ and increased R_{sh} "from the as-grown sample may be due to the modification of surface states by the ALD Al_2O_3 layer." Transmission line structure measurements gave a specific contact resistance of 0.13Ω-mm and sheet resistance of 1100Ω/square.

The short-channel device demonstrated 2A/mm current density at 12V drain and +1V gate bias, 3x higher than for the long-channel FET. The short-channel FET had 65nm gate length and 2x50µm width. The gate-source and source-drain distances were 170nm and 850nm, respectively. The long-channel parameters were 1µm gate length, 50µm width, 1.5µm source–gate, and 5µm source–drain.

An 80nm gate-length FET had increased current density of 2.8A/mm at +3V gate and 12V drain bias. The higher current was due to a shorter gate-source spacing leading to lower source access resistance, according to the team. However, the device only had half a gate width, which made it unsuitable for frequency performance testing.

The high-current performance was comparable to that of state-of-the-art GaN FETs and a significant improvement over AlN/GaN devices produced on AlN/sapphire templates (~1.4A/mm).

The on-resistance of the long- and short-channel FETs was 8.4Ω-mm and 1.8Ω-mm, respectively. The short-channel device had a high output conductance due to short-channel effects that could be suppressed by using thinner QW and gate barrier stacks. A thinner QW would bring increased benefits from the AlN back barrier.

Studies of the gate leakage indicated that the non-optimal MBE process generated defects. The gate leakage was reduced in the short-channel devices by the Al_2O_3, improving the on/off current ratio by three orders of magnitude.

The peak extrinsic transconductance of the 65nm FET came in at 250mS/mm, at –6.8V gate potential and 8V drain bias. Correcting for source access resistance, the intrinsic transconductance was 270mS/mm. The threshold voltage was –9.1V, giving normally-on behavior, reflecting the high sheet carrier density and the gate capacitance.

Pulsed large-signal (10V) measurements showed an 18% gate lag and a 16% drain lag. Improved large-signal performance and environmental robustness are expected from the use of passivation to reduce the effects of surface states.

Radio frequency (0.25–30GHz) measurements gave a 120GHz current-gain cut-off (f_T) and 24GHz power-gain cut-off (f_{max}). The low f_{max} could be improved by moving from rectangular to T-gate structures,

The researchers suggest that using thicker large-bandgap AlN barrier layers with AlGaN channels could achieve improvements in breakdown characteristics and thermal handling over existing state-of-the-art and could lead to high-power applications. ■

http://dx.doi.org/10.1063/1.4975702

Author: Mike Cooke

N-polar gallium nitride gives record power density and efficiency at 94GHz

High-power solid-state transmitter applications could benefit through greater integration with fewer stages at both chip and system levels.

University of California Santa Barbara (UCSB) in the USA claims record power density (6.7mW/mm) and power-added efficiency (16.9% PAE) at the 'W-band' frequency of 94GHz for metal-insulator-semiconductor high-electron-mobility transistors (MISHEMTs) based on N-polar gallium nitride (GaN) [Steven Wienecke et al, IEEE Electron Device Letters, published online 16 January 2017].

The electric field arising from charge polarization field effects in the N-polar devices is opposite to that in the more usual Ga-polar material used for GaN HEMTs. "For N-polar, the polarization fields create a natural back-barrier that displaces the [two-dimensional electron gas (2DEG)] towards the gate electrode and decouples the design of the primary charge inducing layers and the gate barrier," the researchers explain.

The material was grown by metal-organic chemical vapor deposition (MOCVD) on silicon carbide (Figure 1). The n^+-GaN in the source–drain access regions was grown by plasma-assisted molecular beam epitaxy (PAMBE). The access regions were found to have 220Ω/square resistance, compared with 385Ω/square in the gate recess region.

The fabricated devices had 45nm gate-foot length and 2x25μm width. The gate-top length was 450nm. The source–drain distance was 600nm, and the gate–source distance was 125nm. The 375μm silicon carbide (SiC) substrate was not thinned. Measurements were performed on-wafer.

The peak DC extrinsic transconductance was

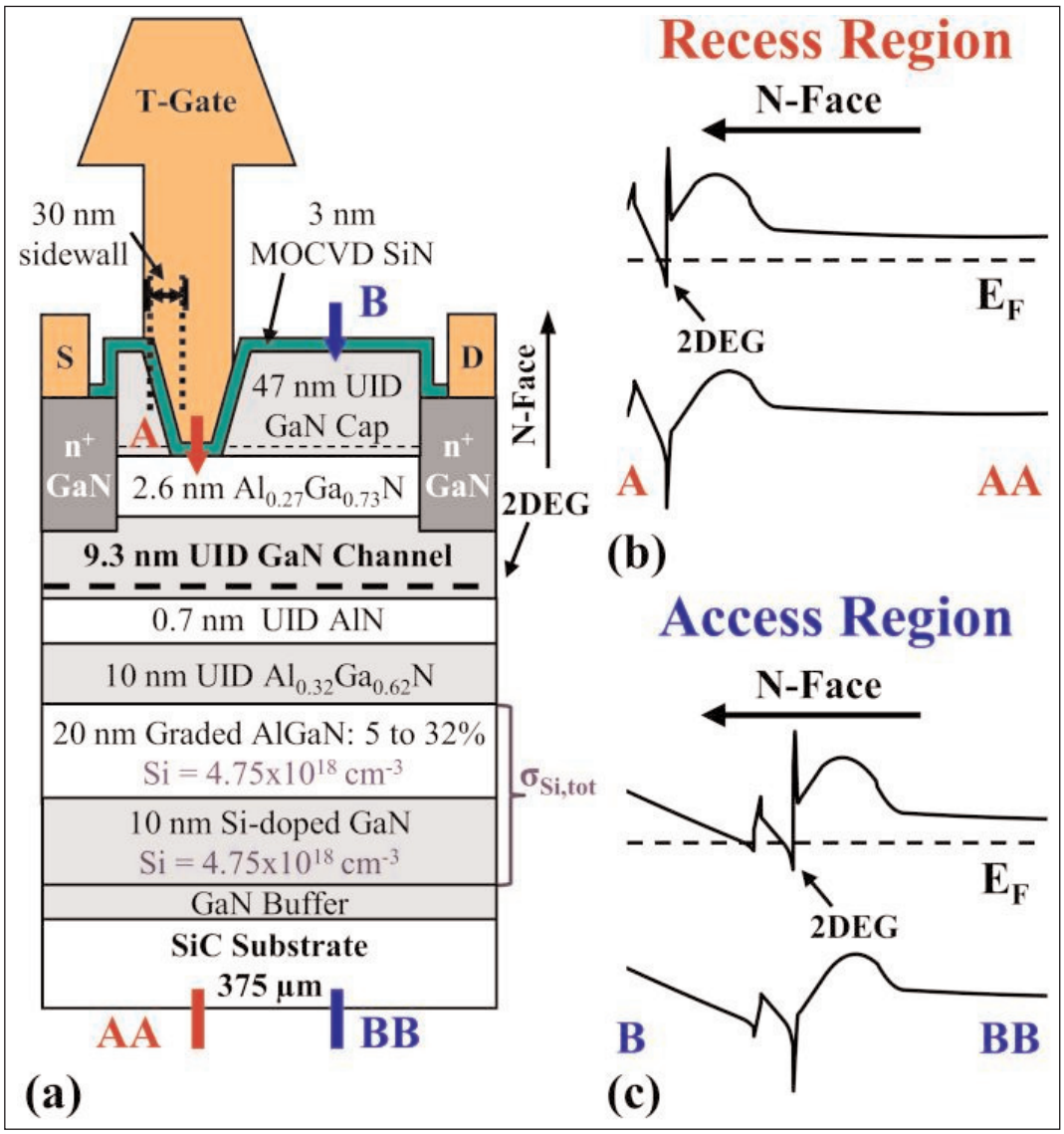

Figure 1. (a) Cross-section of N-polar GaN cap MISHEMT device structure (not to scale). Calculated energy band diagram at equilibrium in (b) gate recess and (c) access regions.

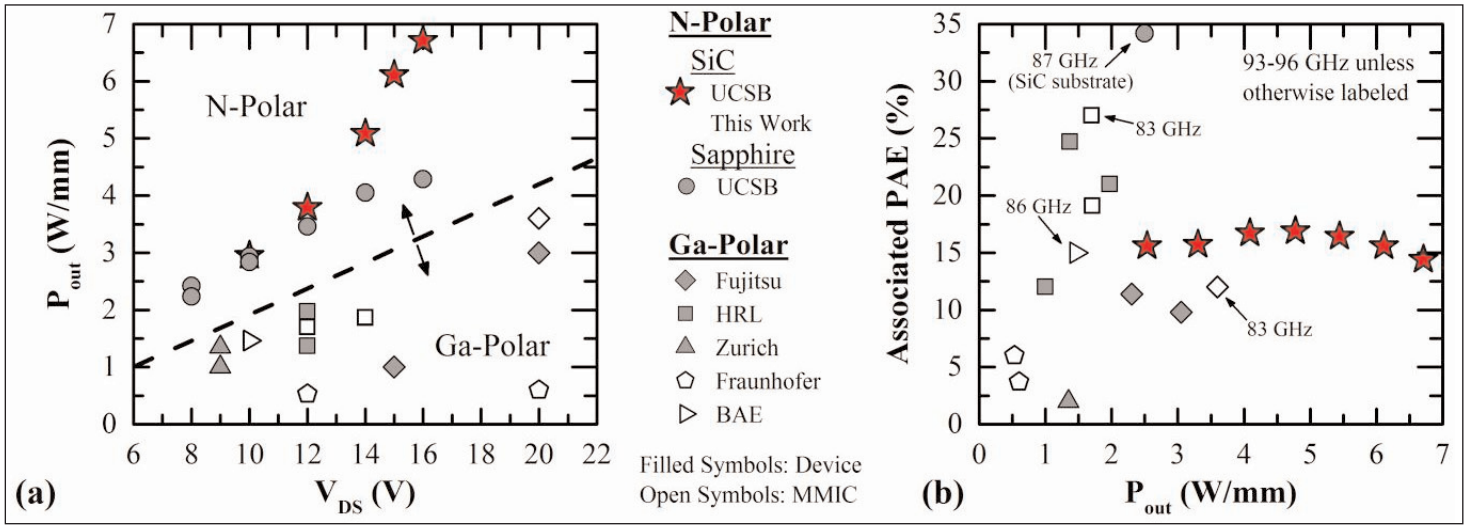

Figure 2. Comparison of W-band (75–110GHz) GaN HEMT technologies at frequencies above 83GHz: (a) output power versus drain bias; (b) associated PAE versus output power. For both plots, open symbols correspond to data taken on monolithic microwave integrated circuits (MMICs) and filled symbols correspond to single device cells either with or without on-wafer pre-matching.

650mS/mm with 5V drain bias. The maximum drain current (I) at 0V gate potential was 1.9A/mm with 0.61Ω-mm on-resistance. The researchers report: "No current collapse or knee walkout is seen in pulsed IV, illustrating the effectiveness of the N-polar GaN cap design in mitigating dispersion"

Frequency measurements were made up to 67GHz, resulting in cut-off frequencies of 112GHz for current (f_T) and 323GHz for power gain (f_{max}) with the effects of contact pads 'de-embedded'. The quiescent bias conditions were –1.75V gate potential, 13V drain bias, and 1.03A/mm drain current.

The 94GHz power performance was measured using a passive-tuner load-pull system from Maury Microwave Corp. The uncooled continuous-wave operation was under class-AB amplifier conditions. The nominal quiescent source–drain current was 500mA/mm. The relative high current was chosen to maximize power-added efficiency.

At 16V drain and 444mA/mm current, the maximum total output power (P_{out}) was 25.26dBm (336mW) with associated PAE of 14.4%. The researchers report: "This corresponds to a very high power density of 6.7W/mm which, to the best of our knowledge, represents the highest output power density ever recorded for a GaN device measured at W-band."

A clear pathway towards improved gain and efficiency in load-pull exists through optimization of the existing probe pad layout and a thinning of the silicon carbide substrate. Additional performance enhancements in gain, efficiency and power density are expected with further vertical and lateral scaling of the device dimensions

Comparing with other benchmarks (Figure 2), the team adds: "The output power density of this N-polar MISHEMT exceeds that of any reported Ga-polar device by a significant margin and scales extremely well with drain bias, suggesting an RF current swing close to 2A/mm."

The performance does not saturate at higher drain bias. The researchers attribute this to the use of SiC substrates, which has higher thermal conductivity, giving better thermal management and thus reduced self-heating. The maintenance of high PAE at high output power is credited on the N-polar GaN cap removing surface states, and hence dispersion effects (e.g. current collapse), without the use of thick silicon nitride passivation.

The maximum PAE was 16.9%, achieved at 15V drain voltage and 500mA/mm drain current. The associated output power was 4.8mW/mm. By making various improvements, the researchers expect that 22% PAE with no reduction in output power density could be reached using the technology.

The team comments: "A clear pathway towards improved gain and efficiency in load-pull exists through optimization of the existing probe pad layout and a thinning of the SiC substrate. Additional performance enhancements in gain, efficiency and power density are expected with further vertical and lateral scaling of the device dimensions."

They see opportunities for high-power solid-state transmitter applications through greater levels of integration with fewer power-combining stages at both the chip and system level. ■

https://doi.org/10.1109/LED.2017.2653192

Author: Mike Cooke

Gallium nitride on silicon on insulator metal-organic vapor phase epitaxy

A buried oxide layer has been used to increase the breakdown voltage from vertical through-wafer current by 400V.

Researchers based in Finland and Poland have compared gallium nitride (GaN) grown on bulk silicon with material grown on silicon-on-insulator (SOI) wafers [J. Lemettinen et al, Semiconductor Science and Technology, accepted manuscript online 13 January 2017].

Along with lower dislocation densities in GaN/SOI, the researchers from Aalto University in Finland, the Institute of Electronic Materials Technology in Poland and Okmetic Oyj in Finland found 400V higher breakdown in vertical through-wafer current testing. "These results show that the GaN-on-SOI platform is promising for power electronics applications," the team comments.

Along with providing templates for power high-electron-mobility transistors (HEMTs) or light-emitting diodes (LEDs), the researchers suggest that the insulating buried oxide (BOX) layer of the SOI wafer could reduce losses and crosstalk in high-frequency applications.

Three different 6-inch substrates were compared: 1000µm-thick bulk silicon, and SOI wafers with 2µm silicon on 1µm- or 2µm-thick BOX layers. The silicon was oriented with the (111) surface suitable for GaN growth. The handles for the SOI wafers were 650µm (100) p-Si. Okmetic supplied the substrates.

Metal-organic vapor phase epitaxy (MOVPE) was performed using standard 1060°C step graded AlGaN layers to transition between the aluminium nitride (AlN) nucleation and GaN top layers (Figure 1). The 260nm AlN was grown at 980°C and 1085°C. The GaN layer was grown at 1040°C. Variations in the AlGaN buffer layers with 0.5x and 1.5x scaling were also implemented (see Table 1). The buffers were grown at 100mbar pressure, while the GaN was grown at 400mbar.

The researchers comment: "The higher growth pressure increases the crystalline quality of GaN while material grown at 100mbar pressure has a higher carbon concentration and forms a semi-insulating layer. This type of semi-insulating layer is typically used for device insulation, for example, in GaN HEMT."

Figure 1. Schematic cross-sectional view of layer stack fabricated on SOI substrate.

Table 1. Fabricated sample structures, with thicknesses in µm.

Sample	A	B	C	D	E	F
Handle Si	1000	675	675	675	675	675
BOX	—	1	1	2	2	2
Device Si	—	2	2	2	2	2
AlN/AlGaN buffer	1	1	1.5	0.5	1	1.5
GaN	1	1	1	1	1	1

Table 2.

Sample	A	B	C	D	E	F
Total (10^{10}/cm^2)	1.93	1.02	0.82	0.914	0.73	0.833
Edge (10^{10}/cm^2)	1.93				0.73	
Screw & mixed (10^7/cm^2)	0.81				1.34	

Defects and strain of the resulting materials were studied using x-ray analysis and selective etching. Although the x-ray diffraction peaks of GaN/SOI were broader, the etched defects were about half that for material grown on bulk silicon. However, the etching results were in line with detailed x-ray studies that differentiated dislocation types in terms of ratios and density (see Table 2). Deeper studies of strain conditions resulted from synchrotron x-ray topography carried out at the TOPO-TOMO beamline of the ANKA (Angströmquelle Karlsruhe) facility in Germany.

Among their discoveries, the researchers found that a thicker BOX layer allowed them to reduce the buffer thickness while maintaining GaN quality. They comment: "The thinner buffer reduces the growth time by 1 hour, and thus reduces the total process cost. In addition, our results indicate that varying the SOI device Si layer thickness could lead to even better crystalline quality."

Vertical through-substrate leakage current measurement found that the BOX layer significantly improved breakdown characteristics — "the onset of breakdown is delayed by approximately 400V," according to the researchers (Figure 2). "The vertical through-substrate current of sample A is approximately the same at 80V bias than sample E current at 480V bias," they add. The contacts for the measurements were aligned 1mmx1mm pads of titanium and gold on the top and bottom of the wafer. ■

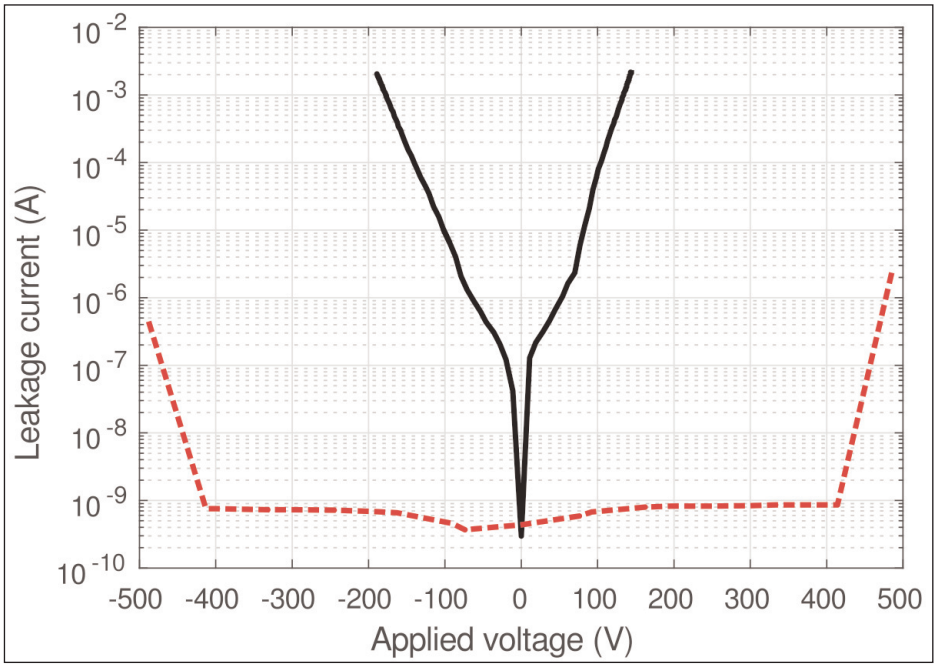

Figure 2. Vertical through-substrate leakage current of epitaxial layers of sample A grown on bulk Si (black, solid) and sample E grown on SOI (red, dashed) substrate.

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Author: Mike Cooke

Vertical gallium nitride moves for power electronics

Mike Cooke reports on transistor and diode performance enabled by vertical device designs.

There has been increased reporting of research and development work on gallium nitride (GaN) vertical electronics devices in the past couple of years. Vertical devices offer improved breakdown voltage, current handling and thermal performance in a smaller footprint, compared with more conventional lateral GaN high-electron-mobility transistors (HEMTs), planar metal-oxide-semiconductor field-effect transistors (MOSFETs) and Schottky barrier diodes (SBDs).

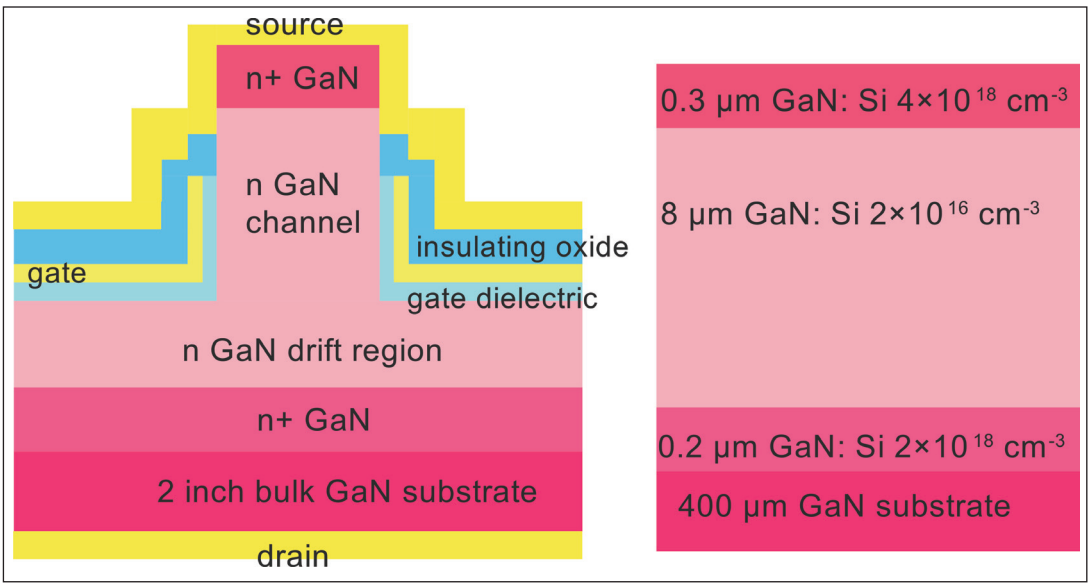

Figure 1. Schematic of vertical fin power FET and starting epi-structure.

Vertical devices are mainly fabricated from material grown on expensive free-standing GaN substrates. Despite the cost, such devices should make better use of GaN's material properties such as ultralow conduction loss under high voltage and high temperature than the restriction to lateral devices of GaN grown on foreign substrates such as sapphire, silicon carbide (SiC) or silicon.

Free-standing GaN also has much lower dislocation densities, which is vital for efficient vertical high current conduction and blocking.

Most reports of vertical GaN devices use expensive free-standing substrates, but with increased interest in vertical applications researchers hope material costs will continue to fall in the near future with development. Here, we report on some recent vertical GaN devices, produced mainly, but not exclusively, on free-standing or bulk substrates.

Fin power FETs

Massachusetts Institute of Technology (MIT) has developed a vertical GaN fin power field-effect transistor (FET) [Min Sun, et al, IEEE Electron Device Letters, online 17 February 2017]. The device structure avoids the use of material re-growth of p-GaN layers. Material re-growth increases process complexity and (in a manufacturing context) cost. Layers with p-type GaN tend to have high resistance due to the difficulties of magnesium doping.

The MIT researchers are targeting high-voltage, high-current, low-cost, high-performance power electronics applications. The demonstrated fin power FET with suitable electric field engineering techniques achieved an 800V hard breakdown in the off-state with 0V gate potential.

Lateral GaN devices are now commercially available with 650V breakdown. The MIT teams see the advantages of vertical structures as being:
(1) die area does not depend on breakdown voltage;
(2) surface is far from high electric field regions, minimizing trapping effects;
(3) high current levels, thanks to easier current extraction when source and drain contacts are positioned vertically on opposite sides of wafer; and
(4) high thermal performance due to more widely spread current and electric field distribution.

The epitaxial material was grown using metal-organic chemical vapor deposition (MOCVD) on 2-inch bulk GaN (Figure 1). Submicron fins with 70º sidewalls were etched using inductively coupled plasma based on chlorine/boron trichloride chemistry. The dry etch was followed by hot tetramethylammonium hydroxide (TMAH) wet etching to give vertical sidewalls.

Alignment of the fins with the <11$\bar{2}$0> a-plane of the GaN crystal structure gave smoother fins. The fins were 100mm long and 0.18mm wide.

The gate consisted of 15nm atomic layer deposition (ALD) aluminium oxide dielectric and sputtered molybdenum metal electrode. The metal electrode and dielectric were removed from the tops of the fins. Plasma-enhanced chemical vapor deposition (PECVD) silicon dioxide was used as a spacer to isolate the gate metal from the source electrode. The source and backside drain metals were annealed titanium/aluminium.

The on/off current ratio was as high as 10^{11} with a 5V drain bias (Figure 2). The gate leakage was less than 10^{-4}A/cm^2 at a gate-source potential difference of 5V. The threshold voltage for an on/off current ratio of 10^5 was 1.0V. Based on extrapolation, a higher threshold of 1.5V was found. The researchers comment: "The threshold voltage can shift more positively by reducing the doping density in the channel or scaling down the channel width even further."

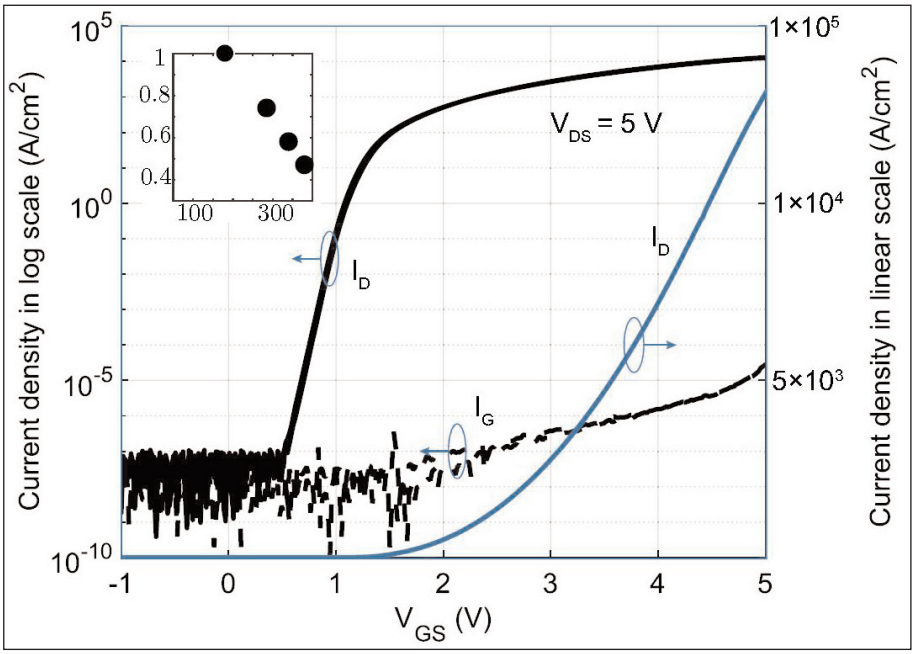

Figure 2. Double sweep transfer curves of fabricated vertical fin power FET with channel width 180nm: left — y-axis in log scale; right — y-axis in linear scale. Inset: threshold voltage (V_{th} (y-axis, in volts) as function of channel length (x-axis, in nm).

The subthreshold swing was as low as 75mV/decade and hysteresis effects were small. The on-resistance was 0.36mΩ-cm^2 based on fin area and 3.24mΩ-cm^2 based on device area. The low annealing temperature of the source-drain electrodes gave imperfect ohmic behavior.

Without edge termination, hard 0V gate off-state breakdown occurred at 100V. A gate field-plate termination structure on silicon dioxide at the device periphery increased breakdown to 400V. "In both cases, the breakdown mechanism is due to gate dielectric failure," the team reports. Further increase in breakdown voltage to 800V was enabled by filling the trenches of the device with 100nm silicon dioxide before gate formation.

The researchers also present a benchmark comparison with the performance of power transistors produced by other groups (Figure 3).

Junction barrier Schottky diodes

Cornell University, Qorvo Inc and IQE RF LLC in the USA have worked on vertical junction barrier Schottky diodes (JBSDs) produced on free-standing GaN [Wenshen Li, et al, IEEE Transactions on Electron Devices, published online 21 February 2017]. The aim was to combine the good characteristics of SBDs and pn diodes (PNDs) for power applications.

SBDs have low turn-on voltage, but suffer from higher current leakage under reverse bias. By contrast, pn diodes have high turn-on and low reverse-bias leakage. High current under reverse bias reduces the effective breakdown voltage (BV) characteristics of SBDs.

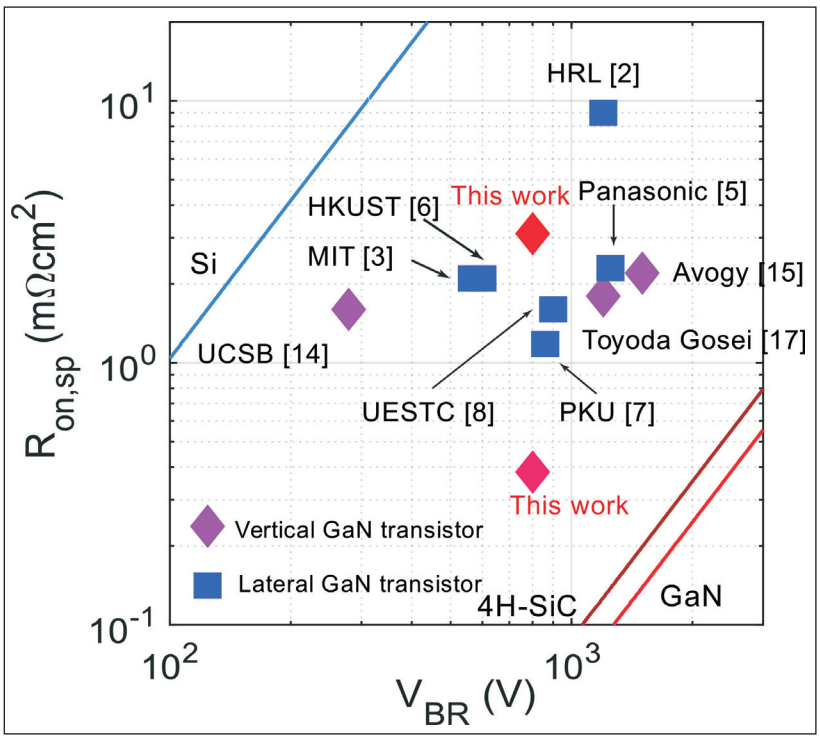

Figure 3. Specific on-resistance ($R_{on,sp}$) versus breakdown voltage (V_{BR}) of GaN vertical fin power FET, along with other normally-off lateral and vertical GaN transistors. Top point averaged by total device area and other point averaged by total fin area.

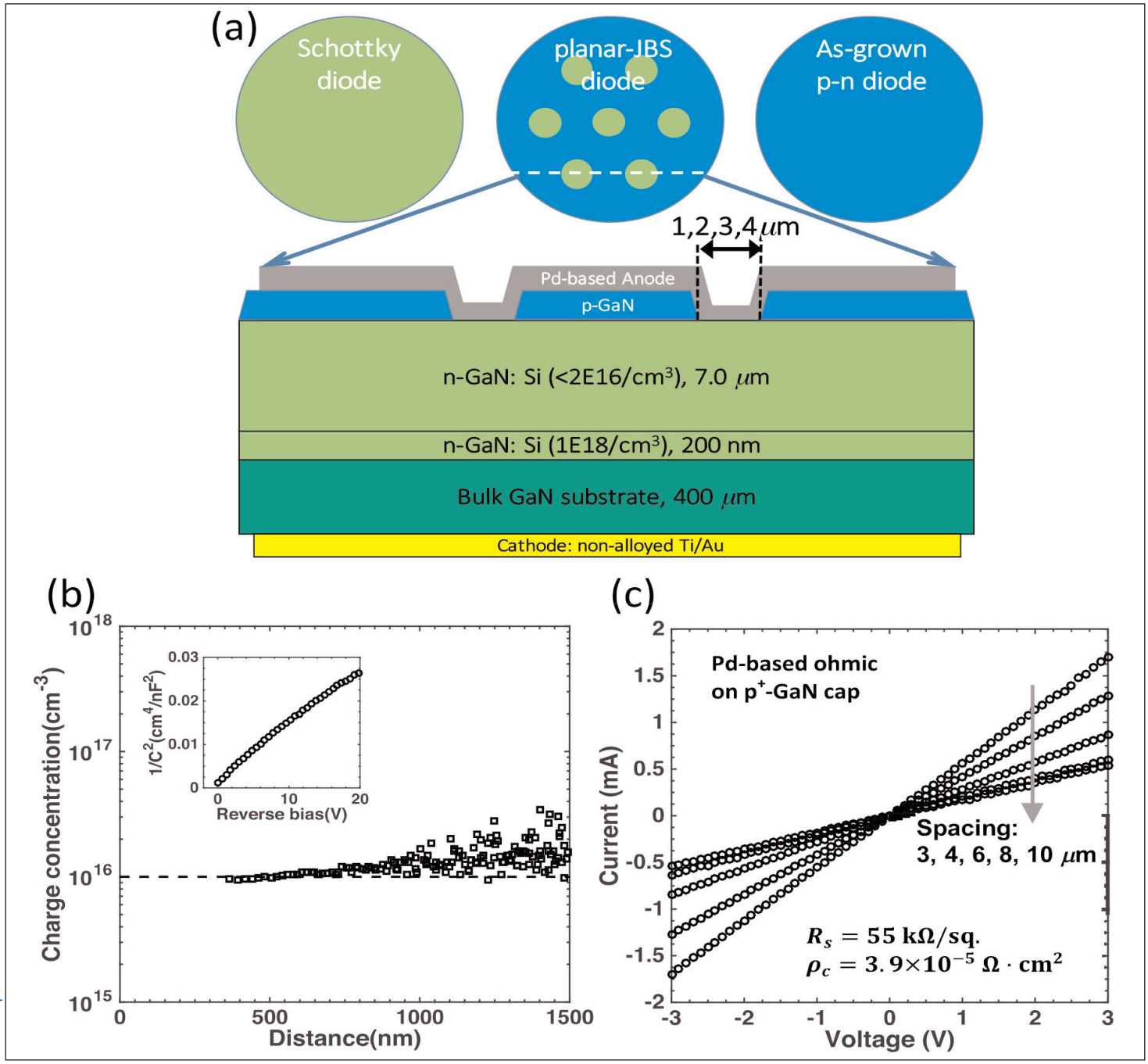

Figure 4. (a) Schematic device top view and cross section of fabricated trench JBSD. Total Schottky (trench) area is designed to be the same for each trench diameter. (b) Carrier concentration in n-GaN drift layer extracted by capacitance–voltage measurement at 1MHz. (c) Representative transmission line method current–voltage characteristics of Pd-based ohmic contact on p-GaN with calculated sheet resistance (R_s) and specific contact resistivity (ρ_c).

By using pn and Schottky barrier structures, the JBSD can combine low turn-on with low reverse-bias leakage through reducing the surface field (RESURF). However, attempts to use lateral pn junctions suffer from increased process complexity from using ion implant or re-growth steps.

Instead, Cornell/Qorvo/IQE used a vertical structure with trenches in p-GaN material reaching down to give Schottky contacts with n-GaN (Figure 4).

The team comments that Panasonic used a similar trench JBSD to give superior breakdown and simultaneously low on-resistance in work presented in 2015. Cornell/Qorvo/IQE add: "However, the RESURF effect could not be explicitly confirmed, since the characteristic shift of the turn-on voltage was not observed and the leakage behavior of the diodes was not reported."

MOCVD on free-standing GaN was used to create the semiconductor material of the diodes. The substrate had a threading dislocation density of ~2x10^6/cm^2. High dislocation densities lead to higher reverse-bias leakage in general. Non-free-standing GaN substrates such as sapphire and silicon carbide tend to lead to

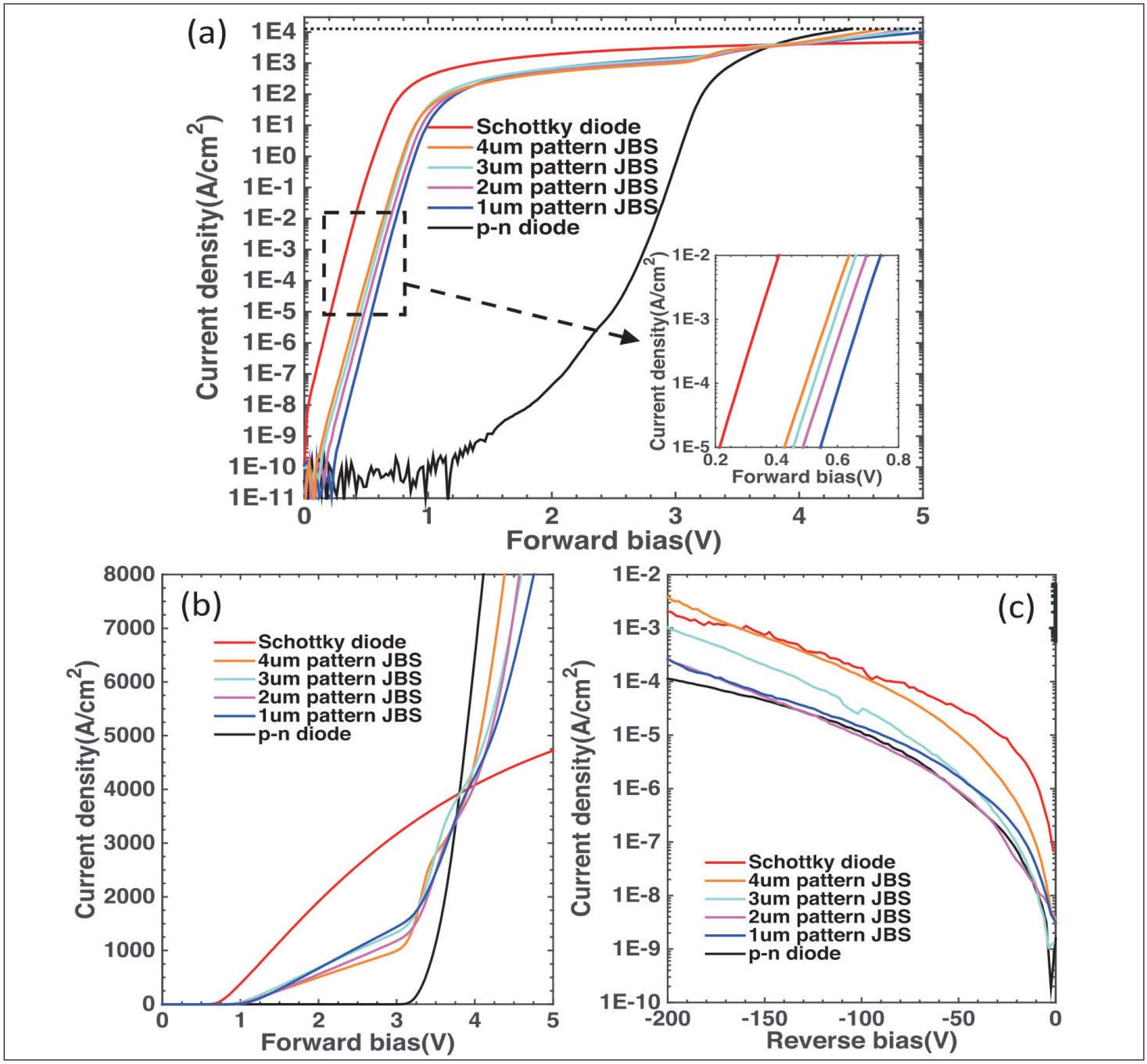

Figure 5. Measured current-voltage characteristics of trench JBSDs. (a) Forward bias characteristics in log scale. (b) Forward bias in linear scale showing two-step turn-on. (c) Reverse bias in log scale.

higher-dislocation-density GaN epitaxial material due to lattice mismatch.

The trenches for the JBSD structure were formed by dry etching. Circular trenches were chosen since the researchers expected this to result in a more uniform field profile along the periphery, giving a less restricting size constraint compared with striped/linear trenches.

The anode of the diode was palladium-based (Pd-), giving ohmic and Schottky contacts with p-GaN and n-GaN, respectively. The devices were 100mm in diameter. The researchers comment: "No additional field-plate (FP) structures are used for edge termination, since the additional leakage often associated with the FP process might mask the trend in the leakage current of trench JBSDs designed with varied trench sizes."

Simulations with stripe trenches suggested that the surface electric field arising from positive charge under the Schottky contact terminates at the depletion region in the p-GaN instead of the Schottky contact, reducing the surface field's vertical component.

The JBSDs and the comparison SBD turned on with around 1V forward bias and an ideality factor in the range 1–1.05 (Figure 5). The turn on shifts upwards as the trench becomes smaller. Reverse-bias leakage was reduced as the trench size was scaled downwards. "Up to 20 times reduction in leakage current is achieved in the 1mm trench JBSDs compared with conventional SBDs, reaching the pn diode leakage level," the team

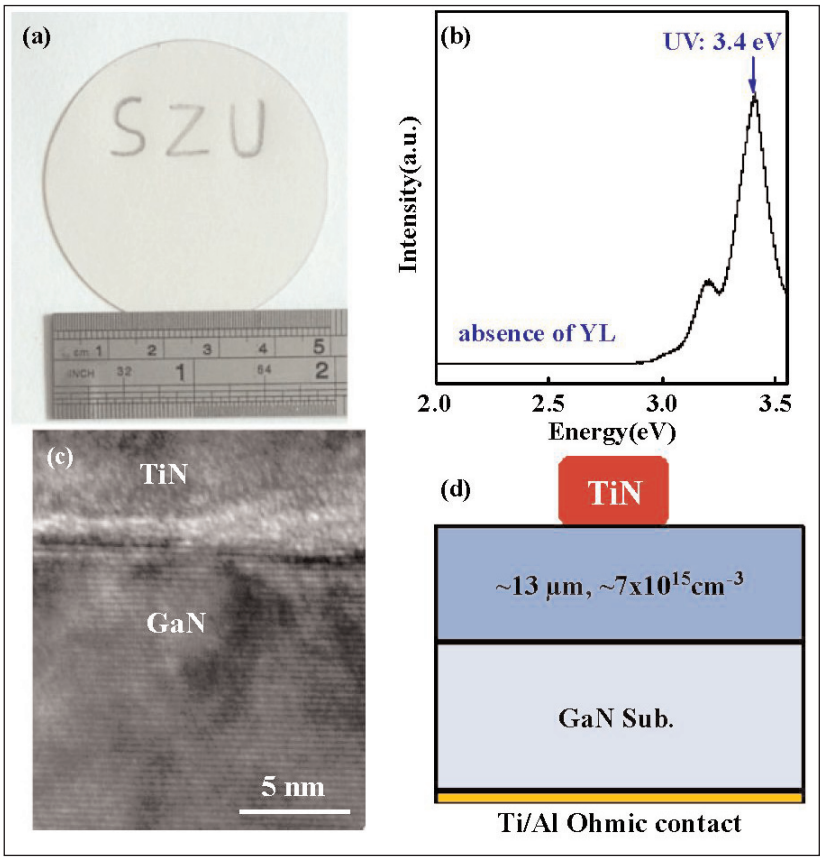

Figure 6. (a) Photograph of free-standing GaN wafer. (b) Room-temperature photoluminescence spectrum of free-standing GaN wafer with strong peak at 3.4eV from near-band-edge ultraviolet transition. (c) Transmission electron microscope cross-section of TiN/GaN stack. (d) Schematic of fabricated vertical GaN SBDs.

reports, adding: "As the total trench area is designed to have the same total area, the reduction in leakage current is due to the RESURF effect arising from the trench JBSD design."

The breakdown voltages of the pn diodes and JBSDs were similar, in the range 250–650V. The SBD breakdown was generally somewhat lower, in the range 275–425V. The SBD performance was probably affected by severe edge field crowding at the anode metal edge. The researchers expect high breakdown voltages with suitable edge termination structures.

The reverse current leakage at 150V bias increased from pure pn diode to Schottky barrier diode, through increasing-trench-size junction barrier Schottky diodes. The pn diode current density leakage was in the range 10^{-5}–10^{-4}A/cm^2, while the SBD leakage was spread between ~3x10^{-4}A/cm^2 up to ~10^{-1}A/cm^2.

Gold-free Schottky barrier diodes

Researchers in China and Japan have developed a gold-free Schottky contact for GaN, claiming records for on/off current ratio and breakdown voltage for vertical GaN Schottky barrier diodes [Xinke Liu et al, Jpn. J. Appl. Phys., vol56, p026501, 2017].

The team from Shenzhen University, Shanghai University, Shanghai Institute of Microsystem and Information Technology, and Suzhou Institute of Nano-Tech and Nano-Bionics (SINANO) in China and Tokushima University in Japan believe that such a development could lead to the use of underutilized small-diameter silicon CMOS fabrication facilities. They explain: "In silicon CMOS foundries, gold is typically not used in the front-end process, because gold could cause deep-level traps in silicon, which are the carrier recombination centers that can reduce the carrier lifetime in silicon." Usually, Schottky contacts on GaN use nickel and gold.

"These devices could be generally useful for cost-competitive power switching circuits with a supply voltage in the range of 500–700V," the researchers write.

The 2-inch free-standing (0001) GaN wafer was grown by hydride vapor phase epitaxy (HVPE) with typical defect density ~10^5/cm^2. The resistivity was about 0.01Ω-cm and the surface roughness was about 0.2nm. A 13mm GaN layer was

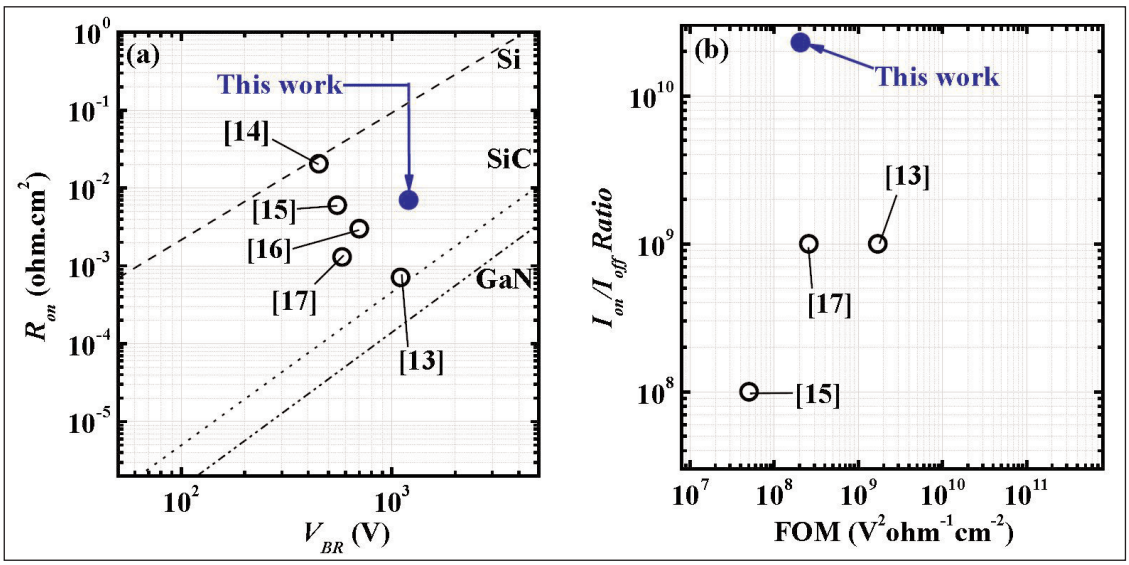

Figure 7. Open symbols: GaN SBDs with gold; solid symbols: GaN SBDs without gold: (a) V_{BR} versus R_{on} and (b) I_{on}/I_{off} ratio versus FOM of fabricated and state-of-the-art GaN SBDs.

added by MOCVD. The background doping was around $7x10^{15}/cm^3$. The Hall mobility was measured at ~1250cm²/V-s.

The 250mm-diameter circular SBD structure consisted of 100nm of sputtered titanium nitride (TiN) that was etched into an electrode through chlorine-based plasma reactive ion etch (Figure 6). The etch process had a selectivity factor for TiN over GaN of around 100. The back-side contact consisted of alloyed 50nm Ti and 200nm aluminium.

The turn-on voltage of the SBD was around 0.69V. The ideality and Schottky barrier height were 1.1 and 0.92eV, respectively. The saturation current under reverse bias was $1.8x10^{-12}$A, close to the value of $2.5x10^{-12}$A expected on the basis of forward bias behavior. The on/off current ratio (I_{on}/I_{off}) was $2.3x10^{10}$ using measurements at +1.6V and −2V.

Hard breakdown (V_{BR}) under reverse bias occurred at 1200V. The researchers suggest that the breakdown mechanism could be impact ionization. The power device figure of merit (FOM) V_{BR}^2/R_{on} was $2.1x10^8V^2/\Omega$-cm², using the specific on-resistance (R_{on}) of 7mΩ-cm² from the linear region of the current–voltage curve. The team plotted benchmark comparisons of R_{on}, V_{BR}, I_{on}/I_{off}, and FOM (Figure 7).

The researchers comment: "Compared with other reported GaN SBDs, the GaN SBDs in this work fabricated with a gold-free process shows the highest breakdown voltage of 1200V. However, the on-state resistance of the fabricated GaN SBDs in this work is slightly higher, implying that further reduction in non-gold ohmic contact resistance is required."

Silicon substrate

Massachusetts Institute of Technology has developed quasi- and fully vertical pn GaN diodes on silicon, claiming a number of record performance characteristics [Yuhao Zhang et al, IEEE Electron Device Letters, published online 30 December 2016]. The researchers see possible application of the techniques to include vertical power transistors and advanced rectifiers, leading to competitive low-cost devices for 200–600V power switching.

The MIT researchers estimate silicon wafer costs to be $0.08/cm², which compares with ~$2.2/cm² for 4-inch sapphire and ~$100/cm² for 2-inch GaN substrates.

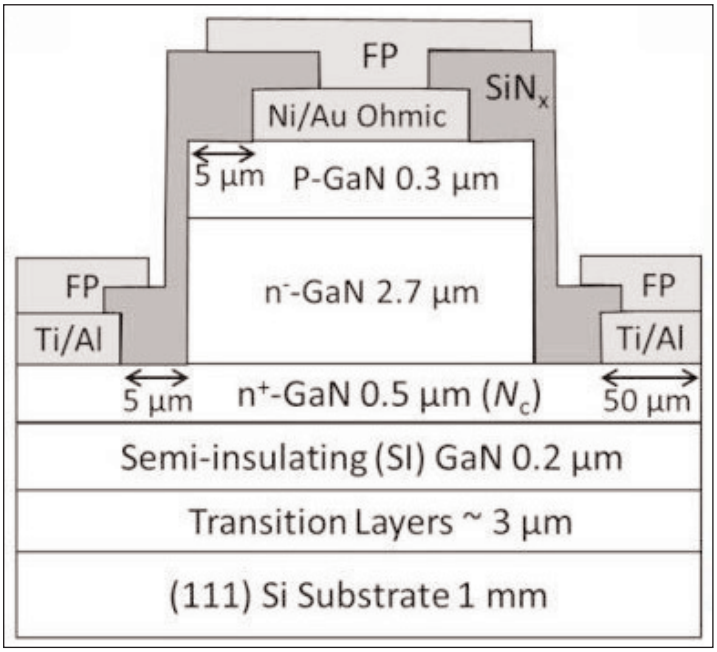

Figure 8. Quasi-vertical pn diode with passivation and field-plate (FP) structures.

The III-nitride epitaxy consisted of MOCVD on 2-inch (111) silicon. The transition layers used aluminium gallium nitride (AlGaN) alloys. The semi-insulating GaN was achieved with iron doping. The low-electron-carrier-density n⁻-GaN drift layer used carbon doping with propane precursor.

The quasi-vertical diodes (Figure 8) used deep etch down to the n-GaN cathode layer for mesa isolation and silicon nitride passivation.

For the fully vertical structure (Figure 9), the epitaxial material was flipped and bonded to a (100) silicon substrate. Before bonding, the device mesa-isolation regions were defined by deep etching down to the (111) silicon growth substrate.

The compression bonding was carried out at 300ºC for 20 minutes. A nickel layer protected the (100)

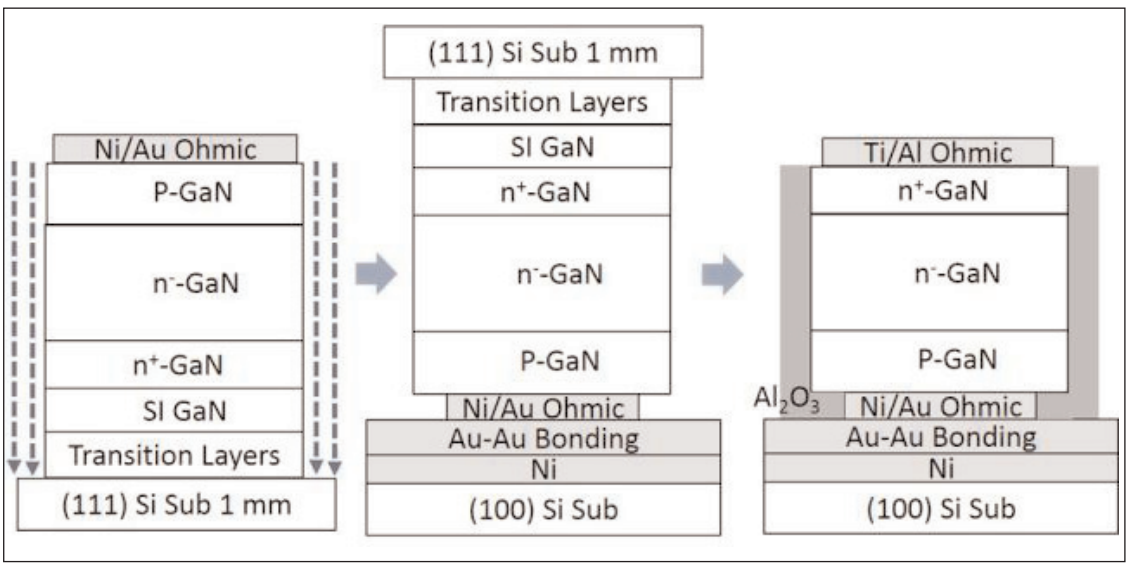

Figure 9. Fabrication sequence for fully vertical pn diode.

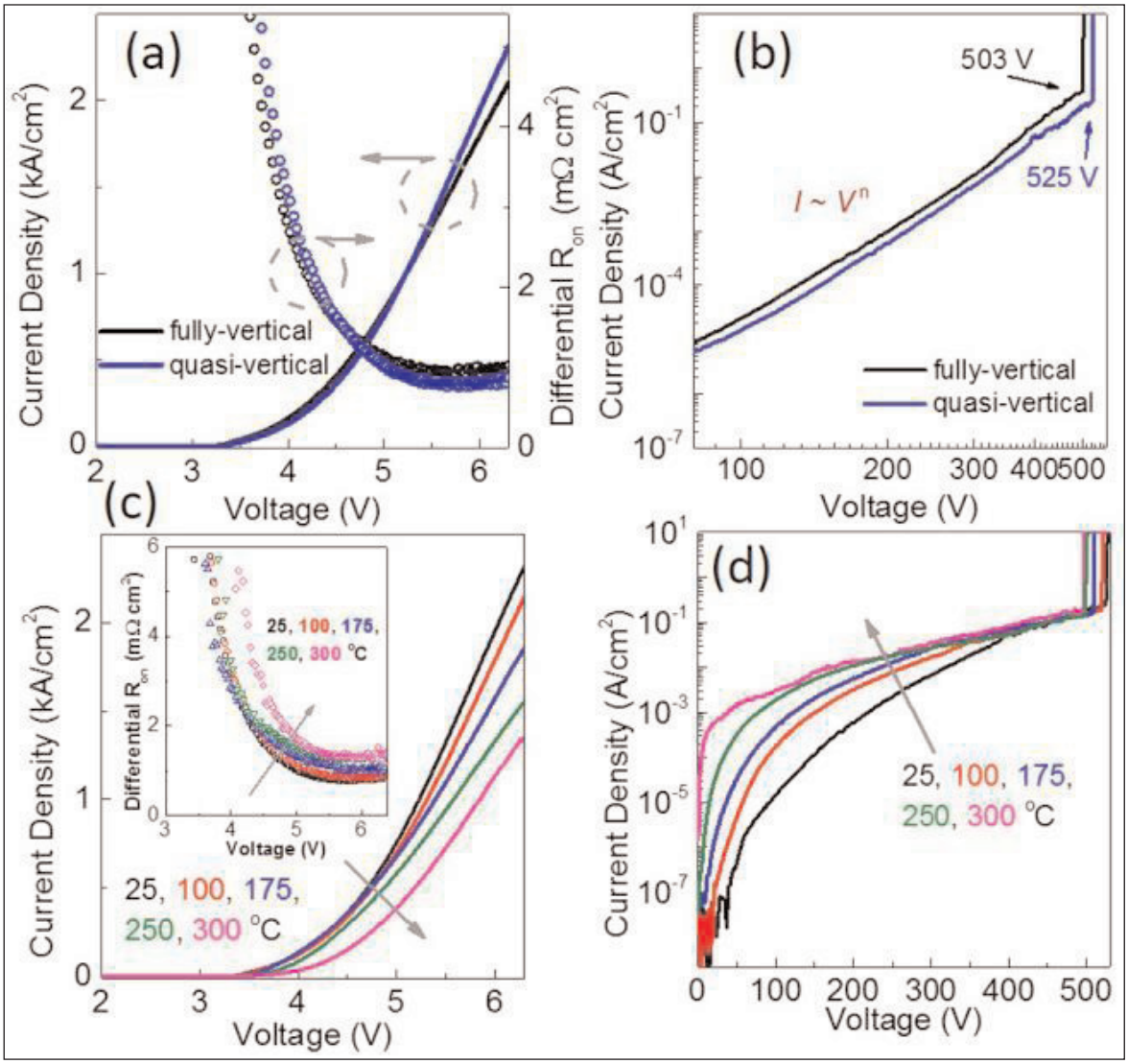

Figure 10. (a) Forward and (b) reverse characteristics of diodes, along with corresponding (c and d) temperature-dependent measurements.

silicon wafer during the sulfur hexafluoride (SF_6) deep plasma etch used to remove the growth substrate. Further etching through the transition layers exposed the n^+-GaN contact for subsequent formation of the ohmic contact. ALD aluminium oxide (Al_2O_3) provided 20nm-thick passivation.

At a forward bias of 5.3V, the differential specific on-resistance was 0.8mΩ-cm^2 for the quasi-vertical and 1mΩ-cm^2 for the fully vertical diodes (Figure 10). The current density was of the order of kA/cm^2. "This high forward current level is comparable to state-of-the-art GaN-on-GaN vertical diodes," the researchers write. The slightly higher differential on-resistance for the fully vertical device is attributed to flow through the silicon substrate and etch-induced defects in the n^+-GaN under the top ohmic contact.

The specific on-resistance of the fully vertical diode as a simple voltage/current ratio was 3mΩ-cm^2 at 5.5V (so the current density (V/R) was 1.8kA/cm^2). This is claimed to be "the best report for all GaN-on-Si vertical diodes".

The breakdown voltage under reverse bias was more than 500V for both devices. The leakage at 300V reverse bias was about $5x10^{-3}$A/cm^2, and still less than 10^{-2}A/cm^2 at 400V. These values are two orders of magnitude better than previous GaN-on-Si vertical diodes, according to the team. Further, the leakages are the lowest among all reported GaN vertical diodes on foreign substrates, lower than for lateral GaN diodes, and comparable with commercial SiC diodes, it is claimed.

The peak electric field was estimated to be 2.5–2.6MV/cm. Reference diodes without the carbon-doped n^--GaN layer demonstrated lower breakdown voltage and increased reverse bias leakage. The researchers believe that reducing edge-type dislocations could increase the breakdown to 800V. Even higher values could be achieved with material able to sustain higher peak fields in the 2.8–2.9MV/cm range.

The devices also performed well at increased temperatures up to 300ºC with little degradation of on-resistance. The differential on-resistance at 300ºC was as low as 1.35mΩ-cm^2. Improved heat management could be provided by substrate thinning.

The devices also had reverse recovery times (~50ns, for switching from ~400A/cm^2 to 200V reverse bias) "comparable to the best reports for GaN-on-GaN diodes". Another claimed record for GaN-on-Si vertical diodes is the Baliga figure of merit (BV^2/R_{on}) of 0.32GW/cm^2. ■

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MARUWA is a global supplier of ceramic substrates and wafers made of aluminium nitride (AlN), alumina (Al_2O_3), ZTA and silicon nitride (Si_3N_4). Products meet required properties such as high thermal conductivity and bending strength for power devices, especially wafers are suitable as a bonding wafer (GaN, SOI) for epi wafers.

sp3 Diamond Technologies
2220 Martin Avenue,
Santa Clara, CA 95050, USA
Tel: +1 877 773 9940
Fax: +1 408 492 0633
www.sp3inc.com

Sumitomo Electric Semiconductor Materials Inc
7230 NW Evergreen Parkway,
Hillsboro, OR 97124,
USA
Tel: +1 503 693 3100 x207
Fax: +1 503 693 8275
www.sesmi.com

III/V-Reclaim
Wald 10,
84568 Pleiskirchen, Germany
Tel: +49 8728 911 093
Fax: +49 8728 911 156
www.35reclaim.de
III/V-Reclaim offers reclaim (recycling) of GaAs and InP wafers, removing all kinds of layers and structures from customers' wafers. All formats and sizes can be handled. The firm offers single-side and double-side-polishing and ready-to-use surface treatment.

Umicore Electro-Optic Materials
Watertorenstraat 33,
B-2250 Olen, Belgium
Tel: +32-14 24 53 67
Fax: +32-14 24 58 00
www.substrates.umicore.com

Wafer World Inc
1100 Technology Place, Suite 104,
West Palm Beach, FL 33407,
USA
Tel: +1-561-842-4441
Fax: +1-561-842-2677
E-mail: sales@waferworld.com
www.waferworld.com

4 Epiwafer foundry

Spire Semiconductor LLC
25 Sagamore Park Drive,
Hudson, NH 03051,
USA
Tel: +1 603 595 8900
Fax: +1 603 595 0975
www.spirecorp.com

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

Intelligent Epitaxy Technology Inc
1250 E Collins Blvd,
Richardson,
TX 75081-2401,
USA
Tel: +1 972 234 0068
Fax: +1 972 234 0069
www.intelliepi.com

IQE
Cypress Drive,
St Mellons, Cardiff
CF3 0EG,
UK
Tel: +44 29 2083 9400
Fax: +44 29 2083 9401
www.iqep.com
IQE is a leading global supplier of advanced epiwafers, with products covering a diverse range of applications within the wireless, optoelectronic, photovoltaic and electronic markets.

OMMIC
2, Chemin du Moulin B.P. 11,
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France
Tel: +33 1 45 10 67 31
Fax: +33 1 45 10 69 53
www.ommic.fr

Soitec
Place Marcel Rebuffat, Parc de Villejust, 91971 Courtabouef, France
Tel: +33 (0)1 69 31 61 30
Fax: +33 (0)1 69 31 61 79
www.picogiga.com

5 Deposition materials

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

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

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

Matheson Tri-Gas
6775 Central Avenue,
Newark, CA 94560,
USA

Tel: +1 510 793 2559
Fax: +1 510 790 6241
www.mathesontrigas.com

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

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

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

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

6 Deposition equipment

AIXTRON SE
Dornkaulstr. 2,
52134 Herzogenrath,
Germany
Tel: +49 2407 9030 0
Fax: +49 2407 9030 40
www.aixtron.com

AIXTRON is a leading provider of deposition equipment to the semiconductor industry. The company's technology solutions are used by a diverse range of customers worldwide to build advanced components for electronic and optoelectronic applications (photonic) based on compound, silicon, or organic semiconductor materials and, more recently, carbon nanotubes (CNT), graphene and other nanomaterials.

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

Ferrotec-Temescal
4569-C Las Positas Rd,
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CA 94551,
USA
Tel: +1 925 245 5817
Fax: +1 925 449-4096
www.temescal.net

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Fax: +33 (0) 1 39 47 45 62
www.riber.com

SVT Associates Inc
7620 Executive Drive,
Eden Prairie, MN 55344, USA
Tel: +1 952 934 2100
Fax: +1 952 934 2737
www.svta.com

Veeco Instruments Inc
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Woodbury, NY 11797,
USA
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Fax: +1 516 714 1231
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Veeco is a world-leading supplier of compound semiconductor equipment, and the only company offering both MOCVD and MBE solutions. With complementary AFM technology and the industry's most advanced Process Integration Center, Veeco tools help grow and measure nanoscale devices in worldwide LED/wireless, data storage, semiconductor and scientific research markets—offering important choices, delivering ideal solutions.

7 Wafer processing materials

Air Products and Chemicals Inc
7201 Hamilton Blvd.,
Allentown, PA 18195, USA
Tel: +1 610 481 4911
www.airproducts.com/compound

MicroChem Corp
1254 Chestnut St. Newton,
MA 02464, USA
Tel: +1 617 965 5511
Fax: +1 617 965 5818
www.microchem.com

Praxair Electronics
(see section 5 for full contact details)

8 Wafer processing equipment

EV Group
DI Erich Thallner Strasse 1,
St. Florian/Inn, 4782,
Austria
Tel: +43 7712 5311 0
Fax: +43 7712 5311 4600
www.EVGroup.com
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Scotland, UK
Tel: +44 (0) 1389 875 444
Fax: +44 (0) 1389 879 042
www.logitech.uk.com

Oxford Instruments Plasma Technology
(see section 6 for full contact details)

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

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

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

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

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

9 Materials & metals

Goodfellow Cambridge Ltd
Ermine Business Park,
Huntingdon,
Cambridgeshire
PE29 6WR,
UK
Tel: +44 (0) 1480 424800
Fax: +44 (0) 1480 424900
www.goodfellow.com
Goodfellow supplies small quantities of metals and materials for research, development, prototyping and specialised manufacturing operations.

10 Gas and liquid handling equipment

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

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

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

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

11 Process monitoring and control

Conax Technologies
2300 Walden Avenue,
Buffalo, NY 14225, USA
Tel: +1 800 223 2389
Tel: +1 716 684 4500
E-mail: conax@conaxtechnologies.com
www.conaxtechnologies.com
Ideas. Solutions. Success.
Conax Technologies is a designer and manufacturer of standard and custom-engineered temperature sensors, compression seal fittings and feedthroughs, probes, wires, electrodes and fiber-optic cables. The company is headquartered in Buffalo, New York, with locations on the US West Coast, Canada, Europe and Asia.

k-Space Associates Inc
2182 Bishop Circle East, Dexter,
MI 48130,
USA
Tel: +1 734 426 7977
Fax: +1 734 426 7955
www.k-space.com
k-Space Associates Inc specializes in in-situ, real-time thin-film process monitoring tools for MBE, MOCVD, PVD, and thermal evaporation. Applications and materials include the research and production line monitoring of compound semiconductor-based electronic, optoelectronic, and photovoltaic devices.

KLA-Tencor
One Technology Dr,
1-2221I, Milpitas, CA 95035, USA
Tel: +1 408 875 3000
Fax: +1 408 875 4144
www.kla-tencor.com

LayTec AG
Seesener Str. 10–13,
10709 Berlin,
Germany
Tel: +49 30 89 00 55 0
Fax: +49 30 89 00 180
www.laytec.de

LayTec develops and manufactures optical in-situ and in-line metrology systems for thin-film processes with particular focus on compound semiconductor and photovoltaic applications. Its know-how is based on optical techniques: reflectometry, emissivity corrected pyrometry, curvature measurements and reflectance anisotropy spectroscopy.

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

12 Inspection equipment

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

13 Characterization equipment

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

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

14 Chip test equipment

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

15 Assembly/packaging materials

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

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

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

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

16 Assembly/packaging equipment

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

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

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

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

17 Assembly/packaging foundry

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

18 Chip foundry

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

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

19 Facility equipment

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

20 Facility consumables

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

21 Computer hardware & software

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

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

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

22 Used equipment

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

23 Services

Henry Butcher International
Brownlow House, 50–51
High Holborn,
London WC1V 6EG,
UK
Tel: +44 (0)20 7405 8411
Fax: +44 (0)20 7405 9772
www.henrybutcher.com

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

24 Consulting

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

25 Resources

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

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

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

event calendar

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

18–21 April 2017
SNEC's 11th International Photovoltaic Power Generation Conference & Exhibition (SNEC PV Power EXPO 2017)
Shanghai, China
E-mail: info@snec.org.cn
www.snec.org.cn

21–23 April 2017
International Conference on Engineering Physics and Optoelectronic Engineering (ICEPOE 2017)
Thammasat University Rangsit Campus, Thailand
E-mail:icepoe@iased.net
www.icepoe.org

24–25 April 2017
IEEE WAMICON 2017 — 18th annual IEEE Wireless and Microwave Technology Conference
Hilton Cocoa Beach, FL, USA
E-mail: weller@usf.edu
www.wamicon.org

24–27 April 2017
SPIE Optics + Optoelectronics 2017
Clarion Congress Hotel, Prague, Czech Republic
E-mail: info@spieeurope.org
www.spie.org/SPIE-Optics-Optoelectronics

1–3 May 2017
13th International Conference on Concentrator Photovoltaics (CPV-13)
University of Ottawa, Canada
E-mail: info@cpv-13.org
www.cpv-13.org

14–18 May 2017
Compound Semiconductor Week (CS Week 2017), including:
44th International Symposium on Compound Semiconductors (ISCS 2017)
29th International Conference on Indium Phosphide and Related Materials (IPRM 2017)
Berlin, Germany
E-mail: info@csw2017.org
www.csw2017.org

14–19 May 2017
Conference on Lasers and Electro-Optics (CLEO 2017)
San Jose Convention Center, San Jose, CA, USA
E-mail: CLEO@compusystems.com
www.cleoconference.org

16–17 May 2017
ITF Belgium (Imec Technology Forum 2017)
Antwerp, Belgium
E-mail: Olfa.Marzouk@imec.be
www2.imec.be/be_en/events.html

16–18 May 2017
PCIM Europe (Power conversion and Intelligent Motion) 2017
Nuremberg Messe, Germany
www.mesago.de/en/PCIM/main.htm

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21–23 May 2017
International Wide Bandgap Materials Power Electronics Applications Workshop (IWBGPEAW 2017)
Stockholm, Sweden
E-mail: veyrier@yole.fr
www.b2match.eu/iwbgpeaw2017

22–25 May 2017
2017 CS ManTech: International Conference on Compound Semiconductor Manufacturing Technology
Hyatt Regency Indian Wells Resort & Spa, CA, USA
E-mail: lynn_fincher@msn.com
www.csmantech.org

28 May – 1 June 2017
29th International Symposium on Power Semiconductor Devices and ICs (ISPSD 2017)
Sapporo, Japan
E-mail: ispsd2017reg@ech.co.jp
http://eds.ieee.org/eds-meetings-calendars.html

30 May – 2 June 2017
Intersolar Europe Exhibition and Conference (ISE 2017)
Messe München, Munich, Germany
E-mail: info@intersolar.de
www.intersolar.de

4–6 June 2017
IEEE Radio Frequency Integrated Circuits Symposium (RFIC 2017)
Hawaii Convention Center, Honolulu, HI, USA
http://rfic-ieee.org

4–9 June 2017
IEEE MTT-S International Microwave Symposium (IMS 2017)
Hawai'i Convention Center, Honololu, HI, USA
E-mail: ims2017.info@gmail.com
www.ims2017.org

5–8 June 2017
2017 Symposia on VLSI Technology and Circuits
Rihga Royal Hotel, Kyoto, Japan
E-mail: vlsi@vlsisymposium.org
www.vlsisymposium.org

11–14 June 2017
Joint EuroCVD21 – Baltic ALD 15
Linköping, Sweden
E-mail: henrik.pedersen@liu.se
www.eurocvd-balticald2017.se

25–29 June 2017
CLEO/Europe-EQEC 2017: Conference on Lasers and Electro-Optics/ Europe & the European Quantum Electronics Conference
Munich, Germany
E-mail: info@cleoconference.org
www.cleoeurope.org

25–30 June 2017
44th IEEE Photovoltaic Specialists Conference (PVSC 2017)
Marriot Wardman Park Hotel, Washington DC, USA
E-mail: info@ieee-pvsc.org
www.ieee-pvsc.org/PVSC44

26–29 June 2017
LASER World of PHOTONICS 2017 (23rd International Trade Fair and Congress for Photonics Components, Systems and Applications)
Messe München, Munich, Germany
E-mail: info@world-of-photonics.com
www.world-of-photonics.com

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

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

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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