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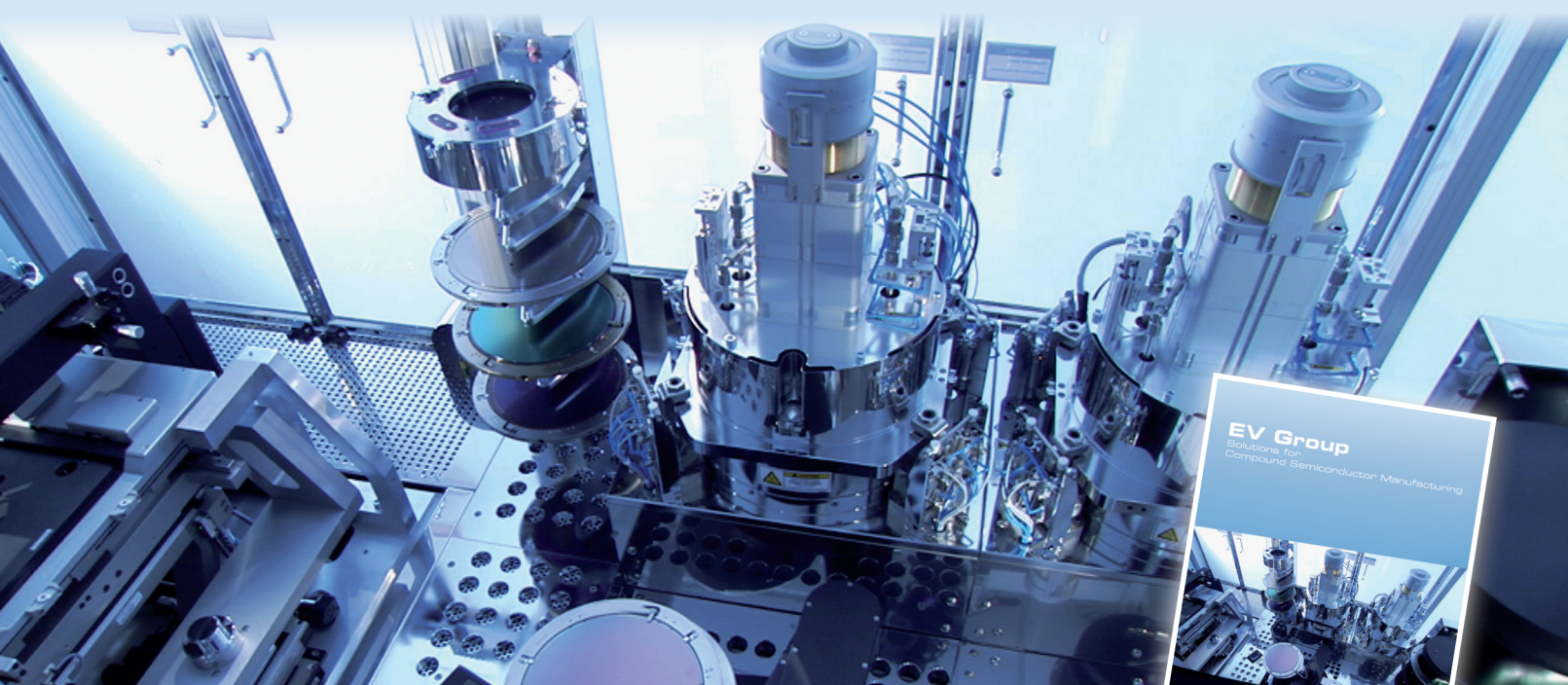
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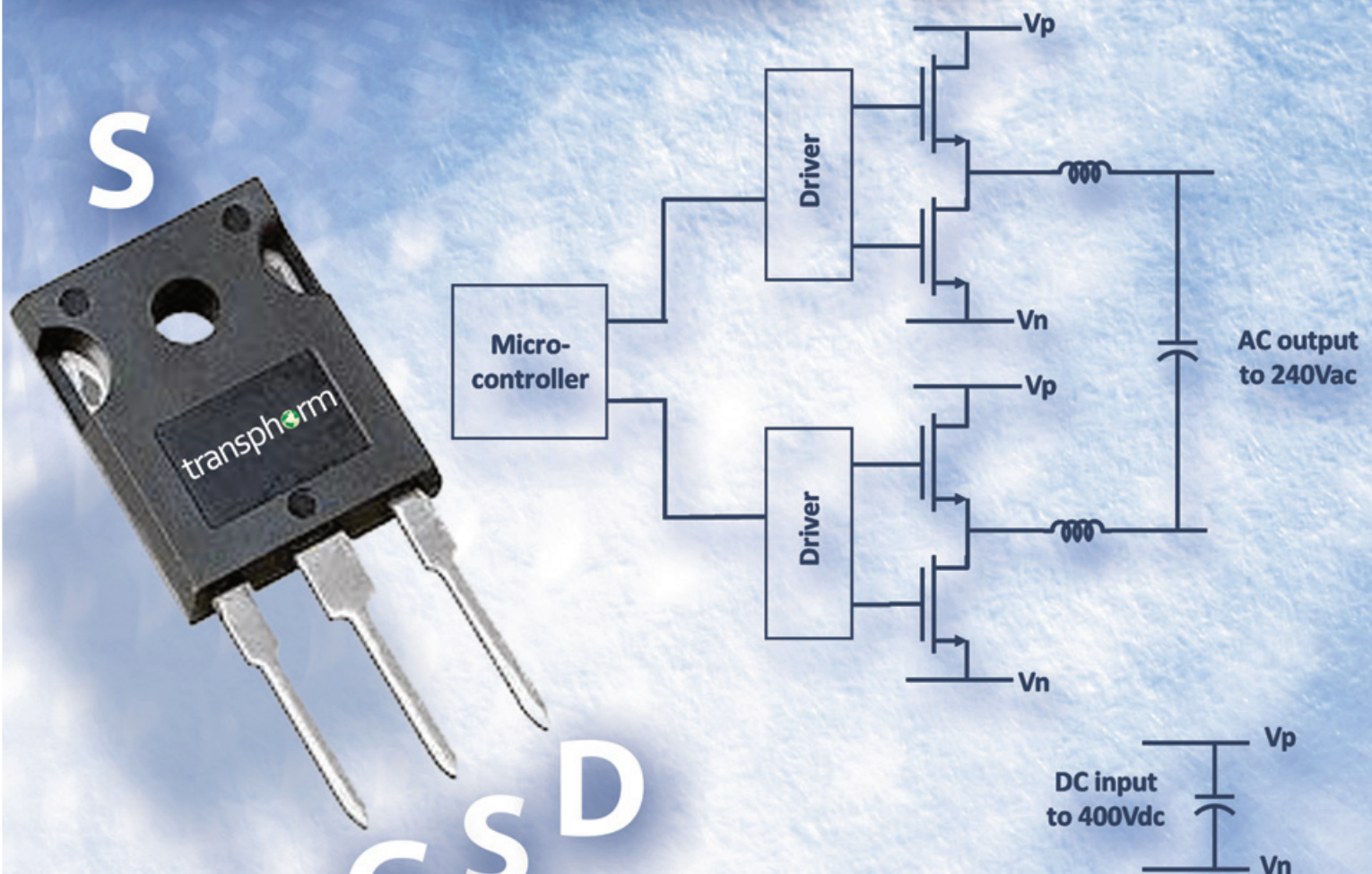
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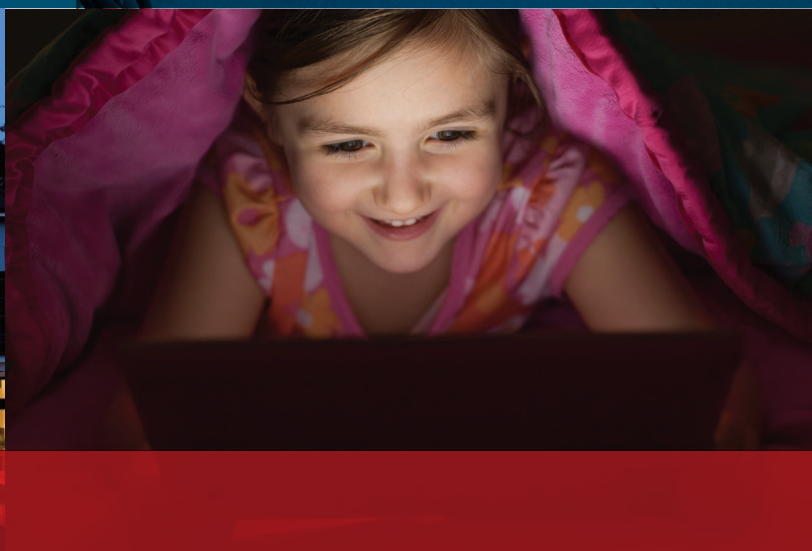
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News from APEC 2015

Mobile World Congress • Riber buys MBE Control Solutions
RayVio raises \$9.3m • JDSU's CCOP unit to become Lumentum



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Veeco's New TurboDisc EPIK700 GaN MOCVD System

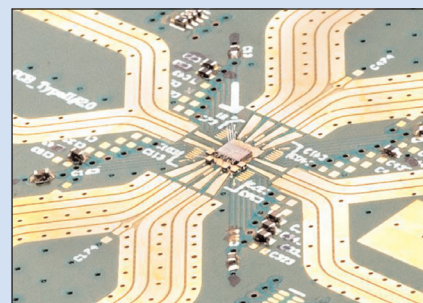
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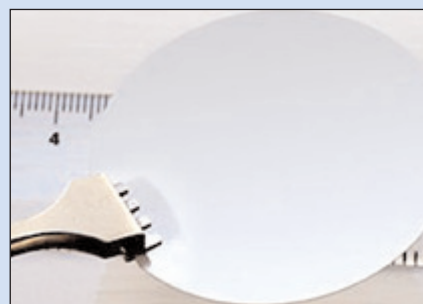
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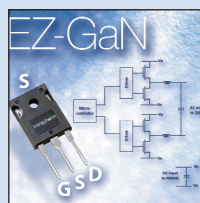
p16 Imec and Panasonic have presented 28nm a CMOS transceiver chip for 79GHz phase-modulated continuous-wave radar.



p30 Kyma has launched two-dimensional MoS₂ materials and crystal growth tool product lines.



p44 Seren Photonics has launched LED-grade semi-polar GaN-on-sapphire templates, starting with 2".



extends the EZ-GaN portfolio to support PV inverters with power levels from a few 100W (micro-inverters) to several kW (residential central inverters). **p27**

GaN/SiC and silicon combine for large-scale production

In this issue, we cover developments reported at not only the Mobile World Congress in Barcelona in early March (see pages 10–13) but also the Applied Power Electronics Conference (APEC 2015) in North Carolina, which evidenced the increasing activity targeting applications of wide-bandgap materials silicon carbide (pages 16–18) and gallium nitride (pages 22–27). Japan's Panasonic is particularly active, in both SiC (in concert with module firm Sansha Electric) and GaN (agreeing to integrate its enhancement-mode GaN-on-silicon transistors into the surface-mount device packages of Germany's Infineon). With Panasonic licensing its normally-off GaN transistor structure to Infineon, the firms aim to establish a dual manufacturing source for enhancement-mode (E-mode) normally-off 600V GaN power devices.

Also at APEC, Infineon announced the expansion of its GaN-on-silicon technology and product portfolio, so the firm now offers both E-mode and cascode configuration GaN-based platforms. This follows its recent acquisition of International Rectifier (including its GaN platform). Among other firms introducing GaN-based devices, Transphorm launched 600V GaN-on-silicon cascode transistors (plus a 240W reference design) co-branded with silicon-focused chip maker ON Semiconductor (page 26). This follows the partnership formed last September between US-based ON Semiconductor, Transphorm Inc and its subsidiary Transphorm Japan Inc. The GaN HEMT devices of Transphorm (a spin-off from University of California Santa Barbara that emerged from 'stealth mode' only in 2011) entered mass production at Fujitsu Semiconductor's CMOS-compatible 150mm wafer fab in Japan in January.

Such activity is motivated by a GaN-on-Si related market for power semiconductors that market research firm IHS expects to increase at a compound annual growth rate (CAGR) of more than 50%, from just \$15m in 2014 to \$800m by 2023. In addition, on pages 94–95 we cover the overview by Yole Développement of the power electronics industry. This forecasts that silicon insulated-gate bipolar transistors (IGBTs) — aided by the adoption of SiC and GaN — will contribute to a CAGR of 6.9% for the power semiconductor device market, from 2014 to more than \$17bn in 2020. The growth is being driven by a significant increase in sales of electric and hybrid-electric vehicle (EV/HEV), as well as the ramp-up of renewable energy and increasing implementation of smart-grid technology.

Away from APEC, SiC chip supplier Monolith Semiconductor is relocating from Ithaca, NY to Round Rock, Texas. This follows a strategic partnership last June to manufacture its SiC switches in the high-volume 150mm silicon production line of X-FAB Texas (as well as collaborating with Texas Tech University to demonstrate power electronics systems using its SiC devices).

Back in the 'semiconductor' (i.e. silicon) industry, former III-V turned silicon chip firm Vitesse is being acquired by Microsemi (see page 14), which itself uses not only silicon but also GaAs, SiC and GaN. Meanwhile, Freescale (which has GaAs and GaN-on-SiC as well as silicon products) is being acquired by silicon-focused firm NXP (page 15), which already has GaN-on-Si technology. So, as market adoption proliferates, there is increasing cross-over between the 'compound semiconductor' and 'silicon' industries.

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Semiconductor Today covers the R&D and manufacturing of compound semiconductor and advanced silicon materials and devices

(e.g. GaAs, InP and SiGe wafers, chips and modules for microelectronic and optoelectronic devices such as RFICs, lasers and LEDs in wireless and optical communications, etc).

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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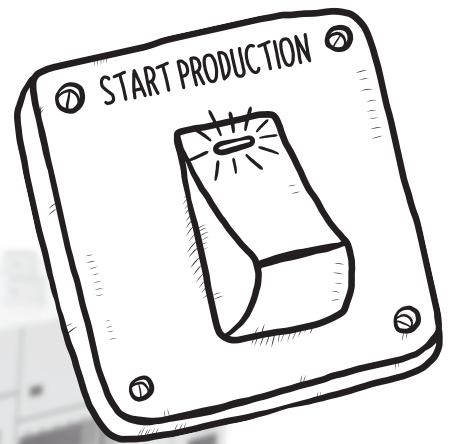
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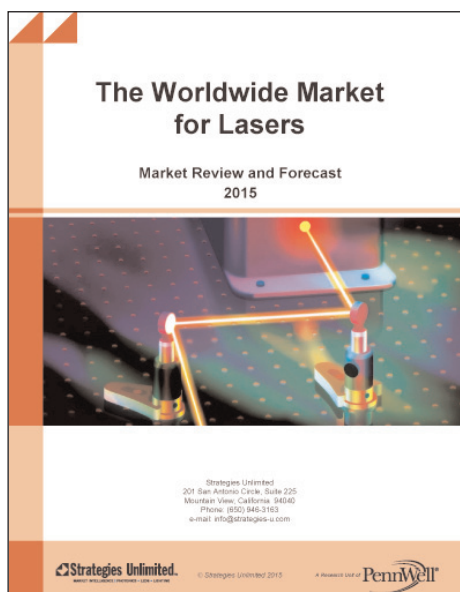


Laser market growing at 5.5% to over \$12bn by 2019

High-power diode and fiber lasers to be fastest-growing types

The total laser market will grow at a rate of 5.5% from 2013 through to 2019, bolstered by a double-digit compound annual growth rate (CAGR) in display and lightshow laser revenue, according to market research firm Strategies Unlimited's annual review and forecast 'The Worldwide Market for Lasers 2015'.

The laser market in 2014 was relatively strong, given that the global economic climate is still slowly recovering from a strong recession in some regions of the world. Still, not only did some of the smaller sectors experience strong growth, which is true in most years, but most encouraging was very strong growth in the larger sectors. The communications and high-power industrial segments, both with over \$1bn in annual revenue, grew by 7% or more in 2014.



"With many promising technology and application trends, 2014 was a fantastic year for laser revenue growth," says senior analyst Allen Noguee. "Besides displays, many segments — including sensors, medical, photolithography, and

large materials processing — had growth rates above average," he adds.

New to the annual report this year is increased coverage of fiber lasers and quantum cascade lasers (QCLs). In the forecast period to 2019, Strategies Unlimited anticipates that high-power diodes as well as fiber lasers will be the fastest-growing laser types in terms of revenue. "This isn't surprising, seeing as they both are reliable, have a long life, their prices are dropping, and they are very energy efficient," comments Noguee. "Fiber and direct-diode lasers are both important in the industrial area and are replacing other laser types," he adds. "Fiber lasers are slowly replacing CO₂ lasers, and high-power diode lasers are replacing many other types of lasers, including solid-state lasers used in laser lightshows."

www.strategies-u.com

LED lighting market to grow at CAGR of 25.89% to 2019

The global LED lighting market is increasing at a compound annual growth rate (CAGR) of 25.89% over 2014–2019, according to a report from TechNavio. "China is by far the market leader, and the growth of the LED Lighting Market in China will have a direct effect on the global market"

The new report 'Global LED Lighting Market 2015-2019' emphasizes the rapid decrease in LED prices that has accelerated demand for LED devices in the market. The decrease in price stems from massive R&D investment in LED chips and packages in China, which has resulted in brighter LED chips, says the market research firm.

"China is by far the market leader, and the growth of the LED lighting market in China will have a direct

effect on the global market," notes TechNavio vice president Faisal Ghaus.

"The increasing penetration of LEDs in the lighting market mainly comes from the correction in the price of LEDs in recent years, which has accelerated the use of LEDs in numerous applications," says Ghaus.

The new report also draws attention to the ability of LEDs to provide high-quality

Increasing penetration of LEDs in the lighting market mainly comes from the correction in the price of LEDs in recent years, which has accelerated the use of LEDs in numerous applications

and energy-efficient lighting, compared to existing lighting technologies, which has accelerated the demand for LEDs worldwide. The growing use of LEDs for lighting in a variety of industries will gain momentum during the forecast period, it is reckoned.

Key vendors mentioned include Cree, GE Lighting, Nichia, Osram Sylvania and Philips Lumileds Lighting. Other prominent vendors include Acuity Brands Lighting, ATG Electronics, China Electric, Epistar, Everlight, LED Microsensor NT, LG Innotek, Lighting Science Group, Panasonic, QD Vision, Samsung LED, Seoul Semiconductor, Toshiba Lighting Technology, Toyoda Gosei and Utech LED.

www.technavio.com/report/global-led-lighting-market-2015-2019

LED replacement lamps to rise from 4% of residential light bulb shipments in 2014 to 42% in 2022

As LED light quality improves and prices continue to drop, more consumers are choosing to replace incandescent, halogen and compact fluorescent lamp (CFL) bulbs in their homes with efficient and environmentally friendly LED bulbs. Hence, by 2022, 42% of light bulb shipments to the residential sector will be LED replacement lamps, compared to just 4% in 2014, forecasts market research firm IHS in a Market Insight note by Fabian Hoelzenbein (analyst, Lighting and LEDs).

LED bulbs are designed to replace traditional bulbs, so the fittings or luminaires that house the bulbs generally remain in place. While that is convenient for consumers, and helps to keep the initial costs down, in terms of engineering the situation is far from ideal, says IHS. Not only do driver electronics need to be squeezed into the base of the bulb, but heat dissipation is also a challenge, due to the relatively small size of the bulbs.

One alternative to bulb-integrated driver electronics is to integrate the

LED light source and driver electronic into the luminaire itself. Incandescent bulbs must be replaced every year (or even more often) due to their short lifetime of about 1000 hours, whereas LED bulbs have lifetimes of up to 50,000 hours so there is no need to replace them for 20 years or more. Because there is far less need to replace bulbs, hard wiring the LED chips and electronics into the luminaire has several benefits: it offers greater flexibility in terms of design and heat management and, because fewer parts are needed, the cost of an LED integrated luminaire is potentially lower than the cost of a traditional luminaire plus an LED replacement bulb.

It may take some time until LED integrated luminaires find their way into buildings where

Last year 39% of all street-light luminaires shipped were LED integrated...that number is forecast to increase to 82% in 2022

fittings already exist, but they are obviously an attractive option for new construction, notes IHS.

Some luminaire types are better suited than others for integrated LED lamps. Last year 39% of all street-light luminaires shipped were LED integrated, and that number is forecast to increase to 82% in 2022. Retrofitting street lamps with replacement bulbs often makes little economic sense, since they tend to be upgraded to smart lights, which require new wiring and fittings anyway.

Overall, about 44% of luminaire shipments are expected to be LED-integrated in 2022 and, even in the residential sector (which has the slowest LED penetration) the number is forecast to exceed one third of the market. Traditional replacement lamps might not vanish from store shelves just yet, but a future in which the lights are only replaced when a building is renovated seems increasingly likely, concludes IHS.

<https://technology.ihs.com/526530/say-goodbye-to-traditional-light-bulbs-the-future-is-integrated>

General lighting LED lamps installations in Europe to reach 2.9 billion units in 2019

The number of LED lamps installed for general lighting in Europe (including indoor & outdoor accent and functional lighting for residential, commercial and government areas) will rise from 288 million in 2014 to 2.9 billion units in 2019 at an average annual growth rate of 58.7% (slightly faster than forecast for the USA market for 2014–2019), according to a report by ElectroniCast Consultants.

ElectroniCast forecasts that Western Europe — which comprised nearly 48% of the market in terms of unit volume in 2014 — will maintain its leadership in relative market share throughout the forecast period.

The use of LED lamps in general lighting in Northern Europe is forecast to increase at a slower pace. Southern and Eastern Europe are forecast to trail the market leaders, but both will grow at a faster annual rate than the other two sub-regions.

The market forecast is also segmented by major lamp types: parabolic aluminized reflector (PAR), general service lamps/decorative, multi-faceted reflector (MR)-compatible, tube and tape, streetlights, high-bay, and other/miscellaneous LED lighting.

According to ElectroniCast, the consumption value of LED-based general lighting lamps in Europe

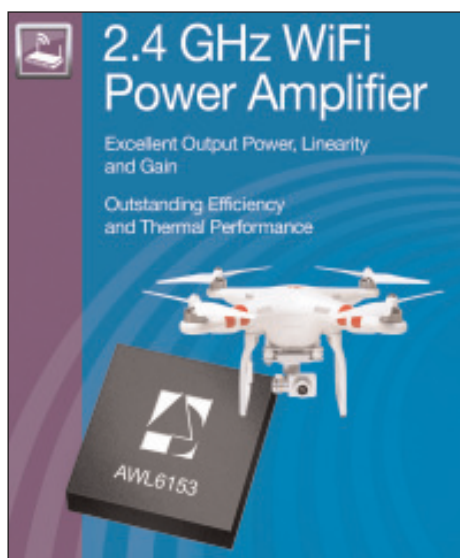
reached \$1bn in 2014. The Commercial/Industrial user category is forecast to dominate in terms of relative market share during 2014–2019. However, both the Government and the Residential/Non-Specific are forecast for faster annual growth. The Commercial/Industrial sector is especially strong in PAR lamps, MR lamps and (near-term) general service lamps. Government is forecast to be a relative heavy user in the streetlight product category. The Residential sector is forecast to have relative strong usage in the general service and MR lamp types.

www.electronicast.com

Anadigics' WiFi PA enables video transmission system in DJI's Phantom 2 Vision drones

Broadband wireless and wireline communications component maker Anadigics Inc of Warren, NJ, USA is shipping production volume of its AWL6153 power amplifier (PA) in support of DJI's Phantom 2 Vision and Phantom 2 Vision+ drones. These feature-rich systems include a lightweight, multi-functional integrated aircraft and camera with anti-vibration and stabilization capabilities. The Phantom 2 Vision and Phantom 2 Vision+ drones also include a range extender that increases WiFi distance to 300m and 700m, respectively. In both Phantom 2 Vision models, the drone and range extender each use two AWL6153 power amplifiers for video transmission, i.e. a total of four PA devices per system.

"Our WiFi power amplifiers are renowned for delivering exceptional gain, output power, and linearity, which are critical specifications for stable connectivity at extended range," says Alex Miller, Anadigics'



Anadigics' AWL6153 2.4GHz WiFi power amplifier.

product marketing manager for WiFi Products. The selection of the AWL6153 PA for the DJI Phantom 2 Vision drones exemplifies Anadigics' "ability to deliver value into new market segments," he adds.

The AWL6153 is part of Anadigics'

WiFi infrastructure power amplifier portfolio. Operating in the 2400–2485MHz frequency band, it features what is claimed to be excellent linearity, 30.5dB of linear power gain, and less than 3% EVM (error vector magnitude) at +25dBm output power, providing optimal performance in infrastructure and multimedia applications. The power amplifier also provides what is reckoned to be best-in-class power efficiency and improved thermal characteristics, enabling manufacturers to develop multi-power amplifier solutions that consume less power and are more thermally efficient.

The AWL6153 is fully matched to 50Ω at both the RF input and output, so no external matching circuits are required. It is offered in a compact 4mm x 4mm surface-mount package to manage heat dissipation while significantly reducing PCB space requirements.

www.dji.com

Anadigics' WiFi front-end integrated circuit selected for Huawei's Honor 4X smartphone

Broadband wireless and wireline communications component maker Anadigics Inc of Warren, NJ, USA is shipping production volumes of its AWL9281 front-end integrated circuit (FEIC) to Huawei for the new Honor 4X smartphone. The value-priced smartphone, available in China and showcased at the 2015 International Consumer Electronics Show (CES) in Las Vegas in January, offers a large 5.5-inch IPS display, 1.2GHz quad-core processor, and 13 megapixel rear-facing camera.

"The growing list of Huawei devices powered by Anadigics' products shows the strength of the relationship forged between our two companies," says Jerry Miller, Anadigics' senior VP of worldwide sales & applications. "We under-

stand the many challenges that manufacturers face as competition continues to fuel smartphone innovation across all price points, from functionality to form," he adds. "Anadigics has responded to these challenges by developing WiFi FEICs that offer a stellar level of performance and integration, enabling compact designs with ultra-fast wireless connectivity and extended battery life."

Anadigics' family of WiFi FEICs leverages its patented InGaP-Plus technology and uniquely designed architectures to combine a high-performance power amplifier (PA), low-noise amplifier (LNA) with bypass option and SP3T Tx/Rx RF switch with Bluetooth on a single die. This level of integration simplifies RF design and greatly

improves manufacturability and reliability, while reducing PCB space requirements and accelerating time-to-market, says Anadigics. Operating at 2400–2500MHz, the AWL9281 FEIC provides error vector magnitude (EVM) of 2.3% in the toughest modulation formats and what is claimed to be outstanding noise figure performance, enabling ultra-high data throughput. The AWL9281 also operates with low current consumption, extending battery life in mobile applications.

The compact 2.5mm x 2.5mm x 0.4mm QFN package also incorporates a high-accuracy, integrated power detector and RF ports internally matched to 50Ω to reduce PCB space requirements.

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Skyworks unveils next-gen diversity receive modules

Skyworks Solutions Inc of Woburn, MA, USA (which manufactures analog and mixed-signal semiconductors) has launched its next-generation diversity receive modules (DRx) for LTE smartphones.

The firm says that its newest DRx modules improve receiver sensitivity and data throughput, deliver higher levels of integration in a smaller footprint, and provide the flexibility to support multiple antenna configurations. From single-feed, broadband antennas to advanced multi-feed antennas addressing carrier aggregation, the solutions allow users to select the optimal configuration for their platform requirements.

The family of DRx modules incorporate low-loss RF switches, high-performance receive filters and low-noise amplifiers (LNAs), leveraging the firm's systems-level expertise to deliver highly integrated solutions that dramatically enhance downlink data rates in LTE advanced MIMO systems. By amplifying the receive signal, receiver sensitivity and data throughput are improved, increasing network efficiency.

"Skyworks continues to push the integration and performance envelope while capturing significantly higher content per platform," says David Stasey, VP & general manager of analog solutions. "Our next-

generation diversity receive models support multiple LTE bands, reduce RF complexity and enhance data throughput — all in a simple and flexible architecture," he adds.

About 75% of network traffic on mobile devices is on the downlink or receive side. Skyworks' highly integrated DRx modules maximize LTE data throughput, helping mobile communication networks to deliver increasing amounts of data.

Skyworks' family of next-generation diversity receive modules include the following products:

- SKY13740 — an LNA diversity module for cellular mobile devices that is optimized for single-input/output, world-roaming user equipment platforms. The solution supports cellular diversity receiver functions and is compatible with 3GPP GSM, WCDMA, LTE and LTE standards for Bands 1, 3, 4, 7, 8, 20 and 26. The module is baseband-vendor-agnostic, controlled via a standard RF front-end MIPI control interface and contained in a small 5mm x 3mm x 0.8mm 23-lead surface-mount package.

- SKY13741 — an LNA diversity module for cellular mobile devices that is optimized for China-centric user equipment platforms. It supports cellular diversity receiver functions and is compatible with 3GPP GSM, WCDMA, LTE and LTE

standards for Bands 1, 3, 4, 7, 39, 40 and 41. The module is baseband-vendor-agnostic, controlled via a standard RF front-end MIPI control interface and contained in a small 4mm x 3mm x 0.8mm 24-lead surface-mount package.

- SKY13744-11 — an LNA diversity module for cellular mobile devices that is optimized for platforms supporting carrier aggregation or multi-feed antenna designs. It supports cellular diversity receiver functions and is compatible with 3GPP GSM, WCDMA and LTE standards for Bands 1, 3, 4, 7, 8, 20 and 26. Separate control registers allow the user to independently control any two low-band, middle-band, and high-band RF paths. The module is baseband-vendor-agnostic, controlled via a standard RF front-end MIPI control interface and contained in a small 5mm x 3mm x 0.8mm, 29-lead surface-mount package.

For all three modules, additional RF bands can be supported through its auxiliary ports. The new diversity receive solutions are available now for both sampling and production.

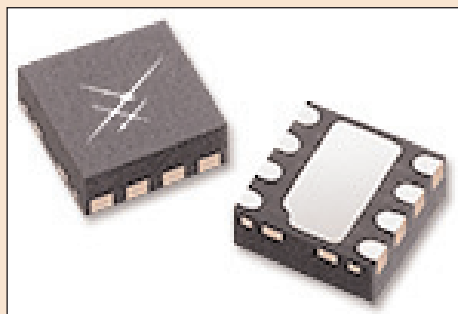
Skyworks showcased its product portfolio at the GSMA Mobile World Congress (MWC2015) in Barcelona, Spain (2–5 March).

www.skyworksinc.com

Skyworks launches high-linearity, active-bias low-noise amplifier

Skyworks Solutions has launched a 0.5–4.0GHz low-noise amplifier (LNA) with an active bias, offering what is claimed to be excellent return loss, low noise and high-linearity performance for applications including high-performance wireless infrastructure, L- and S-band military radio, SDAR, DBS set-top box, and GPS.

As well as featuring internal active bias circuitry that provides stable performance over temperature and process variation, the SKY67103-396LF also offers the



Skyworks' SKY67103-396LF LNA.

ability to externally adjust supply current and gain.

The device is suitable for LTE,

GSM, WCDMA and HSPDA macro base-stations, small cells, cellular repeaters, DAS and RRH/RRUs, as well as 0.5–4.0GHz low-noise receiver and high-temperature receiver applications to +105°C.

The SKY67103-396LF is available in a compact 2mm x 2mm x 0.75mm, 8-pin DFN (dual flat no-lead) package. Samples, evaluation boards and evaluation kit software are available. Pricing depends on quantities.

www.skyworksinc.com

[/Product/3060/SKY67103-396LF](http://Product/3060/SKY67103-396LF)

Skyworks ramps SkyOne Mini for LTE smartphones

Skyworks Solutions Inc of Woburn, MA, USA (which manufactures analog and mixed-signal semiconductors) says that its SkyOne Mini front-end solution is enabling several new smartphone launches. SkyOne Mini, a derivative of the SkyOne platform, specifically addresses the growing demand for value- and performance-oriented solutions in the LTE market by delivering the full functionality of highly integrated SkyOne devices but at a reduced cost and size.

"SkyOne Mini capitalizes on the requirements by OEMs for highly integrated solutions that offer a smaller footprint and lower bill of materials," says Carlos Bori, vice president of marketing. "Our SkyOne Mini devices support multiple chipsets without the need to change the front-end, creating a simple, flexible approach that delivers significant cost and time-to-market advantages," Bori adds.

The SKY78070, SKY78071 and SKY78072 SkyOne Mini solutions



are hybrid, multi-mode multi-band front-end modules that support 2.5G and 3G/4G handsets and operate efficiently in GSM, GPRS, EDGE, TD-SCDMA, WCDMA,

SkyOne Mini devices support multiple chipsets without the need to change the front-end, creating a simple, flexible approach that delivers significant cost and time-to-market advantages

HSPA and LTE modes. The SKY78070 contains four integrated duplexers for Bands 1, 2, 5 and 8 plus an SP16T switch for non-carrier aggregation applications. The SKY78071 contains five integrated duplexers for Bands 1, 2, 4, 5 and 8 plus a DP18T switch for high/low and medium/low carrier aggregation applications. The SKY78072 contains four integrated duplexers for Bands 1, 2, 5 and 8 plus a DP18T switch for high/low and medium/low carrier aggregation applications. The SkyOne Mini family is available now for sampling and production.

According to the June 2014 Ericsson Mobility Report 'On the Pulse of the Networked Society', LTE is one of the fastest-growing segments and is being deployed in all regions of the world. Subscriptions for this technology are predicted to reach 2.6 billion by 2019, representing about 30% of total mobile subscriptions.

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

SkyOne Ultra front-end modules enter volume production

Skyworks Solutions says that SkyOne Ultra, the newest addition to its SkyOne platform, has entered volume production in support of several next-generation smartphones.

The SkyOne Ultra is a highly integrated solution that is optimized for envelope tracking, solves harmonically related carrier aggregation challenges, and delivers what is claimed to be the world's highest power-added efficiency.

The SkyOne family of devices is proliferating across leading smartphone OEMs, says Joel King, VP & general manager of Advanced Mobile Solutions for Skyworks. "SkyOne Ultra is yet another example of how we continue to leverage our broad systems expertise to create highly configurable and customized solutions



that reduce system complexity," he adds.

The SkyOne Ultra family

Ultra is a highly integrated solution that is optimized for envelope tracking and solves harmonically related carrier aggregation challenges

(available now for sampling and production) includes the SKY78041 and SKY78042 hybrid, multi-mode multi-band front-end modules that support 2.5G, 3G/4G and CDMA handsets and operate efficiently in GSM, GPRS, EDGE, WCDMA, HSPA and LTE modes. The SKY78041 leverages integrated duplexers for Bands 8, 12, 20, 26 and 29 targeting Europe, North America and Korea, while the SKY78042 leverages integrated duplexers for Bands 8, 12, 26, 28a and 28b targeting Latin America, Australia and China.

Skyworks showcased its product portfolio at the GSMA Mobile World Congress (MWC 2015) in Barcelona, Spain (2–5 March).

www.skyworksinc.com/Products/622/SkyOne
www.mobileworldcongress.com

Imec, Murata and Huawei report 0.18 μ m RF silicon-on-insulator CMOS electrical-balance duplexer

At the 2015 GSMA Mobile World Congress (MWC2015) in Barcelona, Spain (2–5 March), Imec, Murata and Huawei presented a stand-alone multiband electrical-balance duplexer in 0.18 μ m RF silicon-on-insulator (SOI) CMOS. This type of duplexer is reckoned to be a promising alternative to the fixed-frequency surface-acoustic wave (SAW) filters implemented in mobile phones providing transmit-to-receive (TX-to-RX) isolation.

SAW duplexers are integrated into existing mobile phones to suppress TX-to-RX signal transfer and avoid unwanted frequency components in the RF signal. As SAW duplexers function at a fixed frequency, more and more SAW duplexers would be needed to enable mobile phones to support the evergrowing number of bands adopted by operators. Due to their frequency-flexibility, electrical-balance duplexers are paving the way to an integrated multi-band solution for TX-to-RX isolation in front-end modules in mobile phones.

Since the new 1.9–2.2GHz duplexer (1.75mm²) is implemented in 0.18 μ m RF SOI CMOS technology, it enables high-quality integrated passive devices and high-power duplexer operation (+27dBm TX output). It achieves linearity of over +70dBm IIP3 in both TX and RX, which is comparable to conventional passive SAW filters. This prevents the duplexer from generating non-linear distortion in the presence of external jammer signals at specific sensitive frequencies and its own large TX signal.

The duplexer achieves low insertion losses (under 3.7dB TX and 3.9dB RX) and has isolation characteristics competitive with state-of-the-art SAW duplexers, it is reckoned. It uses a single-ended topology to avoid commonmode leakage issues that could cause the RX to compress for high-power TX input signals. Marking what is claimed to be an industry first achievement — reported at the 2015 IEEE International Solid-State Circuits Confer-

ence (ISSCC) in San Francisco (22–26 February) — it is the first electrical-balance duplexer reported to be linear enough to avoid RX de-sensitization due to inter and cross-modulation between the TX and typical 3GPP-defined jammers.

“Our solution paves the way to integrated reconfigurable multi-band front-end modules for frequency-division duplexing in next-generation mobile phones,” says Joris Van Driessche, program manager reconfigurable radios at Imec. “Our industrial affiliation program on reconfigurable radios leverages on the multidisciplinary expertise of our global partner network and our own scientific expertise to develop disruptive solutions for today’s ever evolving mobile and high-speed wireless communications market,” he adds.

The research received funding through the European Union’s Seventh Framework Program (EU FP7) project DUPLO (no. 316369).

www.imec.be

Cavendish Kinetics adds design wins and ramps shipments of RF MEMS tuners

Cavendish Kinetics of San Jose CA, USA, which provides RF MEMS tuning solutions for smartphones, handheld and wearable wireless devices, says its SmarTune antenna tuning solution is gaining significant traction in the LTE smartphone market, after the first OEM adopted SmarTune at the end of 2014.

Now shipping in five different smartphone models, the new design wins address difficult LTE spectrum band combinations, especially the 2GHz band required in the Chinese market and the 700/800MHz bands required by many European and North American operators. For the first time, SmarTune is now also being used to optimize the performance of the LTE MIMO antenna.

Now that most OEMs recognize the benefit of aperture tuning over impedance matching, they are finding that SmarTune allows them to design very small, highly efficient antennas that are needed to enable ever slimmer smartphones, without sacrificing radio performance, says Cavendish. The firm’s RF MEMS tuners are claimed to outperform traditional antenna tuning solutions based on silicon-on-insulator (SOI) switches by 2–3dB, resulting in much higher data rates (up to 2x) and improved battery life (up to 40%). For network operators the SmarTune-enabled devices provide more efficient spectrum utilization as higher data rates allow more users to be served in the same amount of

spectrum, says Cavendish. Optimizing the MIMO performance in smartphones further improves user data rates and network efficiency.

“The fast-growing number of design wins for our SmarTune antenna tuning solutions underscores the superior performance and unparalleled reliability of our RF MEMS tuners compared to all other tuning solutions,” claims Lars Johnsson, VP product marketing. “The 2–3dB of additional performance that our RF MEMS tuners enable makes a critical difference to ensure that the new generation of ultra-slim smartphones can have outstanding radio performance across the global LTE spectrum footprint.”

www.cavendish-kinetics.com

Peregrine & Murata launch UltraCMOS Global 1 Initiative

Murata filters and packaging integrated into RF front-ends

Peregrine Semiconductor Corp of San Diego, CA, USA — a fabless provider of radio-frequency integrated circuits (RFICs) based on silicon-on-insulator (SOI) — has teamed with Murata Manufacturing Co Ltd of Kyoto, Japan (its parent company since December) to announce the 2015 UltraCMOS Global 1 Initiative. The campaign launched with the UltraCMOS Global 1 PE56500 product demonstration at the GSMA Mobile World Congress (MWC2015) in Barcelona, Spain (2–5 March). The new initiative integrates the PE56500 all-CMOS RF front-end solution and Murata filters.

“Last year at Mobile World Congress, Peregrine announced the industry’s first reconfigurable RF front-end system, UltraCMOS Global 1, and proved that a CMOS power amplifier (PA) could compete with GaAs (gallium arsenide) technology,” says Peregrine’s president & CEO Jim Cable. “Peregrine’s recent acquisition by our long-time partner Murata facilitates the 2015 UltraCMOS Global 1 Initiative and speeds the industry’s transition to an integrated, all-CMOS RF front end [RFFE],” he adds.

“Over our 70 year history, Murata has established a reputation as a leading filter and RF module provider,” says Norio Nakajima, executive VP, director of Murata’s Communication business unit. “Murata holds over 45% of the world’s surface acoustic wave (SAW) filter market and over 60% of the connectivity module market,” he adds. “By combining Peregrine’s Global 1 solution with Murata’s industry-leading filters and module capabilities, we can offer the first completely integrated RF front-end solution from a single company,” he claims.

UltraCMOS Global 1 technology makes a single, global SKU (stock-keeping unit) possible — saving 4G LTE mobile-device makers



Initiative integrates PE56500 all-CMOS RF front-end and Murata filters.

significant time and money, it is reckoned. With the new collaboration between Murata and Peregrine, every component required for one SKU would be available from a single company. The UltraCMOS Global 1 Initiative aims to accelerate the transition of LTE mobile-device makers to reconfigurable RFFE designs, which accommodate the world’s 40-plus LTE bands on a single chip.

Peregrine says that one of the biggest advantages that Global 1 offers the wireless ecosystem is its ease of tunability for LTE device makers. Before Global 1, RF engineers had to manually solder and tune the RF front end through discrete duplexer matching, which can take anywhere from two weeks to one month (delaying the device’s introduction into the market). Global 1 replaces discrete duplexer matching with a tunable matching network that optimizes the PA match across the band. With Global 1 and its supporting software, an engineer can simply plug in the device and use the software to tune the RF front end within a few hours. Also, the device remains reconfigurable and can be tuned to another frequency or band to meet market demand. This capability (which is claimed to be unique) was demonstrated at Mobile World Congress.

The PE56500 is a fully integrated, reconfigurable 3G/4G cellular RF front-end that includes a multi-mode, multi-band (MMMB) PA, PA tuning, post-PA switch and antenna switch in a single package. It has three monolithic MMB linear PAs divided into

low-, mid- and high-band paths that cover 690–915, 1710–2100 and 2300–2700MHz, respectively. Each of the three paths contain a tunable inter-stage and a final tunable matching network to optimize the performance of the multi-mode PA to the operating cellular band.

The PE56500 is configured through a MIPI RFFE v1.1-compliant digital interface, which enables tunable matching and bias optimization for optimal linearity and efficiency tradeoff. The configurable RF and bias minimize phone variations due to mode, frequency and production tolerances.

Peregrine says that the all-CMOS RF front-end provides easy-to-use digitally controlled adaptation across modes and bands, high isolation to solve interoperability issues, and scalability to easily support higher band counts with low-loss switching and tunability. Built on Peregrine’s UltraCMOS 10 technology, the PE56500 combines Peregrine’s RF-SOI switch and tuner technology with new CMOS PA capability that delivers raw performance equivalent to GaAs, it is claimed.

The Global 1 PE56500 will be in volume production in late 2015.

www.psemi.com

www.murata.com

Microsemi agrees to acquire Vitesse for \$389m

Vitesse to provide Microsemi increased focus on communications

Microsemi Corp of Aliso Viejo, CA, USA (which designs and makes analog and RF devices, mixed-signal integrated circuits and subsystems for communications, defense & security, aerospace and industrial markets) has entered into a definitive agreement to acquire Vitesse Semiconductor Corp of Camarillo, CA, USA for \$5.28 per share through a cash tender offer (representing a premium of 32% based on the average closing price of Vitesse's common stock during the 30 trading days ended 17 March). Vitesse's board of directors unanimously recommends that its stockholders tender their shares in the offer. The total transaction value is about \$389m.

In addition to its silicon-based products, Microsemi also provides RF, microwave and millimetre-wave products includes high-reliability diodes, power transistors, limiters, detectors, switches, low-noise amplifiers, power amplifiers and integrated multi-function modules based on silicon carbide (SiC), silicon germanium (SiGe), gallium arsenide (GaAs), gallium nitride (GaN) and indium phosphide (InP).

Vitesse designs high-performance semiconductors, application software and integrated turnkey systems solutions for carrier, enterprise and Internet of Things (IoT) networks. Products enable the fastest-growing

network infrastructure markets including mobile access/IP edge, enterprise cloud access, and industrial-IoT networking.

"This acquisition is further evidence of Microsemi's continuing commitment to grow as a communications semiconductor company," says Microsemi's chairman & CEO James J. Peterson. "Vitesse's highly complementary technology suite will expand our product offering and accelerate growth with differentiated technology in emerging markets, while benefitting from the increased scale, consolidated infrastructure and cost savings of the combined entity," he adds.

"Microsemi will be able to leverage Vitesse's Ethernet technology and capabilities further into the communications market and has the scale to implement the adoption of our industrial IoT strategy," comments Vitesse's CEO Chris Gardner.

Microsemi expects the acquisition to yield significant synergies and to be immediate accretive in the first full quarter after completion (and accretive by

\$0.16–0.20 per share in its first full fiscal year to end-September 2016).

The tender offer is subject to customary conditions, including the tender of at least a majority of the outstanding shares of Vitesse's common stock on a modified fully diluted basis and certain regulatory approvals (including the expiration or termination of the applicable waiting period under the Hart-Scott-Rodino Antitrust Improvements Act) but is expected to close in Microsemi's fiscal third quarter (ending 28 June). No approval of the stockholders of Microsemi is required. Terms of the agreement have been unanimously approved by the boards of directors of both Microsemi and Vitesse. Microsemi has received support agreements from stockholders holding about 22% of Vitesse's outstanding common shares, in which they have agreed to tender their shares.

Under the terms of the merger agreement, Vitesse (assisted by financial advisor Deutsche Bank) may solicit superior proposals from third parties for a 'go shop' period of 21 calendar days continuing through 7 April. The agreement also provides Microsemi with a customary right to match a superior proposal, as well as break-up fees payable to Microsemi if the agreement is terminated.

www.vitesse.com

This acquisition is further evidence of Microsemi's continuing commitment to grow as a communications semiconductor company

MACOM's board gains former Hittite chairman Daly as independent director

M/A-COM Technology Solutions Inc of Lowell, MA, USA (which makes semiconductors, components and subassemblies for analog RF, microwave, millimeter-wave and photonic applications) has appointed Stephen G. Daly as an independent director. Daly brings 25 years of experience and leadership in the RF and microwave industry to MACOM's board of directors.

"Steve's track record of creating shareholder value is exemplary, and the board and I look forward to his future contributions as we enter our next phase of growth," comments chairman John Ocampo.

Previously, Daly was chairman of the board and also president & CEO of Hittite Microwave Corp of Chelmsford, MA, USA (a designer and manufacturer of analog, digital and

mixed-signal RF, microwave and millimeter-wave ICs, modules and subsystems as well as instrumentation). He has held various microwave engineering positions at Raytheon's Missile Systems Division as well as sales management roles at Alpha Industries. Daly received a B.S. in Electrical Engineering from Northeastern University.

www.macom.com

NXP to acquire Freescale for \$11.8bn

NXP Semiconductors N.V. of Eindhoven, The Netherlands has agreed to acquire Freescale Semiconductor Ltd of Austin, TX, USA in a transaction that values the combined enterprise at just over \$40bn.

The merger creates a high-performance mixed-signal semiconductor firm with combined revenue of more than \$10bn, reckoned to become the market leader in both automotive semiconductor solutions and general-purpose microcontroller (MCU) products. The combined firm will also aim to capitalize on the growing opportunities created by accelerating demand for security, connectivity and processing.

"Today's announcement is a transformative step in our objective to become the industry leader in high-performance mixed-signal solutions... focused on the high-growth opportunities in the Smarter World. We fully expect to continue to significantly out-grow the overall

market, drive world-class profitability and generate even more cash," says NXP's CEO Richard Clemmer, who will be president & CEO of the merged company.

"Our combined scale, size and global reach will position our new company to deliver sustainable above-market growth," believes Freescale's president & CEO Gregg Lowe. "It will also serve to accelerate the strategic plans both companies have invested in, enabling us to deliver more complete solutions," he adds.

The transaction is expected to be accretive to NXP non-GAAP earnings and free cash flow. NXP anticipates achieving cost savings of \$200m in the first full year after closing the transaction, with a clear path to \$500m of annual cost synergies.

Freescale shareholders will receive \$6.25 in cash and 0.3521 of an NXP ordinary share for each Freescale

common share held at the close of the transaction. The purchase price implies a total equity value for Freescale of about \$11.8bn (based on NXP's closing stock price as of 27 February) and a total enterprise value of about \$16.7bn including Freescale's net debt.

NXP intends to fund the deal with \$1bn of cash from its balance sheet, \$1bn of new debt and about 115 million NXP ordinary shares. Post transaction (which is expected to close in second-half 2015), Freescale shareholders will own about 32% of the combined firm.

The transaction has been unanimously approved by the boards of directors of both companies and is subject to regulatory approvals in various jurisdictions and customary closing conditions, as well as the approval of NXP and Freescale shareholders.

www.nxp.com

www.freescale.com/RFmilitary

Chalmers' record 44Gbps D-band wireless transmission

Teledyne Scientific & Imaging and test instrument maker Teledyne LeCroy of Chestnut Ridge, NY, USA (a subsidiary of Teledyne Technologies Inc) say that researchers at the Microwave Electronics Lab at Chalmers University of Technology in Sweden have achieved a record D-band wireless communication signal transmission speeds, with a data rate of 44Gbps doubling the previous record.

Advances in wireless transmission reduce the need for long cables, and enable the delivery of high-resolution video to users without the delays inherent in wired networks.

The experiment was conducted using a Tx/Rx chipset developed by Chalmers, using Teledyne Scientific's indium phosphide-based double heterojunction bipolar transistor (DHBT) technology and Teledyne LeCroy's LabMaster 10 Zi oscilloscope. Results of the experiment were reported at the 2014 IEEE

Compound Semiconductor Integrated Circuits Symposium (CSICS) in San Diego last October.

"The Teledyne indium phosphide DHBT-MMIC process plays a vital role in our program due to the wide bandwidths that can be achieved in the circuits," says professor Herbert Zirath, leader of the Chalmers research program, which is supported by the Swedish Foundation for Strategic Research (SSF). "We could not have set the record without this process, and more recently we have pushed the record out to 48Gbps," he adds. "The goal of our program is to reach 100Gbps, and we plan on using additional Teledyne LeCroy equipment to analyze receiver outputs in the next phase of our research."

The Tx/Rx chipset was designed in Teledyne Scientific's ultra-high-speed InP DHBT technology, which features a minimum feature size of 250nm and has demonstrated record RF

performance with higher breakdown voltage and dynamic range than can be obtained using competing silicon technologies. The demonstration was the first implementation of an InP DHBT chipset for D-band data transmission. The chipset was developed for point-to-point wireless communications, including D-band, 4G and 5G markets.

To view and analyze the demodulated QPSK signal, Teledyne LeCroy LabMaster 10 Zi oscilloscopes were used, including the 65GHz LabMaster 10-65Zi. The oscilloscope's serial data analysis capability was used to analyze the demodulated I & Q signals, especially the eye diagrams, and to apply equalization and predict the BER (bit-error rate) performance at 44Gbps. The LabMaster 10 Zi platform's bandwidth and 130fs channel matching is key to the acquisition and analysis of I & Q signals from coherent optical receivers.

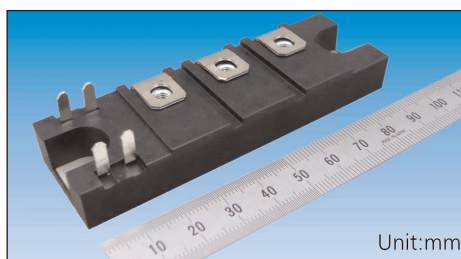
www.teledynelecroy.com

Panasonic and Sansha Electric jointly develop compact SiC power module with low operating loss

Panasonic Corp of Osaka, Japan and Osaka-based Sansha Electric Manufacturing Co Ltd have developed a compact silicon carbide (SiC) power module, together with highly efficient operation of power switching systems. The module is said to have good reliability and helps to reduce the size of power switching systems such as industrial inverters and power supplies.

Due to its superior material properties, SiC is expected to reduce the power consumption of various switching systems. The high-power switching devices need to be packaged into a power module integrating multiple transistors. The new SiC power module that has been developed is based on the following proprietary technologies:

- Panasonic's SiC DioMOS



The new SiC power module.

(diode-integrated MOSFET) has the features of a reverse conducting diode without any external diode. The total SiC chip area is reckoned to be halved from that of a conventional SiC chip, helping to reduce the total footprint of the module. The improved design of the DioMOS structure also reduces on-state resistance to 6mΩ at 150A.

- Sansha Electric's Techno Block module technologies utilize solder

bonding for the SiC chips without any wire bonding. This configuration halves the height of the module and yields three times better endurance in power cycling tests, it is reckoned.

The new SiC power module integrates two SiC transistors into one package and achieves 6mΩ of on-state resistance with a rating current/voltage of 150A/1200V. The module's total volume is reduced by a third compared with a conventional SiC power module, it is claimed. These features, together with good reliability, enable very compact and highly efficient power switching systems, Panasonic adds.

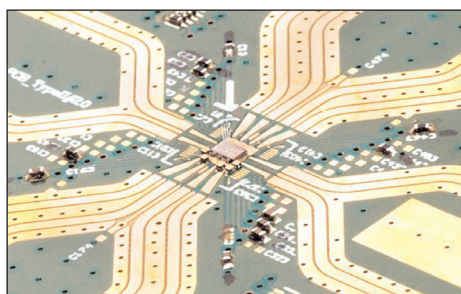
The R&D results were presented at the 30th IEEE Applied Power Electronics Conference (APEC 2015) in Charlotte, NC, USA (15–19 March).

<http://panasonic.net>

Imec and Panasonic present 28nm CMOS transceiver chip for 79GHz phase-modulated continuous-wave radar

At the 2015 IEEE International Solid-State Circuits Conference (ISSCC) in San Francisco (22–26 February), nanoelectronics R&D center Imec of Leuven, Belgium and Panasonic Corp of Osaka, Japan presented a transceiver chip for phase-modulated continuous-wave radar at 79GHz, demonstrating the potential of downscaled CMOS for cheap millimeter-wave radar systems that can be used for accurate presence and motion detection.

Millimeter-wave radar technology is used in advanced driver assistance systems (ADAS) to improve safety in blurry conditions such as dust, fog and darkness, where image-based driver assistance systems lack robustness. It also offers longer range, higher precision and invisible mounting capabilities compared with ultrasound sensors. Imec's 79GHz radar solution is based on 28nm CMOS technology, and is an alternative to existing silicon ger-



28nm CMOS 79GHz transceiver chip.

manium (SiGe)-based technology as it offers a path to a low-power, compact and integrated solution, says Imec. Moreover, at the expected high manufacturing volumes, CMOS technology is intrinsically low cost.

The transceiver chip contains a control loop to suppress the spillover from the transmitter into the receiver without affecting the RF performance. With a power consumption of 260mW, the output power of the transmitter is 11dBm, while the RX gain is 35dB with a

noise figure below 7dB and a TX-to-RX spillover suppression of 15dB. Due to the wide modulation bandwidth, the achievable depth resolution is 7.5cm.

The 28nm CMOS technology presents new opportunities for mm-wave radar systems, not only for automotive radar but also for other applications such as smart homes, unmanned aerial vehicles (UAVs) and robotics, says Wim Van Thillo, program director Perceptive Systems for the Internet of Things at Imec. "This transceiver chip is an important milestone we have realized in our pursuit of a complete high-performance radar system fully integrated onto a single chip."

Interested companies have access to Imec's CMOS-based 79GHz radar technology by joining Imec's industrial affiliation program or through IP licensing.

www.imec.be

<http://panasonic.net>

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GeneSiC launches high-temperature SiC transistors and rectifiers in small-form-factor metal can packages

Silicon carbide (SiC) power semiconductor supplier GeneSiC Semiconductor Inc of Dulles, VA, USA has announced availability of a line of compact, high-temperature SiC junction transistors as well as a line of rectifiers in TO-46 metal can packages.

The discrete components are designed and manufactured to operate under ambient temperatures of greater than 225°C. The use of high-temperature, high-voltage and low-on-resistance-capable SiC transistors and rectifiers can reduce the size/weight/volume of electronics applications requiring higher power handling at elevated temperatures. The devices are targeted at applications including downhole circuits, geothermal instrumentation, solenoid actuation, general-purpose amplification, and switched-mode power supplies (SMPS).

GeneSiC's new 240mΩ high-temperature SiC junction transistors (SJTs) exhibit sub-10ns turn-on/off rise/fall times enabling >10MHz switching as well as a square reverse-biased safe operation area (RBSOA). The transient energy losses and switching times are independent of junction temperature

(up to $T_{jmax} = 250^{\circ}\text{C}$). The switches are gate-oxide free, normally-off, exhibit positive temperature coefficient of on-resistance, and are capable of being driven by 0/+5V TTL gate drivers (unlike other SiC switches, it is claimed). Also, in contrast to other SiC switches, what are claimed to be unique advantages of the SJTs are higher long-term reliability, >20μs short-circuit capability, and superior avalanche capability. The devices (GA05JT01-46 and GA05JT03-46, with blocking voltages of 100V and 300V, respectively) can be used as efficient amplifiers as they promise much higher linearity than other SiC switches, the firm adds.

Current gain (h_{FE}) is more than 110. GeneSiC's new 4A high-temperature SiC Schottky rectifiers (the GB02SHT01-46, GB02SHT03-46 and GB02SHT06-46, with blocking voltages of 100V, 300V and 600V, respectively) show low on-state voltage drops, and what are claimed to be the industry's lowest leakage currents at elevated temperatures (up to $T_{jmax} = 250^{\circ}\text{C}$). Total capacitive charge is 9nC. With temperature-independent, near-zero reverse recovery switch-

ing characteristics, SiC Schottky rectifiers are suitable candidates for use in high-efficiency, high-temperature circuits. The TO-46 metal can packages as well as the associated packaging processes used to create these products critically enable long-term use where high reliability is critical, the firm adds.

"GeneSiC's transistor and rectifier products are designed and manufactured from the grounds up to enable high-temperature operation," says president Dr Ranbir Singh. "These compact TO-46 packaged SJTs offer high current gains (>110), 0/+5V TTL control, and robust performance. These devices offer low conduction losses and high linearity," he adds. "We design our SHT line of rectifiers to offer low leakage currents at high temperatures. These metal-can-packaged products augment our TO-257 and metal SMD products released last year to offer small-form-factor, vibration-resistant solutions."

All devices are tested to full voltage/current ratings and housed in metal can TO-46 packages. The devices are available from GeneSiC's authorized distributors.

www.genesicsemi.com

Cree's SiC technology reduces solar power inverter size, weight and cost

Cree Inc of Durham, NC, USA, which manufactures silicon carbide (SiC)-based power products, says it has demonstrated that its SiC MOSFET and diode technologies enable what are claimed to be previously unattainable levels of power density in string solar inverter products, yielding ultra-high efficiencies (greater than 99.1% at peak) at one-fifth the average size and weight of existing silicon-based inverter units.

Historically, efficiency, reliability and unit cost have been the three primary metrics that designers of

string solar inverters have sought to optimize. However, in recent years size and weight have proven to significantly affect overall system cost, and have subsequently been added to a designer's list of essential design metrics, says Cree.

Using the firm's latest power MOSFETs and diodes, Cree's systems engineering team designed a proof-of-concept 50kW string solar inverter that exhibits a 50% reduction in power loss and operates at 3–5 times the switching frequency that conventional silicon technology

can currently achieve, it is reckoned. The combination of these two factors drastically reduces both the size and weight of the inverter's cooling system, as well as its filtering components, translating into a unit-cost reduction approaching 15%, the firm claims.

This application was on display in Cree's booth at the 30th IEEE Applied Power Electronics Conference (APEC 2015) in Charlotte, NC, USA (16–18 March).

www.apec-conf.org

www.cree.com/power

Monolith relocates from New York to Texas following X-FAB partnership

Texas Tech University collaboration to demo SiC power electronics

Silicon carbide (SiC) diode and MOSFET supplier Monolith Semiconductor Inc of Ithaca, NY, USA is relocating its headquarters to Round Rock, Texas, according to The Round Rock Chamber of Commerce & Economic Development Partnership.

Monolith is a supplier of high-voltage SiC-based switches used in power electronics for applications including electrical energy conversion, smart grid, data-centers, and electric vehicles. The firm has received

multiple federal contracts to develop and manufacture its technology in the USA and is partnering with Google in the 'Little Box Challenge' competition to demonstrate miniaturized solar inverters.

Last June, Monolith announced a strategic manufacturing partnership with X-FAB Texas in Lubbock to manufacture its SiC switches in X-FAB's high-volume 150mm silicon production line. Monolith hence sought to relocate its HQ from Ithaca, NY to a Texas community.

"Round Rock was a natural choice because we can attract the right talent, grow our company, and raise our families in the same community," comments Monolith's CEO Sujit Banerjee PhD.

In addition to X-FAB Texas, Monolith has also formed a collaboration with Texas Tech University, in order to demonstrate power electronics systems using its SiC devices.

www.monolithsemi.com
www.xfab.com

ROHM SiC MOSFETs used in high-voltage pulse generators

ROHM of Kyoto, Japan says that its SCT2080KE silicon carbide (SiC) MOSFET has been adopted in the new SiC-Pulser Series of ultra-high-voltage pulse generators launched by Japan's Fukushima SiC Applied Engineering Inc.

Pulse generators are used in applications including high-voltage accelerators, plasma generators, and laser processing machines. Conventional systems utilize silicon devices or vacuum tubes as switching elements. However, this often entails a large number of system components, which often results in enormous construction and installation costs.

In contrast, SiC switching elements combine high breakdown voltage with very low on-resistance and high-speed switching performance. ROHM says that, by adopting its SiC devices in the switch module, pulse generators can be made considerably smaller and provide a level of performance that cannot be achieved with conventional systems.

"We evaluated a number of different switching elements," says Fukushima SiC Applied Engineering's president Kokubo. "As a result, we determined that ROHM's SiC



Fukushima SiC Applied Engineering's ultra-high-voltage pulse generator.

MOSFET was able to meet our criteria for reliability and performance. This marks the world's first practical application of SiC in a pulse generator," he adds. "For example, when trying to achieve a normal conducting linac (linear accelerator) with a beam output on the order of tens of kW, conventional vacuum tube acceleration technology will result in a linac that is 1600m long. However, by adopting SiC-based acceleration technology we can reduce the length of the linac to less than 6m, thereby decreasing construction and installation costs significantly."

Since the March 2011 Tohoku earthquake, Fukushima SiC Applied Engineering is "supporting

reconstruction by implementing build-to-order manufacturing of advanced power electronics products using these SiC devices at the Fukushima facility," says Kokubo. "Going forward, we would like to work together to expand the possibilities of SiC to a variety of fields," he adds.

ROHM is ramping up production of SiC products, specifically for the power sector. The SCT2080KE SiC MOSFET reduces switching losses by more than 70% compared with silicon IGBTs used in general inverters, the firm claims. Support for higher switching frequencies allows the use of smaller peripheral components, contributing to end-product miniaturization. SiC devices are already employed in converters and inverters in industrial equipment and power conditioners in solar power systems, and ROHM is exploring new markets for SiC devices.

The power device field is a key area for continued growth and ROHM aims to continue to strengthen its lineups of both silicon and SiC solutions to meet current and future demand.

www.rohm.com/web/global/products/-/product/SCT2080KE

Raytheon UK delivering SiC components for use in current-limiting diode project

Rolls-Royce-led project to protect aircraft electronics against lightning

Raytheon UK's semiconductor business unit in Glenrothes, Scotland, UK is partnering on a project that would provide aircraft electronics and wiring with a more efficient device to protect against lightning strikes, which can damage sensitive equipment.

During electrical storms, lightning paths travel cloud-to-ground or cloud-to-cloud, and sometimes aircraft in flight can form part of the path. The outer skin of the aircraft (which is traditionally aluminium) does much to accommodate the lightning's path, and voltage 'surge suppression' devices are used to protect aircraft electronics.

"However, with composite materials replacing metallic components and skin materials, the reduced electrical screening in airframes is forcing a rethink of lightning protection architectures," says John Kennedy, head of Raytheon UK's Integrated Power Solutions. "Current-limiting diodes (CLDs) will essentially absorb much of the electrical energy that the dampening device would otherwise have to channel during a lightning strike," he adds.



The project - led by Rolls-Royce Controls and Data Services Ltd and involving the UK's Newcastle University in the role of design authority as well as Semelab Ltd of Lutterworth, UK (a subsidiary of TT Electronics plc) - is exploring the use of Raytheon's and Newcastle University's high-temperature silicon carbide (SiC) technology to make CLDs; a new kind of lightning protection device that stands to reduce the amount of electrical energy traditional suppressors have to deal with during a lightning strike.

"In striving for lighter and more fuel-efficient aircraft, it is important not to compromise the lightning protection function," says Kennedy. "CLDs have the potential to absorb excess energy surges induced in

the electrical wiring by a lightning strike, while reducing the size and therefore the weight of the traditional suppressor devices," he adds. "CLDs solve a specific problem of dealing with electrical surges by dissipating induced lightning energy more efficiently, while also contributing to the industry's weight-saving goals."

Currently in phase one, Newcastle University is conducting electrical characterization tests while TT Electronics Semelab develops the CLD packaging. The two-phase project, funded under Innovate UK, is expected to be completed by late 2015.

www.raytheon.co.uk/semiconductors
www.controlsdata.com
www.semelab.co.uk

Raytheon recognized by Aviation Week for GaN technology

Raytheon Company of Waltham, MA, USA has been named a 2015 Laureate Award winner by Aviation Week for innovation in introducing gallium nitride (GaN)-based technology to military radar systems. Advancing the capability of radars and other types of sensors, GaN radio frequency (RF) amplifiers are more than five times more powerful than semiconductors currently used. For military systems, GaN delivers higher performance as well as significant cost benefit.

The Advanced Technology Programs team of Raytheon Integrated Defense Systems in Tewksbury, MA has a 15-year history of GaN innovation that has shaped existing radar discrimination technology. Partnerships with organizations such as the US Defense Advanced Research Projects Agency (DARPA) and the Office of the Secretary of Defense (OSD) have advanced the development, production and integration of amplifiers based on GaN technology.

GaN produced in Raytheon's DoD trusted foundry in Andover, MA, has been recognized by the DoD for achieving a Manufacturing Readiness Level production capability of '8', the highest level obtained by any organization in the defense industry for this technology. The foundry provides a center of excellence for ongoing programs that require design and fabrication of military RF amplifiers and modules.

<http://laureates.aviationweek.com/la15/Public/enter.aspx>

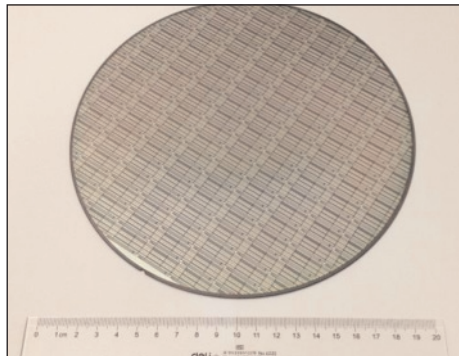
Skysilicon releases China's first GaN power transistor on 8-inch substrate

600V/10A MISHEMT fabricated on 8-inch GaN-on-silicon

Skysilicon Co Ltd of Chong Qing City, China (which makes discrete power devices and power ICs, MEMS sensors and compound semiconductor devices) has released what is reckoned to be China's first gallium nitride power device manufactured on an 8-inch substrate, specifically a GaN metal-insulator-semiconductor high-electron-mobility transistor (MISHEMT) fabricated on an 8-inch GaN-on-silicon wafer.

The firm says that, due to its performance, the N1BH60010A device can be used widely in power electronics systems, e.g. power factor correction (PFC), DC/DC converters, DC/AC inverters etc, in consumer, automotive and industrial markets.

Compared with conventional semiconductor materials such as silicon and gallium arsenide (GaAs), GaN features high breakdown electrical field, high saturation velocity, high power density and low intrinsic carrier density. Based on such performance, GaN devices can therefore be used for high-speed and high-efficiency power electronics applications. In addition, GaN-on-Si power devices have cost advantages,



says Skysilicon. By increasing the diameter of the silicon substrate used for GaN epilayer growth, it is easy to reduce the unit device cost and achieve high-volume production, adds the firm. Skysilicon fabricated the GaN-on-Si power device platform on its in-house 8-inch manufacturing line, which is capable of being used for high-volume production. GaN-on-Si has therefore been considered to be the most promising technology for next-generation power electronics applications.

Skysilicon began research on GaN-on-Si power devices in July 2013. After 18 months of development, it has developed a 600V/10A GaN MISHEMT on 8-inch silicon substrates that shows what are

claimed to be good switching characteristics and small parasitic capacitance, i.e. $I_D > 10A$, $I_{D,pulse} = 35A$ (pulse width = 600 μ s), $V_{DSS} = 600V$, $R_{DS(on)} = 0.27\Omega$, $I_{DSS} < 10\mu A$ ($V_{DS} = 600V$), $I_{GSS} < 10nA$ ($V_{GS} = -10V$), $C_{ISS} = 52pF$, $C_{OSS} = 26pF$ and $C_{RSS} = 21pF$. Compared with a silicon super-junction MOSFET, the GaN MISHEMT can reduce parasitic capacitance by up to 90%, it is claimed. Also, reverse recovery charge can be eliminated due to the fact that there is no PN junction in the GaN device, indicating significant advantages for applications in high-efficiency and fast-switching power electronics systems. Compared to the major GaN power device suppliers, the main characteristics of Skysilicon's GaN power device are either comparable to or better regarding off-state leakage and parasitic capacitance, it is claimed.

The GaN research program at Skysilicon is funded by Chinese National Science and Technology Major Project (NSTMP), which aims to develop 8-inch based GaN-on-Si power devices and technologies.

www.skysilicon.com

Bristol's Kuball receives Wolfson Research Merit Award

Professor Martin Kuball of the University of Bristol's School of Physics in the UK is one of 19 people to receive the UK Royal Society's Wolfson Research Merit Award

Jointly funded by the Wolfson Foundation and the UK's Department for Business, Innovation and Skills, the Wolfson Research Merit Award scheme aims to provide universities with additional support to enable them to attract science talent from overseas and to retain respected UK scientists of outstanding achievement and potential.

Kuball has received the award for the research project 'Gallium Nitride Diamond Electronics – Novel Thermal

Management Concepts', which focuses in particular on microwave and power electronic devices.

For the past 50 years, microwave and power electronic devices have relied on traditional semiconductor materials such as silicon and gallium arsenide (GaAs). Using devices based on materials such as gallium nitride (GaN) would reduce weight, increase efficiency and reduce energy consumption. However, power densities in such devices can now reach levels equal to the surface of the sun. The research therefore focuses on how to keep these device as cool as possible, for example using their

integration with the highest thermal conductivity material known (diamond) as well as the reliability and lifetime of these new technologies.

The Royal Society is a self-governing fellowship of many of scientists drawn from all areas of science, engineering, and medicine. Founded in 1660, its fundamental purpose is to recognise, promote and support excellence in science and to encourage the development and use of science for the benefit of humanity.

www.bristol.ac.uk/physics/people/martin-h-kuball/overview.html
<https://royalsociety.org/grants/schemes/wolfson-research-merit>

Infineon and Panasonic to establish dual sourcing for normally-off 600V GaN power devices

Panasonic's e-mode GaN-on-Si transistor to be integrated into Infineon's SMD packages

Germany's Infineon Technologies AG (which in January acquired US-based power management technology provider International Rectifier Corp) and Japan's Panasonic Corp have agreed to jointly develop gallium nitride (GaN) devices based on Panasonic's normally-off (enhancement-mode) GaN-on-silicon transistor structure integrated into Infineon's surface-mounted device (SMD) packages.

In this context Panasonic has provided Infineon with a license for its normally-off GaN transistor structure. This agreement will enable each firm to manufacture high-performance GaN devices. Customers will also have two possible sources for compatible packaged GaN power switches: an arrangement not available for any other GaN-on-Si device so far, it is claimed. For the first time the firms will showcase samples of a 600V 70mΩ device in a DSO (dual small outline) package at the 30th IEEE Applied Power Electronics Conference & Exposition (APEC 2015) in Charlotte, NC, USA (15–19 March).

GaN-on-Si has been receiving attention as a next-generation compound semiconductor technology that can enable high power density and hence a smaller footprint (e.g. for power supplies and adapters) while also serving as a major key for energy-efficiency improvement. In general, power devices based on GaN-on-Si can be used in a wide range of fields, from high-voltage industrial applications such as power supplies in server farms (a potential application of the showcased 600V GaN device) to low-voltage applications such as DC–DC conversion (e.g. in high-end consumer goods). According to an IHS market research report, the GaN-on-Si related market for power semiconductors is expected to increase at a compound annual growth rate (CAGR) of more than 50% from \$15m in 2014 to \$800m by 2023.

"Infineon is committed to serve its customers with a broad best-in-class product and technology portfolio including reliable power devices based on GaN," says Andreas

Urschitz, president of Infineon's Power Management & Multimarket Division. "Enhancement-mode GaN-on-Si switches, together with our corresponding driver and optimized driving scheme, will provide high value to our customers, while the dual-sourcing concept will help them manage and stabilize their supply chains," he adds.

"Panasonic developed its normally-off GaN power technology, which has a simple configuration and easy-to control dynamics, by making full use of its compound semiconductor experience," says Toru Nishida, president of Panasonic Semiconductor Solutions Co Ltd. "We expect to accelerate the expansion of GaN power devices by licensing our normally-off GaN transistor structure out of our GaN power technology to Infineon," he adds. "We will continuously contribute to solutions for consumer requests by innovating our normally-off GaN technology."

www.infineon.com

www.irf.com

<http://panasonic.net>

MACOM launches 650W GaN-on-SiC HEMT pulsed power transistor for 960–1215MHz avionics applications

M/A-COM Technology Solutions Inc of Lowell, MA, USA (which makes semiconductors, components and subassemblies for analog RF, microwave, millimeter-wave and photonic applications) has launched a 650W gallium nitride (GaN) on silicon carbide (SiC) HEMT pulsed power transistor for L-band pulsed avionics applications, available in standard flange (MAGX-000912-650L00) or earless flange (MAGX-000912-650L0S) packaging.

Optimized for civilian and military pulsed avionics amplifier applications

in the 960–1215MHz frequency range for Mode-S, TCAS, JTIDS, DME and TACAN operation, the MAGX-000912-650L0x is a rugged and robust gold-metalized, internally matched GaN-on-SiC depletion-mode RF power transistor (RoHS-compliant and 260°C reflow compatible), with a mean time to failure (MTTF) of 600 years. Peak output power (P_{out}) is 650W, with 20dB typical gain and 62% drain efficiency. The semiconductor structure is designed to achieve a high drain breakdown voltage (BV_{dss}), enabling reliable and stable

operation at 50V in extreme mismatched load conditions unparalleled with older semiconductor technologies, it is claimed. Other features include flat gain versus frequency performance and a common-source configuration for broadband class AB operation.

"The device is an ideal candidate for customers looking to upgrade L-band avionics systems to the next level of pulsed power performance," reckons senior product director Gary Lopes.

www.macomtech.com

Infineon expands GaN-on-Si portfolio with energy-efficient E-mode and cascode configuration platforms

International Rectifier acquisition and Panasonic partnership combining with Infineon's SMD packaging

At the 30th IEEE Applied Power Electronics Conference & Exposition (APEC 2015) in Charlotte, NC, USA (15–19 March), Infineon Technologies AG of Munich, Germany announced the expansion of its gallium nitride (GaN)-on-silicon technology and product portfolio.

The firm now offers both enhancement-mode (E-mode) and cascode configuration GaN-based platforms optimized for high-performance applications requiring higher levels of energy efficiency, including switch mode power supplies (SMPS) used in server, telecom, mobile power and consumer goods such as Class D Audio systems. GaN technology significantly reduces the size and weight of power supplies, which will open up new opportunities in end-products such as ultra-thin LED TVs, says the firm.

"Infineon's GaN-on-silicon portfolio — combined with the acquisition of International Rectifier's GaN platform together with our partnership with Panasonic — clearly positions Infineon as the technology leader in this promising GaN market," believes Andreas Urschitz, president of Infineon's Power Management & Multimarket Division. "In line with our 'Product to System' approach, our customers can now choose enhancement-mode or cascode configuration technologies accord-

ing to their application/system requirements," he adds.

"At the same time, Infineon is committed to developing surface-mount device (SMD) packages and ICs that will further leverage the superior performance of GaN in a compact footprint," Urschitz continues. "As a real-world example, using our GaN technology, a laptop charger found on the market today could be replaced by one that is up to four times smaller and lighter," he reckons.

Infineon's expanded range will include dedicated driver and controller ICs which enable the topologies and higher frequencies that fully leverage the benefits of GaN. It is further enhanced by a broader patent portfolio, GaN-on-Si epitaxy process and 100-600V technologies resulting from the acquisition of International Rectifier. Additionally, through a strategic partnership, Infineon and Panasonic Corp will jointly introduce devices utilizing Panasonic's normally-off (enhancement-mode) GaN-on-Si transistor structure integrated into Infineon's SMD packages, providing a highly efficient 600V GaN power device with the added benefit of dual sourcing.

As a result, Infineon now offers complete system know-how combined with what is claimed to be the industry's most comprehensive

range of GaN technologies and products. Additionally, it has volume manufacturing capabilities and capacity as well as second sourcing for normally-off GaN power devices in an Infineon SMD package.

Infineon says that GaN-on-Si-based technology delivers increased power density and higher energy efficiency in a smaller footprint compared to silicon-based solutions, and is hence well suited to a wide range of applications from consumer goods such as TV power supplies to Class D Audio amplifiers to SMPS used in server and telecom equipment. According to a market research report from IHS, the GaN-on-Si power semiconductor market will increase at a compound annual growth rate (CAGR) of more than 50%, from \$15m in 2014 to \$800m by 2023.

At APEC 2015, Infineon and Panasonic is showcasing samples of a 600V 70mΩ device in a DSO package. Also featured are demonstrations of both E-mode and cascode configuration technologies, for which device samples will be available to customers under specific non-disclosure agreements (NDA). Fully released mid-voltage cascode devices are available for complying Class D audio customers.

www.irf.com

<http://panasonic.net>

www.infineon.com

Custom MMIC appoints Saguaro as sales representative for Arizona and New Mexico

Monolithic microwave integrated circuit developer Custom MMIC of Westford, MA, USA has appointed Saguaro Technical Sales of Scottsdale, AZ, as its new representative in Arizona and New Mexico.

"Saguaro will help us dramatically

expand our business reach in the southwestern USA," says president & CEO Paul Blount.

Custom MMIC says that Saguaro Technical Sales maintains a highly skilled workforce with engineering that can target solutions for a broad

spectrum of customers. It reckons that Saguaro will play a pivotal role in its continued growth over the next several years as Custom MMIC continues to develop its standard product catalog and design services.

www.CustomMMIC.com

GaN Systems' power semiconductors gain top-side cooling for simpler PCB design

GaN Systems Inc of Ottawa, Ontario, Canada, a fabless producer of gallium nitride (GaN)-based power switching transistors based on its proprietary Island Technology for power conversion and control applications, has announced new top-side cooling technology in its range of high-power enhancement-mode devices.

Top-side cooling enables the use of conventional, well-understood PCB cooling techniques when incorporating the firm's devices into the latest designs for products such as inverters, uninterruptible power supplies (UPS), hybrid electric vehicles/ electric vehicles (HEV/EV), high-voltage DC-DC conversion, and consumer products such as TVs.

GaN Systems' gallium nitride power transistors are based on its proprietary Island Technology — the die consist of islands rather than traditional fingers, which brings advantages in terms of better current handling, lower inductance, scaling, isolation and thermal management, as well as enabling smaller die and lowering cost, it is claimed. With



current ratings ranging from 8A to 250A, the firm's enhancement-mode devices are delivered in its proprietary GaNPX packaging: the die is embedded within a laminate construction and a series of galvanic processes replaces conventional techniques such as clips, wire bonds and moulding compounds. These near-chipscale high-power switching transistors are now packaged to be cooled via the top-side of the chip using a heat-sink or fan — conventional techniques that are well-understood and familiar to design engineers who may be unfa-

miliar with using GaN devices or using them for the first time, the firm says.

GaN transistors can also be cooled from the bottom surface of the die through conduction to the PCB.

GaN Systems says that it is the

first company to have developed and brought to the global market a comprehensive range of devices with current ratings from 8A to 250A — its Island Technology die design, combined with its extremely low inductance and thermally efficient GaNPX packaging and Drive Assist technology means that the firm's GaN transistors offer a 40-fold improvement in switching and conduction performance over traditional silicon MOSFETs and IGBTs, it is claimed. Devices are available now through the firm's worldwide distribution network.

Websolus signed as distributor in South Korea and China

GaN Systems has signed a distribution deal with Seoul-based global group Websolus.

Listed on the Korea New Exchange (KONEX), with 13 Branch Offices in Korea, China, & Thailand, Websolus specializes in three major business sectors: IT consulting & systems integration for power grid; water & energy systems solutions for global infrastructure; and procurement & distribution for electronic components.

GaN Systems claims to be the first company to have brought a comprehensive range of gallium nitride power switches with current ratings from 8A to 220A to the global market. The distribution agreement with Websolus covers

South Korea, China, and Thailand.

Websolus has in-depth knowledge of key customers in the region and will support them locally as they become early adopters of GaN devices in their new products, says GaN Systems' president Girvan Patterson. "The significant advantages [over traditional silicon MOSFETs and IGBTs] offered by gallium nitride power transistors — smaller, lighter and far more efficient power electronics — will help drive innovation in the many products manufactured in the region, including consumer electronics," he adds.

GaN Systems has quickly become the leading choice for GaN devices among tier1 companies in auto-

motive, industrial, enterprise and consumer segments, says Websolus' CEO Kim Hong-sik. "Our companies share a common objective of providing solutions which significantly improve energy efficiency," he adds.

"Websolus has already proven to be a valued partner in Korea, and we are looking forward to expanding this partnership into China," says Charles Bailey, GaN Systems' senior director, marketing & sales, Asia. "Both GaN Systems and Websolus have strong penetration within industrial and enterprise markets, and together we are also penetrating automotive and consumer markets in Korea and China".

www.gansystems.com



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Multi-junction CPV cells
HBTs pHEMTs BiFET/BiHEMTs

Transphorm and ON Semiconductor launch co-branded GaN power devices

At the 30th IEEE Applied Power Electronics Conference and Exposition (APEC 2015) in Charlotte, NC, USA (15–19 March), Transphorm Inc of Goleta, near Santa Barbara, CA, USA (which designs and provides gallium nitride-based power conversion devices and modules) — in partnership with ON Semiconductor — introduced two co-branded 600V GaN cascode transistors and a 240W reference design that utilizes them.

This builds on the partnership announced last September between Transphorm Inc, Transphorm Japan Inc and ON Semiconductor of Phoenix, AZ, USA (which supplies silicon-based power and signal management, logic, discrete and custom devices for energy-efficient electronics) to bring GaN-based power solutions to market.

With typical on-resistances of 150mΩ and 290mΩ, the two new GaN products, TPH3202PS (ON Semi equivalent: NTP8G202N) and TPH3206PS (ON Semi equivalent: NTP8G206N), are each offered in an optimized TO-220 package for easy integration with customers' existing circuit board manufacturing capabilities. Both of the 600V products have been qualified using JEDEC standards and are in mass production.

"At last year's APEC 2014, the Transphorm booth displayed evaluation boards using our 600V TO-220 HEMTs. At this year's show we're excited to announce complete GaN-specific reference designs with ON Semiconductor," says Transphorm's president & co-founder Primit Parikh. "We have consistently demonstrated, since 2011, that our JEDEC-qualified 600V GaN products enable more efficient, compact and low-cost solutions than traditional silicon devices," he claims. "With our partner, ON Semiconductor, we are providing complete reference design platforms and tools that enable designers to take advantage of GaN's benefits while greatly accelerating their design cycles and reduce time to market."

The two-stage evaluation board NCP1397GANGEVB (Transphorm equivalent: TDPS250E2D2) is offered as a complete reference design so that customers can implement GaN cascode transistors in their power designs. The evaluation board is representative of a production power supply that has been re-designed for smaller-size and higher-performance systems, and it aims to highlight the capabil-

ity and potential of GaN transistors in this power range. The boost stage delivers 98% efficiency and utilizes the NCP1654 power factor correction (PFC) controller. The LLC DC-DC stage uses the NCP1397 resonant mode controller to offer a 97% full load efficiency. This performance is achieved while running at 200+kHz and is also able to meet EN55022 Class B EMC performance. Full documentation is available at the Transphorm and ON Semiconductor websites.

Transphorm's GaN HEMT devices are in mass production at the Fujitsu Semiconductor group's CMOS-compatible 150mm wafer fab in Aizu-Wakamatsu, Fukushima, Japan. The large-scale, automotive-qualified facility, which is providing exclusive GaN foundry services for Transphorm and its partners, is intended to allow the expansion of Transphorm's GaN power device business to meet growing demand.

At APEC, Transphorm and ON Semiconductor provided demonstrations of the GaN devices along with a new current-mode LLC power supply and automotive motor driver.

www.transphormusa.com

www.onsemi.com/PowerSolutions/

Mitsubishi Electric to release sample 3.5GHz-band GaN HEMT for 4G base transceiver stations

Tokyo-based Mitsubishi Electric Corp has developed a gallium nitride high-electron-mobility transistor offering high output power and efficiency for use in base transceiver stations (BTS) operating in the 3.5GHz band for fourth-generation (4G) mobile communication.

As a result of the deployment of long-term evolution (LTE) and LTE-Advanced mobile networks, demand is rising for base transceiver stations that can offer greater data volume, smaller size and lower power con-

sumption, says the firm. Mitsubishi has hence developed samples of high-output, high-efficiency GaN HEMTs operating at a drain voltage of 50V and frequencies of 3.4–3.8GHz for macro- and micro-cell BTS.

Product features include what is claimed to be world-leading power output of 100W for macro-cell BTS (realized through transistor optimization), helping to expand BTS coverage range. Also, by adopting GaN HEMTs and transistor optimization, high efficiency helps to reduce

BTS size and power consumption.

The 100W MGFS50G38FT1 device for macro-cell BTS and the 9W MGFS39G38L2 for micro-cell BTS have saturated output powers of 50dBm and 39dBm, respectively, as well as linear gains of 17dB and 19dB, and realize high drain efficiencies of 74% and 67% in load-pull measurements. High efficiency allows a simpler cooling system, contributing to reduced size and power consumption.

www.MitsubishiElectric.com

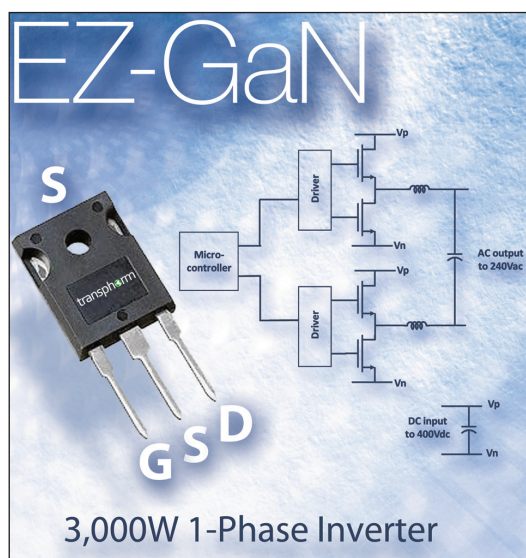
First 600V GaN transistor in TO-247 package

EZ-GaN extended to support PV inverters from a few 100W to several kW

At the 30th IEEE Applied Power Electronics Conference and Exposition (APEC 2015) in Charlotte, NC, USA (15–19 March), Transphorm Inc of Goleta, near Santa Barbara, CA, USA (which designs and provides GaN-based power conversion devices and modules) launched engineering samples of its TPH3205WS, the first 600V GaN transistor in a TO-247 package, it is claimed.

Offering 63mΩ R_{on} and 34A ratings, the device uses the firm's Quiet Tab source-tab connection design, which reduces electro-magnetic interference (EMI) at high dv/dt to enable low switching loss and high-speed operation in power supply and inverter applications. The new device extends Transphorm's EZ-GaN product portfolio to now support photovoltaic (PV) inverter designs with power levels ranging from a few 100W (micro-inverters) to several kW (residential central inverters).

At APEC Transphorm demonstrated how its new TPH3205WS results in ultra-high-efficiency power conversion circuits. One live demo features a 2.4kW bridgeless totem-pole PFC exhibiting near-99% PFC efficiency at 100kHz operation. When combined with a GaN-based



Transphorm's TPH3205WS transistor.

dc-dc conversion stage, the totem-pole PFC enables a greatly simplified 80 PLUS titanium power supply design providing power densities that are unachievable with silicon-based designs, it is claimed. Another live demo is showcasing the TPH3205WS's dynamic R_{on} performance. Transphorm claims that in 2009 it was the first firm to overcome and demonstrate reliable and stable on-resistance across the full range of switching voltages from DC to 400V. The latest device continues this, with an R_{on} increase

under switching of only 5% at 400V, compared with other competitively rated devices with an almost 90% increase, it is reckoned. Transphorm is also displaying a static demo of the TPH3205WS used in a 3kW inverter showing test results at 100kHz and a peak efficiency of 98.8% (and over 99% at 50kHz).

Transphorm says that, over the last several years, GaN has emerged as a leading technology enabler for the next wave of compact, energy-efficient power conversion systems — ranging from ultra-small adapters, high-power-density PCs, server and telecom power supplies, to highly efficient PV inverters and motion control systems.

"Transphorm's increased market footprint with this new higher-current GaN product — along with its access to high-quality, high-scale foundry manufacturing — enables us to meet growing demand from global customers," says president & co-founder Primit Parikh.

Engineering samples of the TPH3205WS are available now from stock. Production release is scheduled for the end of June.

www.transphormusa.com

Cree launches 25W 6–12GHz GaN MMIC power amplifier

Cree Inc of Durham, NC, USA has introduced a 25W gallium nitride monolithic microwave integrated circuit for 6–12GHz performance.

Leveraging the inherent benefits of GaN technology, the MMIC enables extremely wide bandwidths and instantaneous broadband performance, and is suitable for replacing traveling wave tube amplifiers (TWTAs) in applications including radar and jamming, test equipment, and broadband amplifiers.

Based on Cree's GaN high-electron-mobility transistors (HEMTs), the new MMIC is built on a silicon carbide

substrate using a 0.25μm-gate-length fabrication process. The firm says that GaN-on-SiC exhibits several superior properties compared to silicon (Si), gallium arsenide (GaAs), and GaN-on-Si, including higher breakdown voltage, saturated electron drift velocity, and thermal conductivity. GaN HEMTs also offer greater power density and wider bandwidths than Si, GaAs, and GaN-on-Si transistors.

The new reactively matched GaN MMIC power amplifier is available as a bare die (CMPA601C025D) or in a thermally enhanced, 10-lead

ceramic flange package (CMPA601C025F). Both instantaneously exhibit 30% power-added efficiency (PAE) from 6–12GHz, provide 35W of CW output power, are rated for operation up to 28V, and measure just 0.172" x 0.239" x 0.004". However, the die features 32dB small-signal gain and 30W typical saturated output power (P_{sat}), while the packaged part features 33dB small-signal gain and 35W typical P_{sat} .

Currently, the packaged device will be stocked at Mouser.

www.cree.com/rf

TI unveils first 80V half-bridge GaN FET module

Fully integrated GaN FET power-stage prototype contains high-frequency driver and two GaN FETs

Dallas-based Texas Instruments Inc (TI) has introduced what it claims is the first 80V, 10A integrated gallium nitride (GaN) field-effect transistor (FET) power-stage prototype, consisting of a high-frequency driver and two GaN FETs in a half-bridge configuration in an easy-to-design quad flat no-leads (QFN) package.

The new LMG5200 GaN FET power stage is expected to help to accelerate market adoption of next-generation GaN power-conversion solutions that provide increased power density and efficiency in space-constrained, high-frequency industrial and telecom applications (delivering 25% lower power losses compared with silicon-based designs, enabling single-stage conversion). The power stage was highlighted as part of a 48V digital power demonstration at the 30th IEEE Applied Power Electronics Conference (APEC 2015) in Charlotte, NC (16–18 March).

“One of the biggest barriers to GaN-based power design has been

the uncertainties around driving GaN FETs and the resulting parasitics due to packaging and design layout,” says Steve Lambouses, VP of TI’s High-Voltage Power Solutions business. “We help power designers realize the full power potential of GaN technology by offering them a complete, reliable power-conversion ecosystem of optimized integrated modules, drivers and high-frequency controllers in advanced, easy-to-design packaging,” he adds.

Typically, designers who use GaN FETs that switch at high frequencies must be careful with board layout to avoid ringing and electromagnetic interference (EMI). The LMG5200 dual 80V power-stage prototype eases this issue while increasing power-stage efficiency by reducing packaging parasitic inductances in the critical gate-drive loop, says TI. The LMG5200 features multichip packaging technology and is optimized to support power-conversion topologies with frequencies up to 5MHz.

The 6mm by 8mm QFN package requires no underfill, addressing high-voltage spacing concerns, improving board manufacturability and reducing cost. TI says that the reduced footprint solidifies the value of GaN technology and will help to increase adoption of GaN power designs in many new applications, ranging from new high-frequency wireless charging applications to 48V telecom and industrial designs.

In addition to ordering the LMG5200 evaluation module (EVM), designers can get started faster using PSpice and TINA-TI models for the LMG5200 to simulate the performance and switching frequency advantages of the technology.

Prototype samples of the GaN power stage are available from the TI Store. The LMG5200 is priced at \$50 each with a maximum purchase of 10 units. The LMG5200 EVM is available for \$299.

www.ti.com/lmg5200-pr
www.ti.com/tool/LMG5200EVM-01A

SAGE SatCom delivers first 20W linear Ka-band GaN BUC

SAGE SatCom of San Diego, CA, USA (part of telecoms solutions provider REMEC Broadband Wireless), which provides compact Ka-band block up-converter (BUC) and transceiver solutions, is now shipping its high-power 20 watt linear Ka-band BUC solutions to integrator partners in the US and in Europe.

The firm says that gallium nitride (GaN) solid-state technology allows for significant power consumption and size savings compared to the widely used gallium arsenide (GaAs) technology, without compromising RF performance or reliability. The overall size improvement is enough to enable simplified installation directly on the antenna feed arm, without the need for

pedestal mounting. The GaN-based 20W linear Ka-band BUC product is shipping in the same physical enclosure as the firm’s GaAs-based 12W linear Ka-band BUC. SAGE SatCom claims that its Ka-band BUC products offer the highest linear power levels in the most compact and lightweight package on the market.

The block up-converters are built using military-grade components and corrosion-resistant materials, allowing them to withstand extreme weather conditions worldwide. For satellite service providers and integrators that offer solutions using both military and commercial Ka-bands, the BUCs offer simplified system planning, logistics and

sparing as they cover the entire 29–31GHz frequency band in a single unit. Flexibility of monitoring & command (M&C) is enhanced through the use of both RS-485 and HTTP (Ethernet) interfaces. Field-replaceable fuse and weather-proof fans simplify maintenance.

“As the adoption of Ka-band satellite spectrum increases, satellite operators, service providers and integrators are looking for a BUC solution that provides high power, reliability and efficiency along with low CapEx,” says CEO Dave Newman. “SAGE SatCom’s 20W GaN-based block up-converter delivers industry-leading power efficiency and packaging,” he claims.

www.sagesat.com

Keysight launches Infiniium V-Series InP-based oscilloscopes for analysis, debug of high-speed IC designs

Keysight Technologies Inc of Santa Rosa, CA, USA, which provides electronic measurement instruments, systems and related software used in the design, development, manufacture, installation, deployment and operation of electronic equipment, has introduced Infiniium V-Series oscilloscopes, which are claimed to provide superior measurement accuracy, enhanced analysis tools and advanced probing systems. With models ranging from 8GHz to 33GHz, the V-Series is intended to enable circuit designers and engineers to make rapid progress from first silicon to eventual product release.

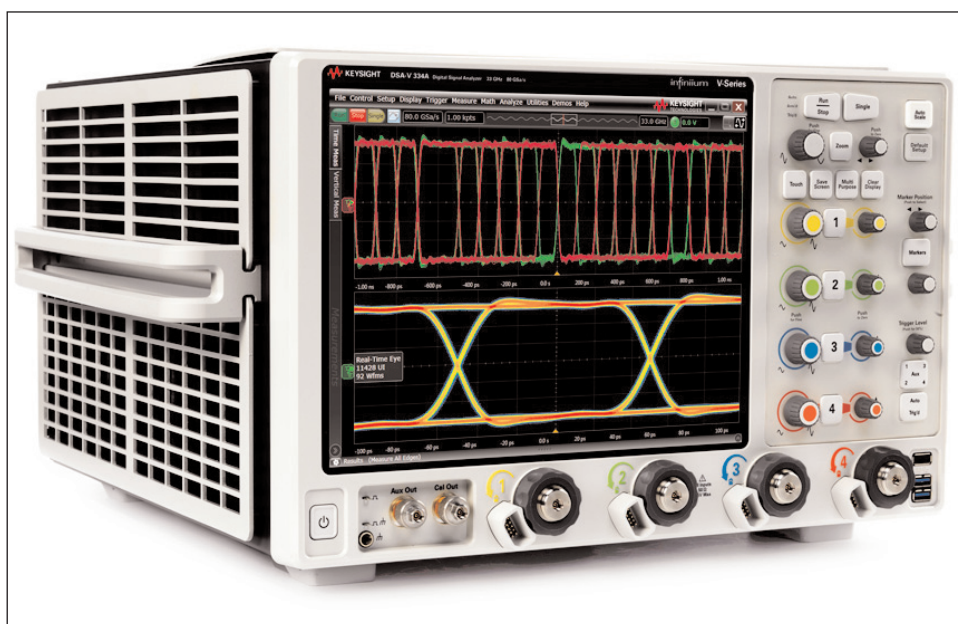
When engineers are designing high-speed digital products or components, they need an oscilloscope to help them debug, validate and optimize their designs, perform precompliance tests, discover the root cause of failures, and maximize design margins, says Keysight. The Infiniium V-Series offers engineers the capability to perform these tests more quickly and accurately, allowing them to get their products to market faster and with more confidence in design quality, it is reckoned.

The V-Series' measurement accuracy is claimed to lead the industry in three areas:

- (1) lowest oscilloscope noise floor;
- (2) lowest real-time oscilloscope jitter floor; and
- (3) highest number of effective bits.

Based on a Keysight-proprietary indium phosphide (InP) integrated circuit process, these advantages enable developers to see highly accurate depictions of their signals and achieve tighter design margins, it is claimed.

To help designers find and debug their most challenging problems, the V-Series includes a 12.5Gbps hardware serial trigger with a 160-bit sequence (the industry's longest). Currently, this is the only hardware serial trigger capable of



Keysight's Infiniium V-Series oscilloscope.

finding 132-bit USB 3.1 (128b/132b) or 130-bit PCIe Gen 3 (128b/130b) symbols, it is reckoned. The V-Series also includes the fastest mixed-signal oscilloscope with 20GS/s digital channels, suitable for triggering, analyzing and debugging DDR4 and LPDDR4 buses, the firm adds.

"The V-Series ensures timely validation and debug, whether designers are looking for answers across multiple serial lanes or a massively parallel bus," says Dave Cipriani, VP & general manager of Keysight's Oscilloscope and Protocol Division. "When they choose the V-Series, R&D labs in today's most competitive industries will be equipped to achieve greater clarity faster," he adds.

To enable high-performance measurements at the probe tip, Keysight is also announcing the N7000A Series Infiniium III+ 8GHz to 20GHz high-speed probing solutions. These come with InfiniiumMode, which enables convenient measurements of differential, single-ended and common-mode signals, using a single probe tip and connection. This capability complements the existing N2800A Series

Infiniium III 30GHz high-bandwidth differential probing solutions. In addition, the new N7010A active termination adapter, which is targeted for HDMI 2.0, DisplayPort and MIPI M-PHY Gear 3 and 4 applications, provides ultra-low-noise voltage termination (with adjustable voltage range from -4V to +4V) to a signal.

Compliance applications are certified to test the exact specifications of standards such as USB 3.1, PCIe Gen 3, LPDDR4, HDMI 2.0, 100G Ethernet and MIPI applications.

Keysight's Infiniium V-Series oscilloscopes are available now. Base pricing is as follows for the three versions:

- digital storage oscilloscopes start at \$95,000 for an 8GHz, 80GSa/s model with 50Mpts per channel (DSOV084A);
- mixed-signal oscilloscopes start at \$110,000 for an 8GHz, 80/40GSa/s model with 50Mpts per channel (MSOV084A);
- digital signal analyzers start at \$110,000 for an 8GHz, 80GSa/s model with SDA, EZJIT Plus and 100Mpts per channel (DSAV084A).

www.keysight.com/find/VSeries

Kyma launches two-dimensional MoS₂ materials and crystal growth tool product lines

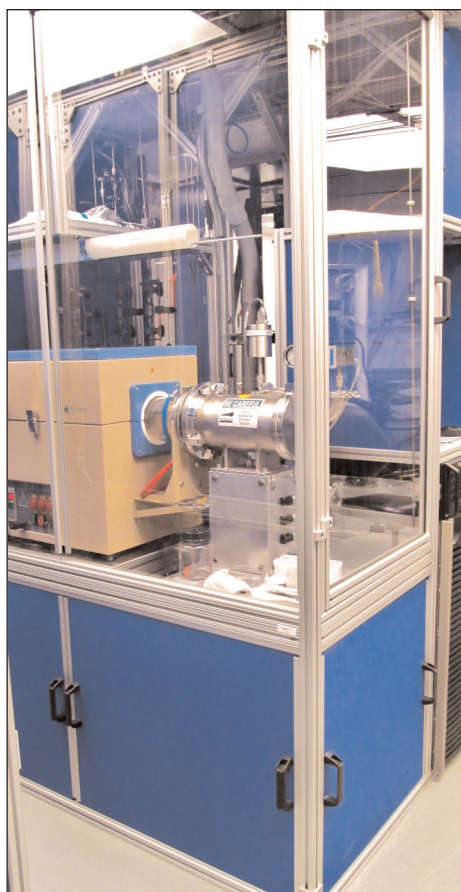
Focus on enhanced deposition uniformity and novel source chemistries

Kyma Technologies Inc of Raleigh, NC, USA (which provides crystalline nitride materials, crystal growth and fabrication equipment, and power switching electronics) has launched crystalline two-dimensional (2D) molybdenum disulfide (MoS₂) materials and growth tools as a key new product line.

Crystalline 2D MoS₂ materials fall in the family of crystalline 2D transition-metal dichalcogenides (TMDs), which are atomically thin semiconductors that are being explored worldwide for their potential to support future applications including flexible electronics and flexible optoelectronics.

Kyma recently won support from the US Air Force to develop the capability to fabricate large-diameter high-quality crystalline 2D MoS₂ materials. More recently, it won support from the US Army to incorporate those materials into RF electronics. Both of those projects are progressing and have enabled Kyma to begin offering crystalline 2D MoS₂ materials to the market.

Kyma says that it uses a novel 2D crystal growth tool to grow crystalline 2D MoS₂ materials. The tool was designed by the firm and features the ability to explore different source chemistries in support of the growth of a variety of different 2D crystalline materials (e.g. MoS₂, WS₂, MoSe₂, WTe₂). To date, Kyma has deposited over 100 MoS₂ films, experimenting with growth conditions and surface preparation approaches. Its effort is supported by an in-house modelling effort and a close collaboration with professor Joshua Robinson's group at Pennsylvania State University's Center for 2-Dimensional



Kyma's 2D crystal growth tool.

and Layered Materials (which was established in 2012).

Kyma's MoS₂ materials include regions with single-monolayer

crystallites and multiple-monolayer crystallites, based on well-established Raman spectroscopy and photoluminescence characterization methods.

The firm's initial efforts use 2"-diameter substrates and have focused on nucleation and growth of large-area single-monolayer MoS₂ crystalline grains. So far the highest-quality triangular crystallites are located in a narrow region of the wafer; enhanced deposition uniformity as well as novel source chemistries will be emphasized in the coming months.

"We have come a long way, from initial collaboration discussions with Josh Robinson of Penn State, to partnering with Josh and transitioning one of his WS₂ growth processes to Kyma (as announced previously) and extending it to larger diameter, to winning Air Force and Army support and producing our own materials," says president & CEO Keith Evans. "Our overall approach to the tool and process for growing MoS₂ has been to reproduce best practices established in academia and to translate that to a commercially robust yet flexible prototype crystal growth tool," he adds.

"These materials will continue to evolve, yet their characteristics are already exciting enough to begin supplying them to next-generation device scientists and engineers," Evans continues. "We are offering steep discounts to those customers who will help us understand our materials better and provide feedback on how we might further engineer their properties."

www.mri.psu.edu/centers/2dlm
www.kymatech.com



Crystalline 2D MoS₂ material grown by Kyma.

US–Ireland UNITE initiative developing 2D transition metal dichalcogenide materials

Tyndall National Institute, Dublin City University, Queen's University Belfast and University of Texas at Dallas target efficient portable electronic devices and data centers

Ireland's Tyndall National Institute (based at University College Cork) says it is participating in a three-year US-Ireland collaborative project that aims to reduce power consumption and increase battery life in mobile devices. Under the auspices of the US–Ireland Research and Development Partnership (launched in 2006), researchers will explore new semiconducting materials enabling the further miniaturization of transistors.

Researchers in the Republic of Ireland (Tyndall National Institute & Dublin City University), Northern Ireland (Queen's University Belfast) and the US (University of Texas at Dallas) — funded by €343,000 from Science Foundation Ireland (SFI), £319,859 from Invest Northern Ireland (InvestNI) and \$420,000 from the US National Science Foundation (NSF) government agencies respectively — are collaborating to develop ultra-efficient electronic materials through the UNITE project 'Understanding the Nature of Interfaces in Two-Dimensional Electronic Devices'.

UNITE's principal investigators are professor Robert Wallace at the University of Texas at Dallas, professor Greg Hughes at Dublin City University, Dr David McNeill at Queen's University Belfast and Dr Paul Hurley at Tyndall National Institute.

UNITE will create and test the properties of atomically thin, two-dimensional layers of transition metal dichalcogenide (TMD) semiconductors. The properties these materials have displayed to date suggest that they could facilitate extremely efficient power usage and high-performance computing.

"Materials that we are currently reliant on, such as silicon, are soon

expected to reach the limit of their performance," says Hurley. "If we want to continue to increase performance, while maintaining or even reducing power consumption, it is important to explore these new TMD materials."

Specifically, UNITE is investigating the synthesis, device fabrication and characterization of 2D TMDs for applications in low-voltage tunnel field-effect transistors. The researchers will explore two separate routes to large-area synthesis through van der Waals epitaxy and atomic layer deposition (ALD). In parallel, characterization and understanding of the surfaces and interfacial regions between commercially available bulk crystals and technologically relevant contacts and insulators will be conducted. This will be accomplished using a combination of in-situ and ex-situ characterization covering questions such as: how can 2D semiconductor surfaces be functionalized to allow uniform and continuous oxide thin films to be formed by ALD; can capacitance-voltage based metrology be applied to metal-oxide-semiconductor systems on 2D semiconductor surfaces; what is the nature of conduction for metal contacts on 2D semiconductors; and how are the atomic-scale elec-

trical properties related to larger-area contacts. The development of growth methods for large-area substrates will not only demonstrate the potential to move 2D semiconductor-based transistors from research to production, but will also provide a source of technologically interesting 2D semiconductor materials for basic study that are not commonly available through geological sources. Finally, the growth and characterization studies will be applied to the fabrication of a tunnel field-effect transistor based on 2D heterostructures.

It is reckoned that, if the UNITE team can understand the issues relating to large-area 2D synthesis, uniform insulator deposition, ohmic contact formation, and charge transport in single- or few-layer 2D semiconductors, then this knowledge will be relevant to a range of potential device architectures.

The application of such 2D TMD materials in transistors could hence not only prolong the battery charge life of portable devices and phones, but also have applications in larger more power-intensive operations such as data storage and server centres. This will have environmental benefits through the reduction of electrical energy consumed by information and communication technologies as well as benefitting consumers.

UNITE builds on the previous US–Ireland collaborative project 'FOCUS' between these academic research partners. The success of this project played a role in demonstrating why funders should back the new project, including training five graduate students in the USA and Ireland, as well as student exchanges between the institutes.

www.tyndall.ie

UNITE is investigating the synthesis, device fabrication and characterization of two-dimensional transition metal dichalcogenides for applications in low-voltage tunnel field-effect transistors

5N Plus revenue grows 10.7% in 2014, despite fourth-quarter slump in commodity pricing

Demand recovering in first-quarter 2015

For full-year 2014, specialty metal and chemical products firm 5N Plus Inc of Montreal, Québec, Canada has reported revenue of \$508.2m, up 10.7% on \$459m for 2013.

5N Plus provides purified metals such as bismuth, gallium, germanium, indium, antimony, cadmium, 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 year was mainly characterized by strong demand for most of our products," says president & CEO Jacques L'Ecuyer. "Demand for our solar products was also high, as one of our main customers continues to make significant progress in terms of efficiency and costs, demonstrating the overall competitiveness of the CdTe technology over other technologies and its ability to penetrate unsubsidized markets. This was recently highlighted by Apple's decision to enter into a 25-year commercial power purchase agreement [PPA], the largest of its kind, for 130MW of electricity produced using CdTe solar cells," he adds. "Sales of our other products were in line with expectations, with important advances having been made during the year in our semiconductor substrate business where we are now fully qualified with both of the main US-based suppliers of space solar cells."

For fourth-quarter 2014, revenue was \$114.8m, roughly level with \$114.4m last quarter but down 4.2% on \$119.4m a year ago. "We experienced however a relatively soft fourth quarter, with demand being negatively impacted by significant underlying commodity price volatility," says L'Ecuyer. "This is especially true for bismuth

and gallium, the pricing of which has been under severe downward pressure following latest developments at the Fanya Metal Exchange, which has forced us to record inventory impairment charges of \$5.3m in the quarter. We expect demand to recover in the first quarter, although pricing volatility may continue."

Full-year adjusted EBITDA rose from \$30.4m in 2013 to \$35m in 2014. "Fiscal year 2014 was close to our highest level in terms of profitability as we reached record EBITDA [excluding the \$45.2m gain realized in 2013 from the litigation settlement regarding MCP Group S.A.], despite a relatively soft fourth quarter," notes L'Ecuyer. Q4 adjusted EBITDA was \$5.7m, down from \$8.1m last quarter and \$7.9m a year ago. Net debt at the end of December 2014 stood at \$84m, up from \$75.9m at end-September and \$58.3m at the end of 2013.

"We improved financial flexibility in 2014, through the issuance of a convertible debenture and the renewal of our credit facility, enabling us to continue making progress in several strategic initiatives aimed at strengthening our position throughout the entire value chain," says L'Ecuyer. "This included, on one hand, additional investments in our Laos facility, with the intent of expanding our primary refining capabilities

and providing an efficient footprint for the treatment of the bismuth feedstock produced in Vietnam; and on the other, investments aimed at expanding our value-added product portfolio by fully leveraging our industrial and technological platform in the semiconductor substrate business and by acquiring the AM&M business and technology as we intend to rapidly position ourselves in the metal powder business." On 3 April 2014, 5N Plus announced that it had acquired the remaining 33.33% ownership stake in germanium substrate subsidiary Sylarus Technologies LLC in St. George, UT, and had changed its name to 5N Plus Semiconductors LLC. Then, on 5 May, the firm completed the acquisition of AM&M Advanced Machine and Materials Inc (and its metal powder atomization technology for electronic packaging, solar modules and additive manufacturing applications).

On 29 May, 5N Plus announced that it had entered into new supply agreements with cadmium telluride (CdTe) photovoltaic (PV) module maker First Solar Inc of Tempe, AZ, USA, the world's leading thin-film solar module manufacturer, covering its compound semiconductor needs until end-March 2019.

Bookings were \$130.8m in Q4, up on \$101.3m last quarter but down on \$156.1m a year ago. Order backlog at the end of December was \$153.2m, up on \$137.2m last quarter but down on \$170.1m a year ago, due mainly to declines in selling prices following the latest trends in underlying commodity prices.

"Current underlying commodity pricing volatility is likely to continue to weigh on our financial performance but we remain cautiously optimistic about future demand and our ability to grow as we execute our strategic plan," concludes L'Ecuyer.

www.5nplus.com

Demand for our solar products was also high, as one of our main customers continues to make significant progress in terms of efficiency and costs, demonstrating the overall competitiveness of CdTe technology over other technologies

UK awards £17.3m for Cardiff University-based Compound Semiconductor Research Foundation

UKRPIF award plus £12m from Wales to boost IQE partnership

The UK Government's Universities Minister Greg Clark MP has unveiled a £17.3m funding award that will underpin the Compound Semiconductor Research Foundation — the first of its kind in the UK, with potential to become one of the leading clusters in Europe (joining four existing European semiconductor clusters), it is reckoned.

Earmarked for Cardiff University's Innovation Campus, the foundation aims to drive testing and development of the technology behind global 'megatrends' including smart-phones and tablets, powering change across sectors including healthcare, biotech and mass communications.

Cardiff is one of seven outstanding university research projects to receive over £100m (in 2016–17)

from the UK Research Partnership Investment Fund (UKRPIF) as part of its fourth round of funding to drive innovation and growth. Set up in 2012, UKRPIF is managed by the Higher Education Funding Council for England (HEFCE), in collaboration with three other UK higher education funding bodies including the Higher Education Funding Council for Wales (HEFCW).

Cardiff's £17.3m UKRPIF award adds to £12m already pledged by the Welsh Government to support the foundation. The funding should strengthen bonds between the university and Cardiff-based epiwafer foundry and substrate maker IQE plc.

"The award from the UK Research Partnership Investment Fund will capitalise on existing academic

expertise at Cardiff University," comments professor Colin Riordan, vice-chancellor of Cardiff University. "It will cement our well-established partnership with IQE to create a global hub for CS technology research, development and innovation," he adds.

"Compound semiconductors are one of the eight great technologies identified by the UK government as essential to leading the UK's economic and industrial growth," notes IQE's CEO Dr Drew Nelson. "We look forward to playing a key role in helping to make Wales and the UK the new European powerhouse for next-generation semiconductor technologies."

www.cardiff.ac.uk

www.iqep.com

www.hefce.ac.uk/rsrch/ukrpif

IQE's Jason Good wins Young Engineer of the Year at ESTnet Awards

Jason Good, senior process engineer at the Photonics business unit of epiwafer foundry and substrate maker IQE plc in Cardiff, Wales, UK, has been named Young Engineer of the Year in an awards ceremony at the Wales Millennium Centre in Cardiff organized by ESTnet (the network for organizations in the electronics and software technologies sector).

The award is in recognition of Good's enthusiasm, commitment and active involvement in a number of process improvement activities that have resulted in his rapid promotion.

"Our people really make the difference when it comes to maintaining our global competitive advantage in the fast-moving, semiconductor technology indus-

try," comments IQE's CEO Dr Drew Nelson. "Jason's award is testament to the skills and talent that Wales can leverage to establish a world-leading position for innovation and technology."

At the ceremony, Nelson also presented the Collaborative Partnership of the Year Award to Sony UK Technology Centre for its work with LED Roadway Lighting Ltd.

Compound Semiconductor Development Centre joint venture in Singapore agreed between IQE, WIN Semiconductor & Nanyang Technology University

Following a memorandum of understanding (MOU) signed last September, IQE has entered into a joint venture agreement with Taiwan's WIN Semiconductors Inc (the world's largest pure-play gallium arsenide foundry) and Singapore's Nanyang Technological University (NTU) to create the Compound Semiconductor

Development Centre (CSDC) in Singapore. As a center of excellence for compound semiconductor technology, the aim is to accelerate the development of new compound semiconductor technology, and to provide an effective incubator for bringing new innovations to market.

IQE has a 50% stake in the JV and, as part of its contribution to

the establishment of CSDC, the firm is setting aside its Singapore facility and providing certain equipment and IP on favourable terms. In return, IQE will be the wafer provider to new high-volume applications that emerge from CSDC.

www.iqep.com

www.winfoundry.com

www.eee.ntu.edu.sg

IQE second-half 2014 revenue up 15% on first-half VCSEL adoption drives 30% full-year growth in lasers & sensors

After giving an unaudited trading update for full-year 2014 in late January, epiwafer foundry and substrate maker IQE plc of Cardiff, Wales, UK has confirmed revenue in line with expectations, at £112m. This is down 11.7% on £126.8m in 2013, due to the industry-wide inventory correction, foreign exchange (about 5%), and lower underlying growth in demand for wireless wafers.

"After several years of strong growth, in 2014 the wireless market paused for breath ahead of the next wave of hardware innovation," explains IQE. "Combined with an industry-wide destocking, this volatility created a short-term challenge. We tackled this head on and delivered increasing underlying profitability and earnings, as well as strengthening our balance sheet as a result of lower deferred consideration and net debt," the firm adds.

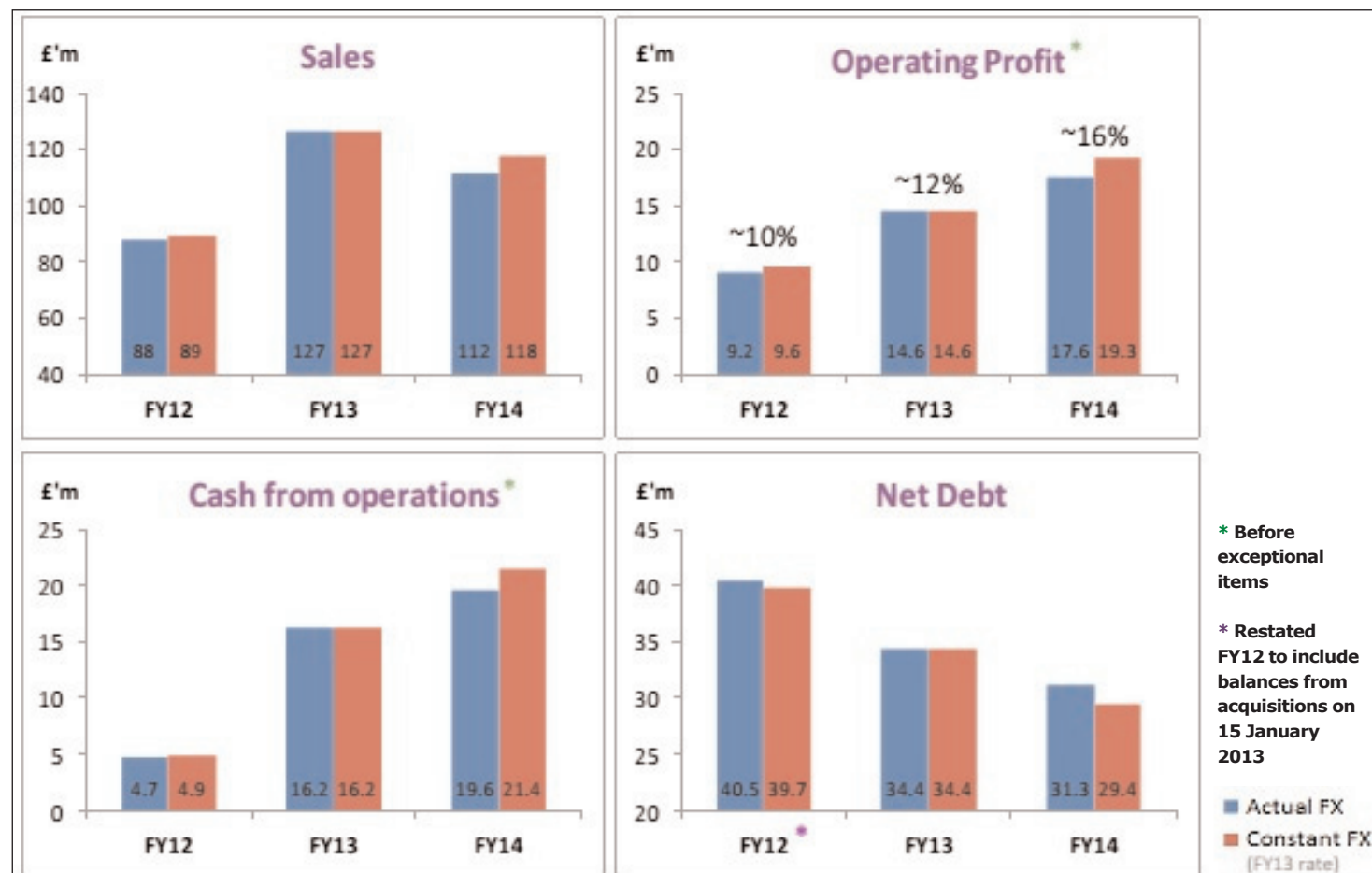
For full-year 2014 (in constant currency), Wireless revenue fell by

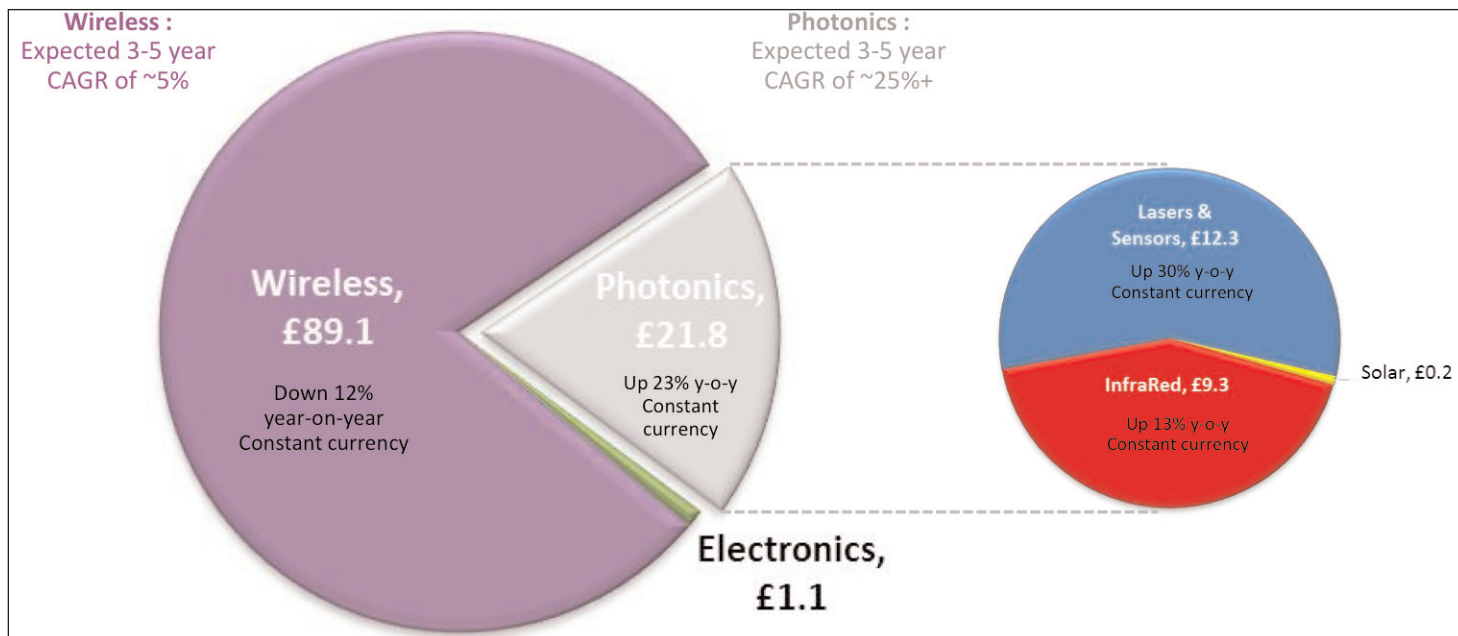
12% year-on-year, from £107.2m in 2013 to £89.1m. Electronics revenue has risen from £0.87m in 2013 to £1.14m. Photonics revenue has grown organically by 23% (more than the expected 20%) from £18.7m in 2013 to £21.8m. This was driven primarily by rapid adoption of vertical-cavity surface-emitting laser (VCSEL) technology by tier-1 customers into a wide range of applications (from data-centers through to industrial processes), helping to drive a 30% rise in (non-IR) lasers and sensors revenue, to £12.3m. There is solid data infrastructure demand, and consumer product design-ins continue to grow, says IQE. "This ramp is at an early stage and has a long and sustainable future," it adds. The Infrared division is winning significant orders, driving revenue up 13% to £9.3m. Revenue from the Solar (concentrated photovoltaic, CPV) business was £0.2m (after

receiving the first orders in Q4/2014).

"Demand from our customers across multiple product areas strengthened through the year," notes president & CEO Dr Drew Nelson. "We enjoyed a significant pick up during the second half which enabled us to deliver improved second-half revenues [£60m, up 15% on £52m in first-half 2014]," he adds. In particular, for the Wireless business (IQE's largest division, with an estimated global market share of more than 50%) enjoyed double-digit sequential growth in second-half 2014 over first-half 2014, driven by the proliferation of increasingly complex wireless communication devices and systems such as LTE/4G, dual-band WiFi, and GPS location devices (which require increasingly complex compound semiconductor solutions).

"As a result of reduced overheads and improving utilization of our





► manufacturing facilities, we achieved better margins and delivered increased full-year earnings and cash flows," says Nelson.

Due largely to cost reductions and improved efficiencies, adjusted gross margin rose strongly from 22% in 2013 to 28.2% in 2014. Correspondingly, adjusted operating profit has risen by 21% from £14.6m to £17.6m. Adjusted operating margin has risen from 11.5% to 15.7%. Adjusted fully diluted earnings per share (EPS) is up 21%, from 2p in 2013 to 2.42p.

Cash generated from operations rose by 21% from £16.2m to £19.6m. Meanwhile, cash investments shrank by £0.7m from £10.1m to £9.4m, reflecting reduced spending on property, plant and equipment (down £2m) offset partly by higher spending on product development (up £0.6m) and new IT systems (up £0.7m). Reflecting the net cash generation, net debt has hence been cut by £3.2m (9%), from £34.4m at the end of 2013 to £31.3m.

"We are making good progress against our strategic objectives," says Nelson. "Our wireless business continues to provide a solid platform, whilst our other markets are delivering encouraging revenue growth and are helping us to diversify our revenues."

Wireless outlook is robust, driven by adoption of 4G LTE for mobile devices and the continuing growth

in mobile data, says IQE, as customer and supplier capacity expansion programs reflect continued confidence within the industry.

Compound semiconductor solutions continue to dominate power amplifier (PA) production, the firm adds.

IQE's Solar business (CPV) has moved into pilot production, with material being deployed into the field in January. Although this was later than originally anticipated, the future for this business remains bright, reckons IQE, as end-market pull should see this ramp into full production through 2015/16.

Conversely, IQE says that its Power business has progressed

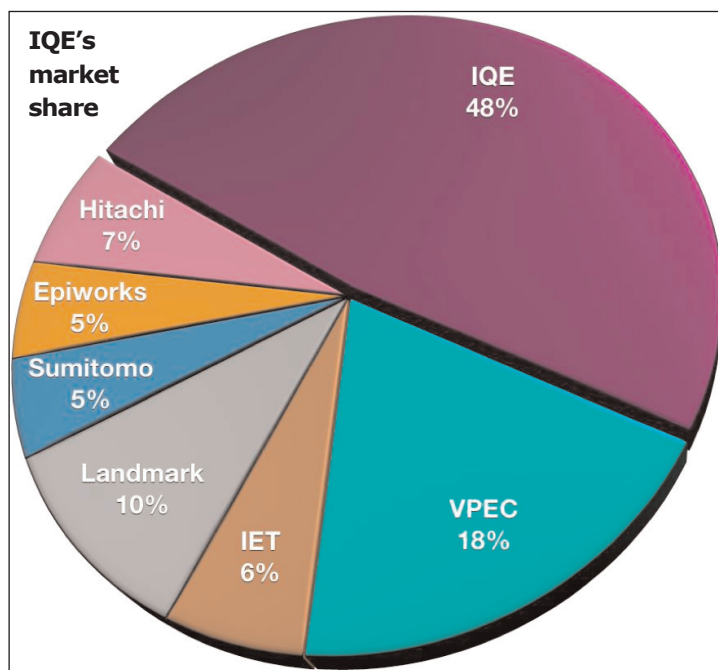
more rapidly than expected, with some major technical milestones and commercial partnerships establishing it in a strong position to commercialize the technology.

In particular, gallium nitride (GaN) is making strong technical progress in both RF for LTE base-station deployment and in power for energy-efficient switching, says

IQE, citing the major supply agreement with M/A-COM Technology Solutions Inc of Lowell, MA, USA to deliver 200mm-diameter gallium nitride on silicon (GaN-on-Si).

"Trading in the first three months of the current year has been in line with our expectations," says Nelson. "The outlook remains positive [with strong prospects driven by the group's diversification strategy], which underpins the board's confidence that we remain on track to achieve our expectations for the full year," he adds. "We anticipate that we will continue to benefit from strong cash flows."

www.iqep.com



Riber acquires MBE Control Solutions

Process control expertise plus maintenance & refurbishment services to strengthen Riber's US operations

Riber S.A. of Bezons, France, which manufactures molecular beam epitaxy (MBE) systems as well as evaporation sources and effusion cells, has acquired MBE Control Solutions of Santa Barbara, CA, USA.

Founded in 2005 by chairman & CEO Andy Jackson, MBE Control Solutions is said to be one of California's leading MBE service and equipment firms. Using its software and automation expertise, the firm operates maintenance and refurbishment services covering all types of MBE systems, with its quality of service and responsiveness aided by infrastructure that includes cleanroom, CNC power tools, etc.

By enabling better regional and commercial coverage, the acquisition is expected to strengthen Riber's customer service activities in the USA. More specifically, as the networks of Riber and MBE Control Solutions merge, it should strengthen

Riber's competitive position throughout America. Jackson will head the firm's operations in the USA.

MBE Control Solutions employs five people and generated revenue of \$1.2m in 2014. Due to its streamlined cost structure, the acquisition of MBE Control Solutions is expected to be accretive for Riber. The acquisition will be financed by using virtually all the treasury shares held by Riber, which were assigned to the objective of external growth (representing nearly 1% of Riber's capital).

"By combining Riber's extensive portfolio of sources and systems with our advanced manufacturing capabilities and expertise in MBE process control, we will be able to serve our customers more effectively," reckons Jackson. "Furthermore, Riber's global commercial network will provide a much broader audience for our products.

Finally and perhaps most importantly, our alliance with Riber is the opportunity to continue innovating and improving our products and services," he adds.

"Our acquisition of MBE Control Solutions will enable us to ramp up our development in a vital market for semiconductor research and innovation," comments Frédéric Goutard, chairman of Riber's executive board. "The operational and commercial synergies between our two companies will pave the way for us to significantly strengthen the quality of our services and our growth forecasts in North America," he reckons. "I am delighted that Andy Jackson and his team are joining Riber. Their vast experience and knowledge of the market will be crucial assets as we continue moving forward with our project for profitable growth together".

www.mbecontrol.com

www.riber.com

Patent for off-axis SiC substrate process to cut epi defects

Jim Edgar, a professor of chemical engineering at Kansas State University, together with researchers at the State University of New York at Stony Brook and the UK's University of Bristol, have been assigned a US patent (number 8,823,014, 'Off-axis silicon carbide substrates') for research that may help to improve electronic devices and could benefit the power electronics industry and manufacturers of semiconductor devices, it is reckoned.

Several years ago, when Yi Zhang, a 2011 doctoral graduate in chemical engineering, was working in the laboratory, she found a substrate sample that was very smooth. The research has subsequently developed a better method for fabricating substrates that minimizes potential defects in epitaxial layers.

Filed in December 2010, the patent hence relates to a method of epitaxial growth of a material on a crystalline substrate that includes selecting a substrate with a crystal plane including a multiple terraces with step risers that join adjacent terraces. Each terrace presents a lattice constant that substantially matches a lattice constant of the material, and each step riser presents a step height and offset that is consistent with portions of the material nucleating on adjacent terraces being in substantial crystalline match at the step riser. The method also includes preparing a substrate by exposing the crystal plane, and epitaxially growing material on the substrate such that the portions of the material nucleating on adjacent terraces merge into a single crystal lattice without defects

at the step risers.

Collaborative researchers at the State University of New York at Stony Brook and the UK's University of Bristol later proved that the epilayer's had fewer defects than on the standard substrate.

"We have applied this process to other systems," says Edgar. "We are working on verifying that it is not just these specific materials we started with, but that it can be applied to a lot of different materials," he adds. Some of Edgar's latest research focuses on two different boron compounds: boron phosphide and icosahedral phosphide.

The researchers received support from the US National Science Foundation (NSF).

www.k-state.edu

Veeco's gas mixing systems chosen by Taiwanese foundry for high-volume silicon germanium epi production

Veeco Instruments Inc of Plainview, NY, USA says a leading Taiwanese semiconductor foundry has placed a repeat order for multiple Apex Gas Mixing Systems. The systems are expected to reduce germane (GeH_4) purchase costs by up to 40% and increase yield for the foundry's most advanced processes by delivering repeatable mixtures of GeH_4 in hydrogen for silicon germanium (SiGe) epitaxy.

"Our Apex Gas Mixing System enables our customer to achieve significant cost savings in high-volume production with a level of precision and control that is unmatched by any other gas mixing system on the market," reckons Christopher Morath, senior director, Veeco Flow Technologies Group.

"The Apex system improves real-time process control by up to a factor of ten as compared to mixed gas



cylinders," he adds. "This improvement will also enable the user to increase both yield and throughput."

Powered by Veeco's production-proven Piezocon Gas Concentration Sensor, the Apex Gas Mixing System is said to improve concentration control versus existing methods, providing tighter process management, increased tool uptime and reduced manufacturing costs. It is optimized for advanced silicon epitaxy applications and other processes requiring low concentration, high precision and cost-sensitive gas mixtures.

"Veeco Flow Technologies Group has been an outstanding partner and their service support has exceeded our customer's expectations," says the president & CEO of Zillion Tek Taiwan, distributor of Apex and Piezocon products.

www.veeco.com/Apex

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Taiwan's Episil manufactures SiC-based high-power management devices using Aixtron CVD system

Deposition equipment maker Aixtron SE of Aachen, Germany says that Taiwanese group Episil Semiconductor Wafer Inc has put into operation an AIX G5 WW (Warm-Wall) chemical vapor deposition reactor for silicon carbide epitaxy.

"We chose the Aixtron Planetary Reactor system because we have been impressed by the excellent material quality produced on Aixtron SiC systems," comments Episil's president Dr Ian Chan. "Episil is already a leading producer of silicon-based epitaxy for power management devices and power management integrated circuits," he adds. "We also have experience with

Aixtron's MOCVD technology for producing gallium nitride on silicon components (GaN-on-Si) and now plan to expand our portfolio into SiC-based devices."

SiC and GaN are both being developed for power applications. While SiC devices have already been used in switch mode power supplies (SMPS), SiC semiconductor material demands very high growth temperatures, requiring specific solutions for the epitaxial processing equipment. Aixtron says that the AIX G5WW matches these requirements for next-generation SiC power electronics. The system can handle up to 8x150mm-diameter

SiC wafers and has the highest wafer throughput in the market, it is claimed, along with fast cycle times and low cost of ownership. Aixtron's engineers have maximized production yields through improved uniformity on 150mm SiC and by developing robust processes.

Episil was the first epitaxial processing facility in Taiwan when it was founded in 1985. The firm now has more than 1400 staff and a total capitalization of about \$100m. It also operates a device foundry producing wafers with bipolar, CMOS, DMOS and BCD processes.

www.episil.com
www.aixtron.com

Nano Carbon chooses Aixtron CVD system for graphene on SiC

In first-quarter 2015 Aixtron received an order for an AIX G5 WW (Warm-Wall) chemical vapor deposition system from Nano Carbon of Warsaw, Poland for graphene production on silicon carbide. Due for delivery by fourth-quarter 2015, the system will be configured to handle either ten 100mm or six 150mm substrates per run.

Nano Carbon is a 2011 start-up based on technology developed at the Institute of Electronic Materials

Technology (IEMT) in Warsaw, and owns a low-cost patented technique for epitaxial graphene that can be implemented on the Aixtron system. "Nano Carbon will use the Aixtron system to continue research on graphene on SiC, and we will commercialize this technology on to production scale using the AIX G5 WW," says IEMT's Dr Wlodek Strupinski.

Aixtron says the G5 WW system provides high wafer throughput

and is designed for the ultra-high temperatures needed for the deposition of epitaxial graphene on SiC.

Nano Carbon is an associate member of the European Union's graphene flagship project in which Aixtron is leading the production work package. The start-up aims to supply high-quality graphene on SiC to the various research groups and industries working on graphene devices.

www.nano-carbon.pl

Picosun establishes ALD research lab at Taiwan's NCTU

Taiwan's National Chiao Tung University (NCTU) and atomic layer deposition (ALD) equipment maker Picosun Oy of Espoo, Finland have established a Joint Industrial ALD Research Laboratory at the premises of the X-Photonics Interdisciplinary Center at NCTU to use ALD technology to realize a new generation of micro- and optoelectronic devices.

Through the collaboration, NCTU and Picosun aim to develop a wide range of interdisciplinary technology solutions for applications such as microelectronic devices for the 7nm

technology node, high-brightness LEDs, and HEMTs. Both fundamental research and advanced device fabrication for industrial applications will be the core objectives of the lab.

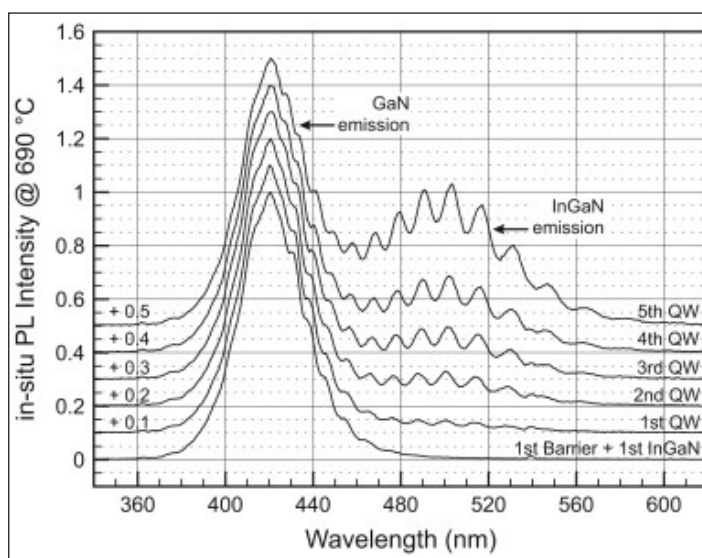
"Picosun, with their world-leading experience in ALD system design and process knowhow, has been chosen as our ALD technology provider," says professor Hao-Chung Kuo, associate VP of NCTU, and a fellow of both the Institute of Electrical and Electronic Engineers (IEEE) and the Optical Society of America (OSA).

"A partnership and a joint research laboratory with NCTU will provide our existing and future industry customers not only local access to our technology for their applications, but also stronger collaboration ties for future-generation products enabled by our ALD technology," says Dr Wei-Min Li, CEO of Picosun Asia and applications director of Picosun. "This is further supported by our newest subsidiary, Picosun Taiwan, established two months ago."

www.nctu.edu.tw
www.picosun.com

First in-situ PL of growing InGaN/GaN MQW LED structure during MOCVD

In a collaboration with professor Dirk Rueter's group at the University of Applied Sciences Ruhr West, in-situ metrology system maker LayTec AG of Berlin, Germany have achieved what is claimed to be the first quasi-continuous in-situ photoluminescence (PL) monitoring of InGaN/GaN multi-quantum-well (MQW) emission wavelength during metal-organic chemical vapour deposition (MOCVD) in an industrial-grade reactor at growth temperature (C. Prall et al, Journal of Crystal



In-situ spectra of a growing InGaN MQW structure at wafer temperature of 690°C. Spectra of the complete QWs were taken after growth of subsequent GaN barrier layer.

Growth 415 (2015), 1–6).

It is known that room-temperature wafer-based PL measurements —

even at an early stage of the growth of the active region — provide an excellent forecast of the emission wavelength and emission intensity of resultant LED devices. In this latest collaborative work, a prototype in-situ PL system was used simultaneously with a LayTec Pyro 400 tool in a commercial multi-wafer MOCVD reactor at growth temperature. The study hence demonstrated accuracy of $\pm 1.3\text{nm}$ (2σ) in the predicted wavelength range. The researchers conclude that the technique thus appears to be suitable for the closed-loop control of the emission wavelength of InGaN LEDs during growth.

The work has been supported by BMWi (German Federal Government) under grant KF3242801NT3.

www.sciencedirect.com/science/article/pii/S0022024814008380
www.laytec.de/pyro400

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LAYTEC
Knowledge is key

Plasma-Therm's Advanced Vacuum processing equipment selected by University of Central Florida's CREOL institute for photonics program

Plasma-Therm LLC of St Petersburg, FL, USA says that its Advanced Vacuum division in Lomma, Sweden (which supplies vacuum solutions including thin-film plasma etch and deposition systems) has been selected by the University of Central Florida (UCF) to provide enhanced compound semiconductor etch and dielectric deposition capabilities.

Established in 1987 as Center for Research and Education in Optics and Lasers (CREOL) and a college since 2004, UCF's College of Optics and Photonics provides research facilities for users from universities and industry locally and internationally from a wide range of disciplines. In addition to serving a key role in the university's academic mission, the center encourages commercialization of internal and external research efforts.

The Advanced Vacuum APEX SLR etching system combines Plasma-Therm's Shuttlelock plasma reactor technology with the cost-effective APEX platform. The recently installed APEX SLR complements CREOL's Plasma-Therm equipment,

which supports the fabrication of devices for next-generation optical communication. Deposition capability at CREOL will soon be enhanced by an Advanced Vacuum Vision 310 system, complementing a Plasma-Therm PECVD (plasma-enhanced chemical vapor deposition) system. The systems will be used to generate light-emitting, detecting, modulating and guiding devices required for chip-to-chip communication.

"The decision to select Advanced Vacuum's APEX and Vision systems was based on several factors, including the high quality and reliability of the products, very competitive quotes for the required specs, the company's reputation, and their long partnership with UCF," comments CREOL's professor Sasan Fathpour, the principal investigator for the federal grants for acquisition of these and other tools.

"We are thankful to the National Science Foundation (NSF) and the Office of Naval Research (ONR) for providing grants that led to the purchase of these tools. These systems contribute to CREOL's Nanophotonics Systems Fabrication

Facility capabilities for conducting advanced academic research and basic industrial R&D in integrated photonics, and better position the college to compete for research opportunities in areas such as heterogeneous photonics," he adds.

"It will also facilitate our competitiveness in larger efforts, such as the ongoing IP-IMI proposal," Fathpour continues, referring to the federal Integrated-Photonics Institute for Manufacturing Innovation, an initiative with potentially more than \$230m in private and public funding to transform the integrated photonics industry into a highly manufacturable ecosystem. UCF is the leading institute for one of only three national teams selected by the US Department of Defense as finalists for the IP-IMI.

"Our equipment and partnership will contribute to achieving the important fabrication goals in the area of heterogeneous photonics integration," comments Plasma-Therm's principal scientist Dr David Lishan.

www.plasmatherm.com

www.Advanced-Vacuum.com

www.creol.ucf.edu

Thermco Systems starts up operations in China

Thermco Systems, a division of Tetreon Technologies Ltd of Washington, West Sussex, UK has opened its new facility in Wuxi, China (80 miles west of Shanghai).

Thermco Systems (Wuxi) Ltd will use the center for its sales, service and manufacturing operations within China. The firm says that this move follows strong demand throughout the Asian market for Thermco furnace products in the semiconductor and PV markets.

"The Wuxi facility is a key step in our strategy to enhance our presence in the Chinese market by giving our customers local sales,



Thermco Systems' new Wuxi facility.

service and manufacturing support," says Thermco Systems' CEO

Gerry Thurgood. "This actions follows on the heels of the recent opening of our office in Taiwan and demonstrates our long-term commitment to the region."

Thermco Systems has sold over 30,000 furnaces horizontal diffusion furnaces since its founding in 1962. The firm designs and manufactures furnace systems, custom wet benches and chemical handling equipment for the semiconductor, MEMS, LED, photovoltaic and nanotechnology industries.

www.thermcossystems.com

CVD and Penn State partner to develop two-dimensional transitional metal dichalcogenide equipment & processes

NSF's EFRI program awards Penn State \$1.96m for 2-DARE project

CVD Equipment Corp of Central Islip, NY, USA (a designer and maker of equipment for developing and manufacturing electronic components, materials and coatings for research and industrial applications) is entering into an industrial partnership with Penn State University.

Through the US National Science Foundation's Emerging Frontiers in Research and Innovation (EFRI) program, Penn State University (PSU) has been awarded \$1.96m for the project Two-dimensional Atomic-layer Research and Engineering (2-DARE). Headed by professor Joan Redwing, the project will leverage CVD Equipment Corp's engineering and manufacturing capabilities to advance the deposition

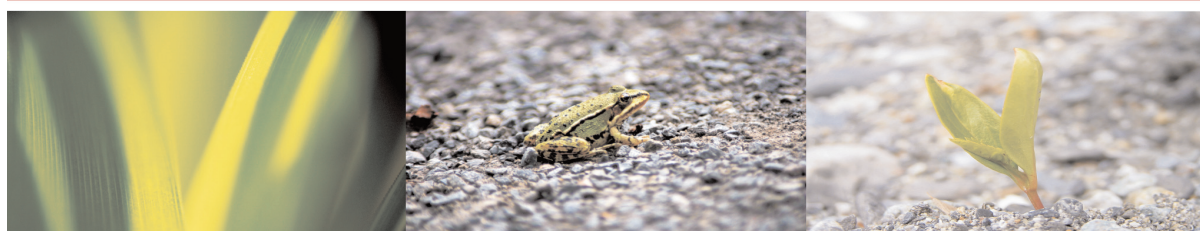
technologies and processes for producing novel 2D materials beyond graphene. The main focus will be on developing and optimizing the techniques for producing crystalline 2D transition metal dichalcogenides (TMDs) such as molybdenum disulfide (MoS_2) and tungsten diselenide (WSe_2). This work should pave the way for the future production of 2D materials as they find their place in widespread industrial applications.

Over recent years, the demonstration of graphene's remarkable physical properties has led to the emerging application of graphene in many next-generation products and devices. Although there is still much work to be done to fully understand graphene, many

researchers have turned their attention to other 2D materials with equally promising and often unique properties.

A host of 2D materials are hence under interdisciplinary scientific study, targeting technical advances in sectors such as semiconductor, optoelectronics, structural and environmental applications. The firm says that chemical vapor deposition (CVD) and atomic layer deposition (ALD) are proving to be powerful techniques for producing these atomically thin materials, but the often home-built university lab deposition equipment is limited in the process capabilities.

www.cvdequipment.com
www.mrsec.psu.edu



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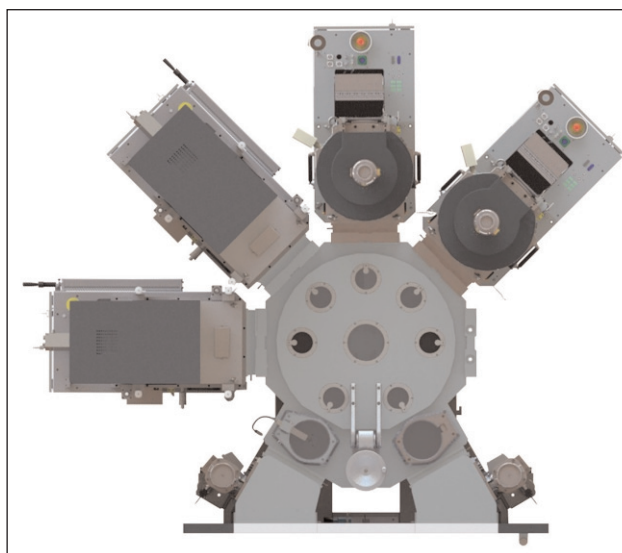
EVG adds two EVG580 ComBond system configurations for university/R&D and high-volume manufacturing

EV Group of St Florian, Austria (a supplier of wafer bonding and lithography equipment for MEMS, nanotechnology and semiconductor applications) has introduced two new configurations to its EVG580 ComBond series of automated high-vacuum covalent wafer bonding systems. Addressing the needs of universities and R&D institutes, and high-volume manufacturing (HVM) requirements, respectively, both system configurations achieve electrically conductive and oxide-free bonds of materials with different lattice constants and coefficients of thermal expansion at room temperature.

Applications that demand room-temperature bonding of substrates with very different material properties and that are supported by the EVG580 ComBond series include engineered substrates, power devices, stacked solar cells and emerging technologies such as silicon photonics.

The new entry-level EVG580 ComBond system for universities and R&D institutes comes with one cassette station or manual load port as well as a single-arm robot, supporting up to three process modules.

The EVG580 ComBond HVM system can be configured with two cassette stations or an equipment front-end module with up to four cassettes



Top view of an EVG580 ComBond automated high-vacuum wafer bonding system.

for continuous mode operation, as well as comes with a dual-arm robot to support up to six process modules for maximum throughput.

Both new ComBond system configurations, as well as the standard system that can accommodate up to five process modules, are built on a modular platform supporting wafers up to 200mm in diameter. In addition to one or more bond chambers, the systems feature a dedicated ComBond Activation Module (CAM), which provides advanced surface preparation by directing energized particles to the substrate surface to achieve a contamination-free and oxide-free

bond interface. The systems operate in a high-vacuum-process environment with base pressures in the range of 5×10^{-8} mbar, which prevents re-oxidation of the treated wafers prior to the bonding step.

"The EVG580 ComBond system with its standard five-module configuration, which was launched last autumn, has already demonstrated its capabilities with multiple R&D partners and customers," says EVG's corporate product management director Dr Thomas Glin-

sner. "With the new three-module system, we will now make this breakthrough technology available to universities and smaller R&D institutes, which often are at the forefront of pioneering advanced electronic materials and device research, such as heterogeneous integration of compound semiconductors for silicon photonics and other leading-edge applications," he adds. "All ComBond systems can be further customized to address specific application development needs, such as with special metrology modules utilizing free ports of the high-vacuum handling."

www.EVGroup.com

Evatec expands Asian sales and service network

Following the acquisition in December of the semiconductor & nanotechnology business of Oerlikon's Advanced Technologies Segment, Evatec Ltd of Flums, Switzerland (which makes thin-film deposition and etch processing equipment for semiconductor, MEMS, optical and optoelectronic applications) has completed the next step of its growth plans for Asia by signing an agency agreement with Zurich-

based global services supplier DKSH for sales and service support of its range of thin-film production platforms regarding customers in China and Taiwan.

"DKSH is already recognised as number-1 in the delivery of high-quality market expansion services [with a focus on Asia], and the agreement brings us access to its market know-how and experienced sales and service professionals,"

comments Evatec's CEO Andreas Waelti. "They are the perfect partner for supporting the growth of our business in next-generation UBM [under-bump metal] solutions with unparalleled throughput and plasma-damage-free gallium nitride (GaN) sputter processing solutions for our customers in advanced packaging, power semiconductors and LED," he adds.

www.evatecnet.com

Nitride Solutions secures \$3m in new funding from Asia-focused investors

Nitride Solutions Inc of Wichita, KS, USA, which manufactures bulk and template nitride substrates for LEDs, lasers and power electronics, has secured \$3m in new funding as Hansol Chemical, Greenpoint Global Mittelstand Fund and Silicon Pastures Angel Investment Network have joined its existing investors (which includes angel investors from Kansas, Nebraska, Oklahoma, Washington DC, California and Alaska). Funds will be used to expand production of the firm's aluminum nitride (AlN) substrates, as well as to accelerate market introduction of its thermal management coatings.

"With Hansol we are gaining an important partner in Korea and

Japan to exclusively represent our products and share critical customer feedback," says CEO Jeremy Jones. "Greenpoint brings deep knowledge of companies in Asia that are seeking US manufacturing capability," he adds.

"Nitride Solutions' technologies for UV LEDs is truly next-generation and are very excited about this investment and partnership," Cho said. "A partnership of this nature will help us accelerate toward technical leadership in electronic chemicals," believes Yeunjo Cho, VP of strategic planning for Hansol Chemical (part of Hansol Group), a leading manufacturer of specialty chemicals in Korea. "In return, Nitride Solutions will gain partner-

ship in the high-demand markets of Asia and will be able to maximize the growth of the company."

"They [Nitride Solutions] bring solutions to some of the most difficult global issues," comments Teresa Esser, managing director of the Greenpoint Global Mittelstand Fund and Silicon Pastures Angel Investment Network. The Greenpoint Global Mittelstand Fund is a private equity fund addressing the challenge of exits. Its strategy is focused on investing in American companies geared for Asian exits, and it maintains relationships with firms in Asia that specifically seek American manufacturing and technology companies.

www.nitridesolutions.com

Teresa Esser and Andy Hannah join Nitride Solutions' board

Nitride Solutions says that Teresa Esser and Andy Hannah have joined its board of directors.

"Teresa brings great knowledge of corporate governance, finance and Asian business, and Andy has an extensive background in starting, growing, and exiting successful businesses," comments Nitride Solutions' CEO Jeremy Jones.

"Andy's experience in the electronic materials space will be of immense benefit to us as we scale the business and accelerate growth," he adds.

Esser is managing director of both the Greenpoint Global Mittelstand Fund and Silicon Pastures Angel Investment Network. During her career as an angel investor and venture capitalist, Esser has led investments in BioSystem Development LLC (now part of Agilent), Genii Inc (where she is on the board), HarQen Inc, Intuitive BioSciences Inc, and Hardcore Computer (now LiquidCool Solutions Inc).

During the past 12 years, Esser has led or participated in 16 other early-stage investments. Beginning in 1999, she researched and

wrote a book 'The Venture Café: Secrets, Strategies, and Stories from America's High-Tech Entrepreneurs' (published by Warner Business Books in 2002) about how MIT students commercialize their ideas and how venture capitalists decide in whom to invest. The ideas in the book and the brand surrounding the book were turned into a real-world Venture Café in Boston's Kendall Square, where weekly evening networking events draw more than 200 entrepreneurs, corporate lawyers, VCs and angel investors.

Hannah has had C-level executive roles at four high-tech start-ups, touching a range of industries such as information, software, consulting and materials science. In 2014, he co-founded OHot, a predictive and prescriptive analytics company that helps customers to predict, understand and change the future through a proprietary process that leverages data mining and analytics tools.

Prior to OHot, Hannah was co-founder & CEO of materials science company Plextronics, which

focuses on OLED flat-panel displays and lithium-ion batteries. Plextronics raised angel, venture and strategic capital and was sold in March 2014 to Belgian chemistry company Solvay.

Hannah has worked with venture firms such as Trident Capital, Advent International, Safeguard Scientific, Draper Triangle and Birchmere, as well as with leading leverage buyout companies including Vestar and corporate VCs such as Samsung and Applied Materials.

Hannah is a board member and advisor to organizations such as the Katz Graduate School of Business, Liquid X Printed Metals, Etcetera Edutainment, and Niche.com. He has also served as a board member of the Organic Electronics Association (vice chair), the Pennsylvania Nanomaterials Commercialization Center, Leadership Pittsburgh, Leadership Development Initiative (co-founder), and the Executive Steering Committee of Pittsburgh's Tech-based Economic Development Strategy.

www.nitridesolutions.com

Seren introduces LED-grade semi-polar GaN-on-sapphire templates

2" sampling now, then 4" in Q3/2015 and 6" in first-half 2016

Seren Photonics Ltd of Pencoed Technology Park, UK (which was spun off from the University of Sheffield in February 2010) has launched its next generation of semi-polar gallium nitride (GaN) on sapphire templates. This latest generation of 11-22 GaN templates continues to be based on Seren's patented approach developed by professor Tao Wang's team at the University of Sheffield.

The improved performance comes about through a manufacturing upgrade that not only improves crystal quality, but also enhances manufacturing yield. This approach has already completed qualification for a 2"-diameter product and, as part of its development activity, Seren has now adapted the enhanced approach to the development of 4" and 6" templates.

"With demand for 4" and 6" accounting for over 75% of the sapphire market for LEDs, the need to provide customers with industry-standard 4" diameter wafers along with the option to upgrade to 6"



makes total commercial sense," says chief development officer Bedwyr Humphreys. The 4" templates for customer sampling are expected during third-quar-

At less than 5mm thick, the GaN layer for these semi-polar templates is the thinnest available on the market, the firm claims, ensuring minimal wafer bow with maximum defect blocking

ter 2015, with 6" planned to come online during first-half 2016.

Semi-polar GaN displays anisotropic behaviour under x-ray diffraction. So, unlike c-plane GaN, the crystal quality is dependent on the direction along the wafer that the measurement is taken. This latest development has overcome this issue, says Seren, yielding a semi-polar GaN

layer with isotropic crystal quality. This not only enhances the optical isotropy of the material but also ensures that electrical properties such as mobility are also isotropic.

The latest generation of Seren's of semi-polar GaN-on-sapphire templates is now available for sampling in 2" diameter or custom sizes. At less than 5µm thick, the GaN layer for these semi-polar templates is the thinnest available on the market, the firm claims, ensuring minimal wafer bow with maximum defect blocking.

www.serenphotonics.co.uk

Rubicon showcases large-diameter 4- and 6-inch patterned sapphire substrates for LED market

At the LED Taiwan 2015 exhibition in Taipei (25-28 March), Rubicon Technology Inc of Bensenville, IL, USA (which makes monocrystalline sapphire substrates and products for the LED, semiconductor and optical industries) showcased large-diameter patterned sapphire substrates (PSS) as well as its line of 4" and 6" polished sapphire wafers for the LED industry.

Rubicon offers highly customizable sub-micron 4" and 6" PSS with tight dimensional tolerances (within ±0.1µm). With an edge exclusion zone as small as 1mm, the firm offers LED chip makers

more usable area to maximize the number of chips per wafer. Patterning is available in a range of shapes, including cone, dome and pyramid, and in a range of orientations.

"Patterning has greatly increased light extraction efficiency for LED manufacturers," notes CEO Bill Weissman. "As these companies continue to seek greater manufacturing efficiency, they are increasingly turning to larger wafers," he adds. "Rubicon is uniquely positioned to help LED manufacturers transition to larger-diameter PSS, and we have end-to-end control of

all aspects of sapphire production, from raw material and crystal growth through polishing and patterning, to maintain exceptional quality and reliability."

At LED Taiwan, Rubicon has a number of sapphire products for the LED market on display, including sapphire cores, large-diameter wafers ranging in size from 4-inches to 6- and 8-inches, and information about large-diameter patterned sapphire substrates.

www.ledtaiwan.org/en
www.rubicontechnology.com/pages#!/products/patterned-sapphire-substrates

SFCE to acquire 51% stake in Lattice Power

Hong Kong-based Shunfeng International Clean Energy Ltd (SFCE) has signed a memorandum of understanding (MOU) to acquire a 51% ownership stake in Lattice Power Corp of Nanchang, China, which claims to have been the first company to realise mass production of gallium nitride (GaN)-on-silicon LEDs.

After changing its name from Shunfeng Photovoltaic International Ltd last November, solar power firm SFCE says that its bid for Lattice Power is a milestone as it transitions to becoming a global low-carbon solutions provider. The firm aims to provide clean energy solutions to large-scale public facilities and commercial users (such as business facilities, office buildings, schools, hospitals sports stadiums and households). Lattice Power's GaN-on-Si technology is exclusively patented worldwide, offering cost advantages compared with LEDs based on sapphire substrates. The partnership expands SFCE's portfolio

and is expected to increase profitability of the listed company.

With LED lighting products serving the general lighting, smart phones and automotive industries, Lattice Power sold more than 100 million LED bulbs in 2014. The firm currently holds more than 200 patents worldwide, and SFCE's global low-carbon solutions are expected to bring a new profit growth opportunity to the company.

"Lattice Power's breakthrough technology represents the next generation of affordable lighting products," comments SFCE's executive chairman Zhang Yi. "The merger creates new opportunities for SFCE in the lighting market," he adds.

"We see tremendous opportunity for the GaN-on-silicon technology, which offers the ideal choice for next-generation silicon chips," says Sonny Wu, executive chairman of Lattice Power and managing director of shareholder GSR Ventures (a venture capital fund that invests in

early- and growth-stage technology firms with substantial operations in China). "Efficient, energy-saving, low-cost LED lighting products are leading the development of the lighting market," he adds. "Global energy consumption stems largely from urban and household lighting needs. As the global population grows and the economy develops, energy-efficient solutions - including energy-saving lighting solutions - will face a huge demand. Many developed countries have legislation prohibiting the use of traditional lighting, thus the investment community is increasingly concerned about new lighting technologies and products," Wu continues. "In collaboration with SFCE, we are excited to integrate Lattice Power's technology and products into emerging lighting markets... We look forward to a long-term partnership."

www.latticepower.com

<http://sfcegroup.com/en>

www.gsrventures.com

ALLOS licences GaN-on-Si epi technology to Epistar

First phases of technology transfer concluded

Engineering and consulting firm ALLOS Semiconductors GmbH of Dresden, Germany says that its unique gallium nitride on silicon (GaN-on-Si) technology has been licensed by Taiwan's Epistar Corp (the world's largest manufacturer of LED epiwafers and chips). The initial phases of the technology transfer project have already been concluded.

The technology transfer project has established ALLOS' 150mm and 200mm GaN-on-Si epiwafer process with what are reckoned to be excellent homogeneities on Epistar's epitaxial reactors. With full control gained over the GaN-on-Si technology during the project, Epistar is now able to integrate it with its own LED technology. Through the know-how transfer and GaN-on-Si technology training of its engineers,

Epistar can then pursue further developments independently. The use of GaN-on-Si opens up the opportunity to use silicon foundries for processing the epiwafers.

Epistar has prior experience with the technology, based on templates supplied in the past by AZZURRO Semiconductors AG. Late last year, ALLOS acquired the technology, know-how and intellectual property of the former AZZURRO, which is now being made available along with the existing consulting and customized development services of ALLOS.

"Gaining full capability via a technology transfer in a very short period is a time- and cost-effective way to move ahead," says Epistar's president Dr M. J. Jou. "GaN-on-Si remains interesting for Epistar as there are advantages in a number

of applications and the cost benefits of larger wafer sizes," he adds.

"Our combined licensing and technology transfer packages allow customers in both the LED and power semiconductor industries to kick-start their own GaN-on-Si programs successfully," says ALLOS' chief technology officer & co-founder Dr Atsushi Nishikawa. "This lets them achieve state-of-the-art results in months instead of trying to catch-up with the pioneers who are years and multi-million dollars of development spending ahead," he adds. Nishikawa sees that the opportunity for customers is to reduce not only cost and time-to-market but also the development and IP risk by building their effort on ALLOS' proven GaN-on-Si platform and know-how.

www.allos-semiconductors.com

www.epistar.com.tw

RayVio closes \$9.3m Series B funding round as it emerges from stealth mode

Funding to accelerate market strategy and grow team, targeting mass adoption of UV LED disinfection

RayVio Corp of Haywood, CA, USA, which provides UV LED-based solutions, has emerged from stealth mode and raised \$9.3m in Series B funding, with existing investors DCM Ventures and Capricorn Investment Group being joined by new investors including Applied Ventures, Augment Ventures, New Ground Ventures and Tolero Ventures. RayVio says that the new capital will be used to accelerate its go-to-market strategy, grow its team, and enable mass adoption of UV LED solutions in the industrial, commercial and consumer sectors (e.g. for industrial curing, for UV medical treatment devices to treat ailments ranging from vitamin D deficiency to multiple sclerosis, and for the UV water, surface and air disinfection).

"This oversubscribed round is a great validation of our breakthrough technology and it will enable us to significantly expand our team and reach critical markets globally," says CEO Dr Robert C. Walker.

RayVio's solutions employ what is reckoned to be a fundamentally new approach enabling the highest-performance, lowest-cost UV LED-based systems (claimed to provide up to 10 times the performance increase over existing

products on the market). The technology targets consumer applications previously limited by cost and performance — ranging from hand-held portable disinfection devices to point-of-use water disinfection faucets that enable safer drinking water.

"UV LED light sources will significantly affect the use of UV disinfection technology by enabling a myriad of affordable, point-of-use disinfection applications, thus improving public health better than before,"

The firm reckons that its patent-protected materials and technology, originally developed at Boston University by co-founders Dr Yitao Liao and professor Theodore Moustakas, unleash 'Haitz's Law' for UV LEDs; the same Haitz's Law that made the mass adoption of cost-effective visible LEDs possible in the display and lighting markets

comments Dr Andreas Kolch, managing director & partner at Hytecon GmbH and former president of the International Ultraviolet Association (IUVA).

"RayVio's technology is coming to market at a critical time," reckons DCM Ventures' general partner Pete Moran. "Access to clean water and the growing prevalence of infectious disease are creating a greater need for solutions that are portable, cost effective and address these problems," he adds. "RayVio has hit the sweet spot of this formula with products that are now proven, and with the partners and customers that can scale globally."

Until now, LEDs for UV applications have been limited to niche markets due to low performance, high cost and compromised reliability, says RayVio. The firm reckons that its patent-protected materials and technology, originally developed at Boston University by co-founders Dr Yitao Liao and professor Theodore Moustakas, unleash 'Haitz's Law' for UV LEDs; the same Haitz's Law that made the mass adoption of cost-effective visible LEDs possible in the display and lighting markets.

www.rayvio.com

Phoseon doubles UV LED output of 365nm air-cooled light sources, enabling adhesive and coating applications

Phoseon Technology of Hillsboro, OR, USA has expanded its FireJet FJ200 air-cooled product family with 8W/cm² peak irradiance at 365nm wavelength.

UV LED light sources at 365nm are suitable for adhesive and coating applications where high peak

365nm irradiance and fast curing of heat-sensitive substrates is

vitaly important. Also, the scalability of the FJ200 allows units to be stacked 'end to end' with contiguous, uniform UV output. FJ200 systems are designed to be versatile and are suitable for high-performance curing applications.

"With these high-power, air-cooled light sources, Phoseon continues to meet its customers' requirements

of higher-power 365nm light sources for curing specific adhesives and coatings," says John North, VP of worldwide sales.

"These high-power light sources address the market's need by providing customers increased productivity where 365nm wavelength is required."

www.phoseon.com

Excelitas unveils UV LED curing system for inkjet printing, edge bonding and small component assembly

Excelitas Technologies Corp of Waltham, MA, USA, which provides customized optoelectronics to OEMs, has launched the OmniCure AC2 Series UV LED curing system.

The compact addition to the AC Series of UV LED curing solutions supplies high irradiance from an LED system small enough to be included in applications where space constraints restrict access to the substrate and quality cannot be compromised. The small-form-factor, air-cooled product provides high curing uniformity and allows for the adjoining of multiple systems to address any length application or working distance. The systems suit applications such as pinning, edge bonding, cable assembly and other small component assembly.

"This newest addition to the OmniCure AC Series represents our commitment to continuously be at



the forefront of innovation and deliver UV curing solutions that provide highest performance with ease of use," says Oliver Scheuss, VP, Solid State Lighting and UV/Microscopy for Excelitas. "The OmniCure AC2 Series achieves just that by providing a small-form-factor option while retaining excellent output performance and flexibility for a wide range of applications in the curing of inks, adhesive, and coatings," he adds.

The AC275 and AC2110 are high-end, compact UV LED systems for users who are either looking to increase throughput by automating their manufacturing process or switching to UV LEDs for their particular applications.

Available in 75mm and 110mm lengths, the AC2 Series features custom optics that reduce the output angle of light while providing higher irradiance and greater flexibility at various working distances. Also, the air-cooled product design allows integration into new or existing production lines, increasing throughput with minimal process interruption and ultimately decreasing costs, says the firm.

The OmniCure product family of UV curing solutions was showcased at the uv.eb WEST 2015 exhibition in Redondo Beach, CA, USA (10–11 March).

www.excelitas.com/

Sensorex launches UV transmittance monitor for water testing using Crystal IS' UVC LEDs

Sensorex (which manufactures sensors for water applications) has introduced the first family of ultra-violet transmittance (UVT) monitors using UVC LEDs instead of mercury-based lamps as a light source. The LEDs are supplied by Crystal IS Inc of Green Island, NY, USA, an Asahi Kasei company that makes proprietary ultraviolet light-emitting diodes (UVC LEDs) grown pseudomorphically (strained) on aluminum nitride (AlN) substrates.

Crystal IS says that UVC LEDs offer light stability, instantaneous response and design freedom over mercury-based lamps. In particular, for environmental monitoring, UVC LEDs offer:

- ease of use across multiple water treatment environments due to the smaller footprint (directly in a pipe, in an open channel, or used offline

as a battery-operated handheld instrument);

- high spectral quality for measurement linearity over a wide range; and

- long lifetime and simple drive electronics that enable maintenance-free, continuous remote operation.

After Sensorex evaluated Crystal IS' UVC LEDs as a light source replacement to mercury-based lamps, testing confirmed that brighter, longer-lifetime UVC LEDs were a significant contribution to a UVT monitoring instrument that: is able to achieve full intensity instantly; optimizes UV disinfection dosage guaranteeing that systems are not under- or over-dosing water; and reveals cost savings greater than the one-time cost of purchasing the UVT monitor.

Crystal IS says that its UVC LEDs allow manufacturers to fully exploit the power of UV-based technology to improve productivity, increase accuracy and create greater flexibility in product designs. Made possible by the unique, low-defect AlN substrate, the firm's UVC LED technology delivers what is claimed to be superior light output, better spectral quality and best-in-class reliability and lifetimes for environmental monitoring, life sciences and analytical instrumentation.

The small footprint, long lifetime and low power consumption of Crystal IS' deep UV LED makes for "a versatile [UVT-LED] product with extremely stable readings in all conditions, over an extended lifetime," according to Sensorex's new business manager Dan Shaver.

www.crystal-is.com

SemiLEDs launches series phosphor-converted amber, red and green LED chips using ReadyWhite technology

LED chip and component maker SemiLEDs Corp of Hsinchu, Taiwan has announced sampling and volume availability of its phosphor-converted (PC) LED chip series.

The series launches with PC Amber, PC Green and PC Red LED chips in a 40mil (1mm x 1mm) chip size. The PC LEDs utilize SemiLEDs' proprietary ReadyWhite phosphor technology to minimize blue pass through, achieving higher luminous flux, efficiency, and lumen maintenance over time and temperature compared to monochromatic LED chips.

SemiLEDs says that PC Amber and PC Red on indium gallium nitride (InGaN)-based materials provide better forward voltage matching in RGBA applications, gaining efficiency and achieving higher lumen per watts. Greater color stability is also achieved by the use of PC Amber and PC Red with respect to input currents and changes in junction temperatures, the firm adds.

With increased efficiencies, PC Green LED offers a broader spectrum and provides a rich color for green applications, SemiLEDs says. The greater color range can provide advantages

in applications such as traffic lights, projection and entertainment lighting.

"With our well established InGaN and ReadyWhite Technology, SemiLEDs' color portfolio is no longer limited to blue, white and UV regions," says Mark Tuttle, general manager for SemiLEDs Optoelectronics Co Ltd. "The new PC amber, PC red, and PC green LED chips will allow more options for our customers in these color ranges," he adds.

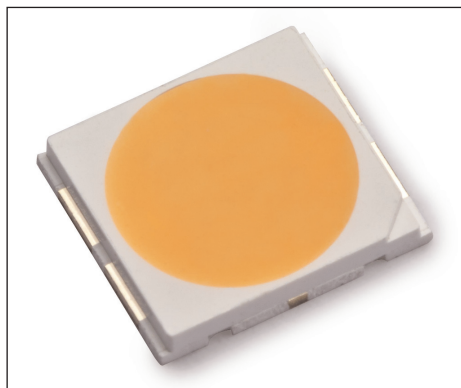
SemiLEDs' PC series of LED chips is RoHS compliant, with production quantities available to order now.

www.semileds.com

Lumileds launches LED for single-source beam control in directional lamps

Philips Lumileds of San Jose, CA, USA has launched the LUXEON 5258 LED, which offers directional lamp makers what is said to be a more affordable LED option for single-source beam control. The multi-die emitter enables the most cost-effective design of PAR 16, PAR 20, MR16 and GU10 lamps using existing drivers at 24V and 96V, claims the firm.

"We are providing a high-flux, high-efficacy LED that improves the quality of light and avoids the unfortunate 'showerhead effect' that users experience with distributed, multi-die solutions," says product manager Ahmed Eweida. "The LUXEON 5258 can achieve



LUXEON 5258 multi-die emitter.

lower system costs compared to solutions using multiple LEDs for 35W and 50W MR16 today," he adds.

Designed to provide the best effi-

cacy and flux metrics with superior reliability and droop curve than competing solutions on the market, Lumileds' initial offering of the LEDs in the 5258 plastic package is in warm-white correlated color temperatures (CCTs) with a minimum color rendering index (CRI) of 80. The 24V solutions provide a luminous flux of 425 lumens at an efficacy of 110lm/W, while the 96V solutions provide 400 lumens at 105lm/W. However, both can be driven to deliver up to 650 lumens. A 5mm-diameter optical source enables precise beam control in directional applications.

www.philipslumileds.com/uploads/news/id239/PR219.pdf

Illumineer of the Year for LUXEON CoB LED with CrispWhite

At the Strategies in Light event in Las Vegas in late February, the Illumineer of the Year title of LEDs Magazine's Sapphire Awards went to the team of Eric Senders, Bob Zona, Rene Helbing, Mushfeque Manzur and Catherine Othick of Philips Lumileds for their work on LUXEON CoB (chip-on-board) LED

with CrispWhite Technology.

"CrispWhite is a great example of how LED technology will take the lighting industry to new heights, delivering a feature set in SSL products that the industry could never achieve with incandescent, halogen, or ceramic-metal-halide (CMH) sources," commented Maury

Wright, editor-in-chief, LEDs Magazine and Illumination in Focus.

Lumileds recently also won the LFI Innovation Award, introduced the first hot-color-targeted LEDs, and announced the first chip-scale-packaged LED that can be directly surface-mount reflowed onto a luminaire board.

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FerroTec

Soraa appoints senior VP of product development

Soraa Inc of Fremont, CA, USA, which develops solid-state lighting technology built on 'GaN on GaN' (gallium nitride on gallium nitride) substrates, has appointed Ann Reo as senior VP of product development.

Reo has more than 20 years of LED product development and lighting design experience. "Over the last year, our product offering has expanded far beyond the MR16 LED lamp that put us on the map," says CEO Jeff Parker. "Ann's background in lighting design and expertise in building LED products from the ground up gives Soraa an edge in pioneering solutions that designers and customers want — and the market needs," Parker believes.

Soraa reckons that Reo's success

in category creation and innovation in the lighting industry gives her the ability to meet the needs of today's architecture with an eye toward human-centric needs. Her background as a trained architect and lighting designer allows her to develop and conceptualize products with specific applications in mind, the firm adds. This focus on end-user needs blends with Soraa's positioning in some of the most demanding architectural environments, including museums, retail, hospitality and health care.

After completing her Bachelor of Science in Architectural Studies and Masters of Architecture at the University of Illinois at Urbana-Champaign, the first decade of Reo's career was split between architectural firms,

lighting companies and design consultancies. Then in 2001 she developed a business plan, raised venture capital investment and launched LED-based luminaire firm io Lighting. As president & CEO, she grew the firm until Eaton's Cooper Lighting acquired it in 2007. Under Reo's leadership, io's products won several design awards, including the Best New Product of the Year at LIGHTFAIR International 2004. At Cooper, Reo stayed on board as VP of Global SSL Solutions and general manager of io Lighting.

Reo will lead Soraa's new product development efforts in light engine design for OEM integration as well as custom solutions for specifiers, OEMS and end-users.

www.soraa.com

Soraa launches PAR20 LED lamp

Soraa has added to its full-visible-spectrum LED product portfolio by launching a PAR20 lamp with high CBCP (center-beam candle power), flawless beam definition and edges, and outstanding color and whiteness rendering, it is claimed. Suitable for both commercial and residential applications, the PAR20 features the firm's Point Source Optics and Violet-Emission 3-Phosphor (VP₃) Color and VP₃ White technologies, providing a replacement for 75W to 90W legacy products.

"The PAR20 provides unmatched color quality with our VP3 technology and superior optics with our Point Source Optics technology, while still delivering 85% energy-efficiency over standard halogen lamps," claims George Stringer, senior VP of America sales & marketing.

The Point Source Optics technology enables the firm to offer the only 10° narrow-spot version of a PAR20 LED lamp while delivering a CBCP almost double that of its nearest competitor, it is claimed. The optics produce high intensity



Soraa's PAR20 LED lamps.

and uniform beams and are available in four beam angles including 10°, 25°, 36° and 60°. With a color-rendering index (CRI) of 95 and deep red (R9) rendering of 95, the 10.8W PAR20 outperforms not only halogen counterparts but also its LED competitors too, the firm reckons.

The firm's Violet-Emission 3-Phosphor (VP₃) LED technology allows for rendering of colors and whiteness. Utilizing every color, especially deep red emission, VP₃ Vivid Color renders warm tones accurately. Also, unlike blue-based white LEDs without any violet/ultraviolet emission, the VP₃ Natural White is achieved by engineering the violet emission to properly excite fluorescing bright-

ening agents including natural objects like human eyes and teeth, as well as manufactured white materials such as clothing, paper and cosmetics.

The PAR20 LED lamps are offered in 75W (Vivid) and 90W (Brilliant) equivalents, and a 50W replacement option will also soon be available. The lamps are available in four color temperatures ranging from very warm white to cool (2700K, 3000K, 4000K and 5000K). Soraa claims to be the only lamp manufacturer that guarantees lamp-to-lamp color consistency to be within a 3-Step MacAdam ellipse for its PAR20 products.

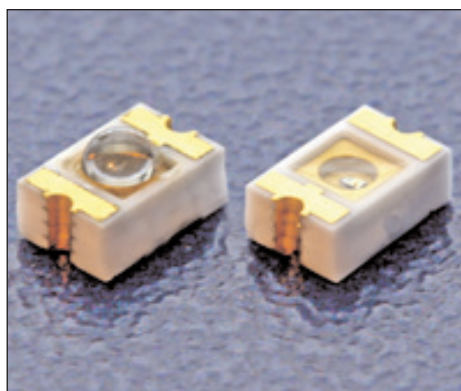
The PAR20 Series is compatible with enclosed fixtures and suitable for damp operating environments. Additionally, all of Soraa's PAR20 10° LED lamps are designed to work with the firm's magnetic accessory SNAP system. With a simple magnetic accessory attachment, beam shapes can be altered and color temperature can be modified, allowing flexibility in design and display.

Marktech adds miniature ceramic package to point-source LED range

Marktech Optoelectronics of Latham, NY, USA, whose capabilities span wafer growth through finished packaging and custom solutions, has added a PLCC-4 and miniature ceramic package to its 650nm and 850nm point-source LED series.

Point-source LEDs are designed to deliver precise and consistent performance in the most demanding applications such as high-speed optical encoders, linear positioning, optical switch and critical sensing applications. As miniaturization continues to be the focus of new product designs, small high-reliability LED packaging will be needed to match performance, says the firm.

Marktech's point-source LEDs are powered by what is claimed to be a unique LED die that produces a well-defined pattern of light similar to a point. These chips — in combination with high-quality optical-grade glass lenses —



Marktech's ceramic-packaged point-source LEDs.

produce an extremely narrow, near-parallel radiation pattern. This unobstructed, radiated beam pattern is made possible by masking the die and relocating the topside electrode. By eliminating the 'dark spot' typically associated with the center of conventional LEDs, the point-source LED yields superior results in critical sensing applications, it is claimed.

Through-hole package options for the series include high-reliability hermetically sealed TO-18 and TO-46 metal cans with a variety of lensing options that produce an array of viewing angles. Devices supplied without optics are manufactured with a flat glass window, allowing the designer to use proprietary collimating or other application-specific optics to take full advantage of the undistorted beam. "The point-source LED is a suitable alternative to laser diodes in short-distance applications offering increased temperature-range capabilities and reduced risk of discharge due to ESD," says Marktech's chief technology officer Vincent C Forte.

Custom packaging designs, which include chip-on-board (CoB) configurations or custom apertures, are also available.

www.marktechopto.com/products.cfm?p=Point-Source-Emitter

Light Source of Year for Soraa's LED optical light engine; AR111 and MR16 LED lamps highly commended

Soraa Inc of Fremont, CA, USA, which develops solid-state lighting technology built on 'GaN on GaN' (gallium nitride on gallium nitride) substrates, says that its LED Optical Light Engine was named Light Source of the Year at the Lighting Design Awards 2015. Also, in the same category, both the AR111 LED with SNAP System and Constant Current MR16 LED lamps were 'Highly Commended'.

Hosted at the London Hilton hotel on Park Lane, the Lighting Design Awards this year gathered more than 700 designers, architects and suppliers. The panel of judges included 28 professionals from all points of the specification and supply chain, including engineers, designers, specifiers, sales professionals and journalists.



Soraa's Light Source of the Year award.

Soraa's small, low-profile series of light engines feature an optical design that provides what is

claimed to be flawless beam definition and smooth beam edges, as well as being customizable via the SNAP System. Designed for seamless fixture integration, the Optical Light Engines are compatible with a wide variety of industry-standard LED drivers and suit use in enclosed, non-ventilated indoor and outdoor fixtures.

The Optical Light Engines are available in three sizes 11, 16, 30 (diameters of 1.5" or 37mm, 2" or 50mm, and 4" or 100mm); lumen outputs of 500 or 1000lm (in 95CRI); beam angles of 9 and 10°, 25° and 36°; color temperatures of 2700K, 3000K, 4000K, and 5000K; and with an optional heat sink.

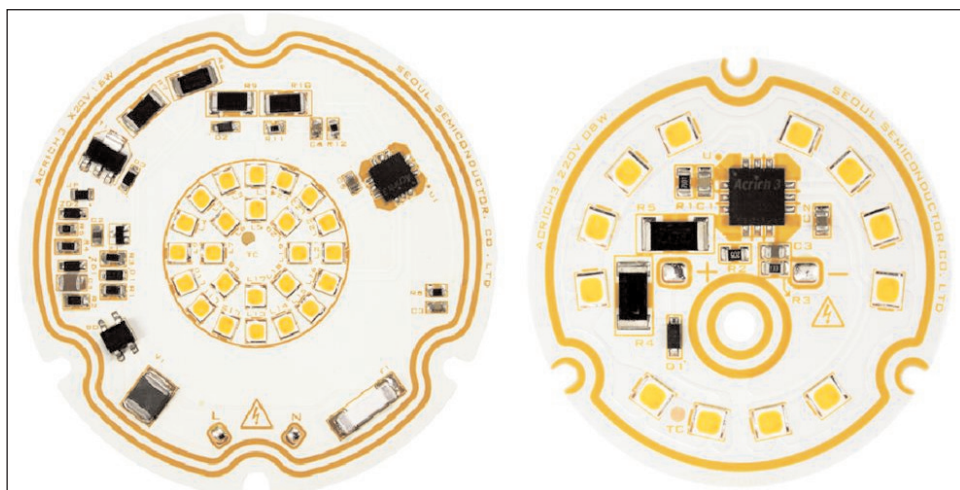
<http://awards.lighting.co.uk/the-winners-2015>
www.soraa.com

Seoul Semiconductor launches Acrich3 LED modules, enhancing compatibility with existing TRIAC dimmers

South Korean LED maker Seoul Semiconductor has announced the availability of Acrich3 modules for a wide range of residential and commercial lighting applications.

The firm says that Acrich3 enables the next generation of smart-lighting systems with the ability to interface through a wide variety of wireless networks and sensors. The technology does not require a complex AC/DC converter and can be operated directly from the AC mains, which simplifies designs, reduces component count and improves the reliability of the luminaire. It also incorporates an analog dimming input and increased compatibility with existing TRIAC dimmers with the ability to do uniform dimming, giving lighting designers an easy-to-implement advanced lighting solution, says the firm.

The Acrich3 modules incorporate Seoul Semiconductor's proven high-voltage LED architecture with the Acrich MJT series of LEDs. The modules are available in



Acrich 3 modules for (left) 16W downlight and (right) 8W bulb.

different lumen outputs and form factors to address a wide range of lighting applications from downlights to street and area lighting. Available in color temperatures of 2700–6500K with color rendering index (CRI) options of 70, 80 and 90, the modules offer typical efficiencies of up to 100lm/W with low total harmonic distortion (THD) and high power factor.

"The new Acrich3 modules from

Seoul Semiconductor offer a complete solution for smart lighting systems with the Acrich3 IC and MJT LEDs," says Kibum Nam, VP of product development. "First launched in 2005, the Acrich technology has provided innovative solutions worldwide to a wide range of applications in the commercial, residential and industrial lighting environments," he adds.

www.seoulsemicon.com

Outdoor LED luminaire for rural utility lighting from Cree

LED chip, lamp and lighting maker Cree Inc of Durham, NC, USA has introduced the LED Rural Utility Light (RUL) Series, designed to deliver a combination of price, performance and quality to accelerate adoption of LED lighting across rural areas in North America.

The first of Cree's outdoor LED luminaires to address the estimated 10–13 million rural street and area light fixtures installed, the RUL Series targets better, more affordable lighting for residential roadways, security, storage and loading areas with high efficacy, rapid payback of less than one year (based on usage of 12 hours per-day and the national average of \$0.11 per kWh electric costs, and compared with 175 watt mercury



vapor luminaire) and Cree's 10-year warranty.

Featuring elements of Cree's SC5 Technology Platform, the LED Rural Utility Light is said to outperform incumbent high-pressure sodium (HPS) and mercury vapor (MV) technology, as well as competing LED products, to provide

unrivalled 110 lumens-per-watt efficacy and system-level performance for expedient payback and reduced cost of ownership for municipalities and utilities. Featuring a lightweight design, tool-less entry and straight-in wiring, the 4000K-color-temperature

LED Rural Utility Light enables seamless installation in addition to long-term maintenance savings over the 100,000 hour rated life-time, says Cree.

The RUL Series is sold through Cree lighting sales channels throughout the USA and Canada.

www.cree.com/lighting/RULseries



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Lawrence Livermore commissions highest peak-power laser diode arrays

Megawatt-class pump modules supplied by Lasertel

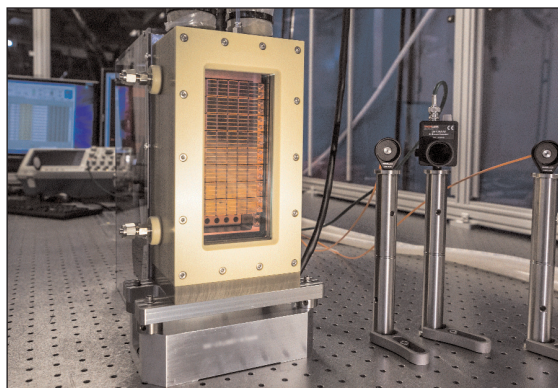
Lawrence Livermore National Laboratory (LLNL) has installed and commissioned what are said to be the world's the highest peak-power laser diode arrays.

With total peak power of 3.2MW, the diode arrays form a key component of the High-Repetition-Rate Advanced Petawatt Laser System (HAPLS, under construction at LLNL). When completed, the HAPLS laser system will be installed in the European Union's Extreme Light Infrastructure (ELI) Beamlines facility, under construction in the Czech Republic.

HAPLS is designed to be capable of generating peak powers greater than 1 petawatt (1 quadrillion watts, or 10^{15}) at a repetition rate of 10Hz, with each pulse lasting 30 femtoseconds (30 quadrillionths of a second). This very high repetition rate represents an advance over existing petawatt system technologies, which rely on flashlamps as the primary pump source and can fire a maximum of once per second. In HAPLS, the diode arrays fire 10 times per second, delivering kilojoule laser pulses to the final power amplifier. The HAPLS is being built and commissioned at LLNL and then installed and integrated into the ELI Beamlines facility starting in 2017.

"The Extreme Light Infrastructure in Europe is building international scientific user facilities equipped with cutting-edge laser technology to explore fundamental science and applications," says HAPLS program director Constantin Haefner. "Livermore is one of the world leaders in high-energy, high-average-power laser systems, and ELI Beamlines in Prague has partnered with us to build HAPLS, a new-generation petawatt laser system, enabling new avenues of scientific research."

To meet the rigorous design specification for HAPLS, LLNL had to look past existing laser pump technology.



The diode arrays represent total peak power of 3.2MW, making them the world's highest peak-power diode arrays. HAPLS will be the world's highest repetition rate petawatt laser system when completed.

Previously, high-energy scientific laser systems — such as LLNL's National Ignition Facility — used flashlamp technology, from which intense flashes of white light pump the laser-active atoms in large slabs of laser glass to a higher or more excited energy state. To reach the high repetition rate required by HAPLS, the team needed to devise technology that transfers less heat than flashlamps and removes it at faster rates, reducing the time between laser shots.

"Flashlamp technology for lasers has been around for more than 50 years, and we've pretty much pushed the limits of that technology and maxed out what we can do with them," says HAPLS systems architect Andy Bayramian. "We've closed the books on flashlamps and started a new one with these laser diode arrays, enabling a far more advanced class of high-energy laser systems," he adds.

To develop these diode arrays, LLNL partnered with high-powered semiconductor laser pump module developer Lasertel Inc of Tucson, AZ, USA (a member of the Finmeccanica Group). Lasertel combined semiconductor laser technology with novel micro-optics to supply the megawatt-class pump modules

in a reliable, integrated platform. "Our collaboration has enabled several new benchmarks for laser performance to be set in a remarkably short period of time," says the firm's president Mark McElhinney. "This is a validation of the significant progress that has been made toward the routine production of high-energy lasers for revolutionary commercial applications and groundbreaking scientific research."

In addition, to drive the diode arrays, LLNL needed to develop a completely new type of pulsed-power system that supplies the arrays with electrical power by drawing energy from the grid and converting it to extremely high-current, precisely shaped electrical pulses. Each power supply is capable of driving 40,000A. LLNL holds a patent on this technology.

It is expected that high-average-power, high-energy laser systems enabled by these technologies will drive international scientific research in areas as diverse as advanced imaging, particle acceleration, biophysics, chemistry and quantum physics in addition to national security applications and industrial processes such as laser peening and laser fusion.

"Combining Lasertel's diode technology with Livermore's highly compact and efficient pulsed-power system is the enabling technology to drive high-energy lasers at rep rate," says Haefner. "This combination of expertise has created a robust, stable, laser driver platform with high reliability, cost efficiency and — most important for the scientific user community — long-term scalability to maintain competitiveness in the future."

<https://lasers.llnl.gov>
www.eli-beams.eu
www.lasertel.com

QD Laser and NanoQuine unveil prototype of retina imaging laser eyewear for low-vision care

QD Laser Inc of Kanagawa Japan (which was founded in 2006 with funding from Fujitsu Ltd and Mitsui Ventures) and the Institute for Nano Quantum Information Electronics (NanoQuine) at the University of Tokyo have unveiled the prototype of their retina imaging laser eyewear for low-vision care. The team is starting its verification test as low-vision aids in collaboration with the department of ophthalmology in medical universities and with educational institutions in Japan. The plan is to commercialize the low-vision oriented retina imaging laser eyewear by March 2016.

The prototype was exhibited at the 30th Annual International Technology and Persons with Disabilities Conference in San Diego, CA, USA (4–6 March).

The laser eyewear has a miniature laser projector on the frame of the glasses, which provides the wearer with digital image information using the retina as a screen. Characteristics, which not achieved by other devices using liquid-crystal displays (LCDs) it is claimed, are as follows:

1. Wide viewing with a small device (owing to the projection principle).
2. High brightness, high color reproducibility and energy reduc-

tion (owing to semiconductor lasers as RGB light sources).

3. Image viewing at any position of the retina (due to the laser scanning system's wide horizontal viewing angle of 60°).

4. Focus-free viewing (Maxwell view optics) - meaning that picture clarity is independent of the individual's visual power (since the image is projected onto the retina after converging the light beam into the observer's pupil).

5. All optics to be installed inside the glasses (owing to the 'focus free' characteristics), so the glasses appear to be normal (enabling a natural fit and fashionable appearance).

The prototype for low-vision care is compact retina imaging laser eyewear with the following functions (all useful for low vision care):

- Imaging digital information of characters and pictures from digital devices such as personal computers.
- A camera module sited in the center of the frame of the glasses.
- Left, right and binocular vision provided by both-side optics.
- Adjustment of the laser light intensity.
- Multi-step fitting for each individual.

- Shading with a cover on the frame.

In collaboration with departments of ophthalmology in medical universities and with educational institutions in Japan, QD Laser and University of Tokyo are beginning verification testing of the equipment as low-vision aids for a variety of eye diseases. Based on test results that are expected to confirm the benefits and safety of the system (i.e. Class 1 laser power, safe under all conditions of normal use, based on JIS/IEC safety standards), the team plans to complete the mass-production prototype by September and to release the commercial product (complete with comfortable hardware, an attractive design and a flexible user interface) by March 2016.

By further miniaturizing, optimizing the shape of optics, reducing the energy consumption and developing wireless technologies, QD Laser plans to open up a new medical device market, with support tools in the work place and consumer-oriented wireless smart glasses, by the end of 2017.

www.qdlaser.com

www.nanoquine.iis.u-tokyo.ac.jp/index-e.html

www.csun.edu/cod/conference/

OSI Laser Diode launches high-power 1625nm pulsed laser diode module for optical testing

OSI Laser Diode Inc (LDI) of Edison, NJ, USA (an OSI Systems Company) has launched the SCW 1632-350R high-power pulsed laser diode module for optical testing applications.

Housed in a 14-pin butterfly package, the ridge waveguide (RWG) Fabry-Perot (FP) laser diode is optically coupled to a single-mode fiber (SMF) pigtail and includes a thermoelectric cooler (TEC) and an electrically isolated temperature-sensing thermistor.

Operating at 1625nm with optical power of 350mW (typically), the SCW 1632-350R joins a family of high-power pulsed laser diode modules including the SCW 1532-500R (which operates at 1550nm with more than 500mW optical power). Both modules are RoHS compliant and feature industry-standard pin-out packaging, offering excellent pulse drift performance and high stability.

Suitable for applications where high peak pulsed optical power is

required, the new SCW 1632-350R pulsed laser diode module is specifically designed for use in optical spectrum analyzers (OSAs) and optical time-domain reflectometers (OTDRs). The higher power gives OTDR manufacturers greater dynamic range capability.

The SCW 1632-350R was showcased at the Optical Fiber Communications conference & exposition (OFC 2015) in Los Angeles (24–26 March).

www.laserdiode.com

VCSEL-based automotive LiDAR firm TriLumina closes \$8.5m Series A funding round

Stage 1 Ventures leads investment to drive product development and commercialization

TriLumina Corp of Albuquerque, NM, USA, which provides illumination solutions based on vertical-cavity surface-emitting laser (VCSEL) arrays for automotive laser radar (LiDAR) and sensing platforms, has closed an \$8.5m Series A round of funding led by Boston-based Stage 1 Ventures, joined by existing investors Cottonwood Technology Fund and Sun Mountain Capital (both of Santa Fe, NM). The funding will be used to support active and future customer integration projects as well as the firm's revenue ramp.

TriLumina has developed a small, fast and powerful infrared semiconductor laser, suitable for automotive LiDAR (light detection and ranging) solutions and smart illumination products for both automobiles and consumer devices. The lasers enable the production of all-solid-state, high-resolution LiDAR for 3D sensing around vehicles, accelerating the automotive market's move into semi-autonomous and autonomous operation.

"LiDAR is the next step for automotive safety enhancements, and TriLumina's solid-state LiDAR solutions are an excellent complement

to today's radar and vision systems," comments Stage 1 Ventures' managing director David Baum.

Stage 1 is leveraging its experience in the automotive industry to support TriLumina's unique devices, and the promise of providing Automated Driver Assistance Systems that meet stringent automotive requirements for size, performance and reliability. Cottonwood and Sun Mountain Capital originally invested on the basis of the core technology and the promising applications that TriLumina's devices enable.

"TriLumina provides the fastest, smallest and most powerful semiconductor emitter of its kind — making laser radar in automobiles a reality," claims TriLumina's president Kirk Otis. "Stage 1 Ventures, Cottonwood and Sun Mountain Capital

TriLumina says that it continues to develop products with Israel-based gesture-based user interface company eyeSight Mobile Technologies

share our vision for a safer car, better sensors and connectivity, and they are important partners as we develop our products and broaden our customer engagements," he adds.

Baum will join TriLumina's board of directors. With his strong focus on the automotive industry, he will play a key role in guiding the firm as it builds its relationships with tier-1 suppliers and innovative automotive OEMs.

In addition, TriLumina will use proceeds to accelerate development and commercialization of smart illumination technology for consumer products and automotive applications (driver monitoring). TriLumina says that it continues to develop products with Israel-based gesture-based user interface company eyeSight Mobile Technologies.

"The ongoing collaboration between eyeSight and TriLumina will offer a powerful gesture interface solution for smart TVs, set-top boxes, laptops and mobile devices that works as well in dark rooms as it does in direct sunlight," says eyeSight's CEO Gideon Shmuel.

www.trilumina.com

<http://eyesight-tech.com>

Princeton Optronics launches 4kW CW VCSEL array linear heater for printing and additive manufacturing

Princeton Optronics Inc of Mercerville, NJ, USA, which manufactures high-power single- and multi-mode vertical-cavity surface-emitting lasers (VCSELs), has announced the availability of 808, 976 and 1064nm high-power laser heating systems consisting of multiple VCSEL arrays with power output of >4kW.

The heater is 20cm long and consists of a line of VCSEL arrays for 5mm x 5mm size each delivering a

power output of 200W/cm. Princeton Optronics has also fabricated heaters in wavelengths such as 808, 976 and 1064nm.

High-power heating is needed for applications such as drying for industrial printing and additive manufacturing and other similar applications. With this laser heater, one can make a high-power line generator by using a cylindrical lens in front of it. The product is suitable for making meter-long line

generators for a range of industrial applications. Heaters with higher power/cm can also be built.

Princeton Optronics has a diverse line of products suitable for many high-power laser applications including illumination, sensing, and solid-state laser pumping. The firm claims to have the highest power (>200W from a single 5mm x 5mm array) and highest efficiency level (>63%) in the VCSEL industry.

www.princetonoptronics.com

Penn State's Nanoscale Science center granted \$15m

The Center for Nanoscale Science, a US National Science Foundation-funded Materials Research Science and Engineering Center (MRSEC) at Penn State University, has won a six-year, \$15m grant to continue nanoscale materials research.

MRSECs are funded to support materials research that would be beyond the scope of one or a few investigators. By funding long-term multi-investigator projects, NSF promotes an interdisciplinary approach to address fundamental problems in science and engineering. In the Center for Nanoscale Science, four interdisciplinary research groups (IRGs) will develop new classes of materials through predictive modeling, newly developed methods of synthesis at the nanoscale, and advanced methods of testing and characterizing materials and devices.

The four topics addressed include: (1) designing functionality into layered oxide ferroic materials (which change shape in response to electrical signals and could be used for tunable microwave devices, energy storage, piezo-transistors, and high-temperature magnetoelectrics); (2) new types of autonomously powered nano- and micro-motors that can sense their environment and react in a collective fashion that mimics living microorganisms; (3) high-pressure-enabled electronic metalattices that squeeze electrons into new forms of behavior for solar cells, light-emitting devices, and improved thermoelectrics; and (4) electrically and optically active particles organized into materials that guide light and electrons to create lasers, tiny antennas, and the building blocks for next-generation computer vision.

"Thirty seven faculty members across seven departments and three colleges at Penn State, plus eight faculty members at partner institutions around the world, will join their diverse backgrounds in pursuit of these ambitious goals," says Vincent Crespi, director of the Center for Nanoscale Science and

Distinguished Professor of Physics, Chemistry and Materials Science & Engineering. "The Center for Nanoscale Science also supports high-risk, high-reward seed projects from faculty across the university," he adds. "Seed projects have continuously rejuvenated and redirected the mission of the MRSEC."

Projects sponsored by industry

partners build on and extend the center's research in each of the four IRGs, with sponsored projects contributing about \$500,000 annually. Research in the center has resulted in more than 450 publications and patents since 2008, when the previous group of IRGs was funded.

www.mrsec.psu.edu

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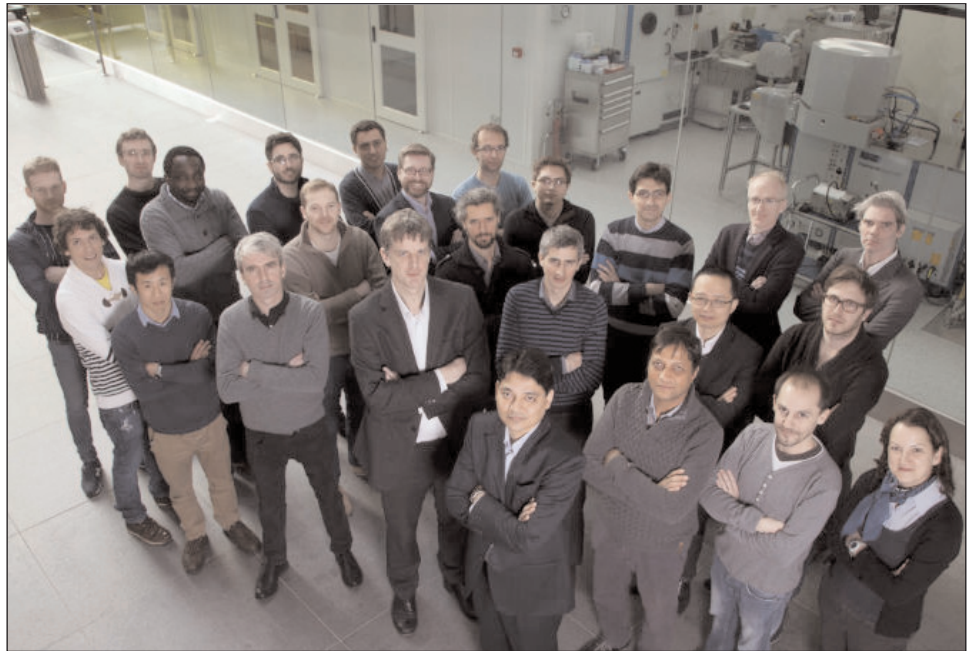
Tyndall to lead EU Horizon 2020-funded €5.2m project developing thermally intelligent smart photonics systems

Intelligent circuit that can thermally control its own operations to boost photonic device data rate five-fold

Ireland's Tyndall National Institute (based at University College Cork) is to lead a European consortium in a European Union (EU)-funded project to develop and demonstrate a scalable, thermally enabled 3D integrated optoelectronic platform that can make photonic devices up to five times more efficient, resulting in faster data transmission at a lower cost.

Funding of €5.2m under Horizon 2020's call for Smart Integration Systems will see industry and research partners from Ireland, Germany, The Netherlands and France collaborate on the three-year project 'Thermally Integrated Smart Photonics Systems' (TIPS). Tyndall will work with partners from III-V Lab, University of Hamburg, Alcatel-Lucent Bell Labs Ireland, CNRS Institutes (INL, ILM and IMN), Stokes Institute University of Limerick, LioniX BV, Alcatel-Lucent Bell Labs France, and Communi-craft Ltd.

With an anticipated 11.5 billion mobile-ready devices in the world by 2020 and the connectivity of those devices increasing through the Internet of Things, the existing operational bandwidth will be insuf-



The TIPS team at Tyndall National Institute.

ficient to cope with Europe's ever-increasing data demands. Significantly more bandwidth is therefore required to avoid bottle-necking Europe's expanding digital economy.

"We will seek to develop an intelligent circuit that can thermally control its own operations, making it up to five times more efficient," says project coordinator Dr Kafil M. Razeeb, senior research scientist at

Tyndall. Specifically, TIPS will heterogeneously integrate micro-thermoelectric coolers and micro-fluidics with optoelectronic devices. "By precisely self-tuning its own temperature, the device can produce a more precise wavelength, meaning faster data transmission at a lower cost," Razeeb adds.

www.tyndall.ie

<http://ec.europa.eu/digital-agenda>

Advanced Photonix and Luna to close merger in May

Advanced Photonix Inc (API) of Ann Arbor, MI, USA (which designs and makes APD, PIN, and FILTRODE photodetectors, HSOR high-speed optical receivers, and T-Ray terahertz instrumentation) and Luna Innovations Inc of Roanoke, VA, USA (which makes fiber-optic sensing and test & measurement products for the telecoms, aerospace, automotive, energy and defense markets) have jointly given an update to the timing of their planned merger (announced on 12 February).

The closing of the merger is subject to the satisfaction or waiver of customary closing conditions, including the effectiveness of a Form S-4 registration statement filed in February by Luna with the US Securities and Exchange Commission (SEC) and the approval of certain matters related to the merger by each firm's stockholders.

However, the SEC registration statement is not yet effective, and the firms have yet to finalize the dates of their respective stockhold-

ers meetings.

Luna expected to file an amendment to the Form S-4 during March and, following effectiveness of the form, Luna and Advanced Photonix will mail the joint proxy statement/prospectus included in it to their stockholders for consideration at their respective meetings.

The companies currently expect to hold the stockholder meetings, and close the merger, in May.

www.advancedphotonix.com

www.lunainc.com

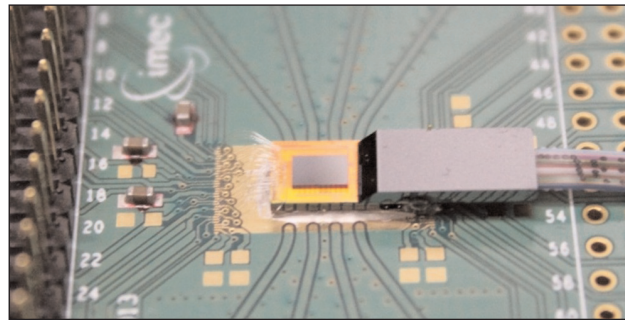
Imec, Tyndall, KULeuven and UGent demo compact 4x20Gb/s WDM CMOS silicon photonics transceiver

High-density single-mode fiber links targeted at data-center connectivity

At the 2015 IEEE International Solid-State Circuits Conference (ISSCC) in San Francisco (22–26 February), nanoelectronics R&D center Imec of Leuven, Belgium — in collaboration with Ireland's Tyndall National Institute, the University of Leuven (KULeuven) and Ghent University (UGent) — demonstrated a 4x20Gb/s wavelength division multiplexing (WDM) hybrid CMOS silicon photonics transceiver, paving the way to cost-effective, high-density single-mode optical fiber links.

Hybrid CMOS silicon photonics transceivers, transmitting and receiving data over single-mode optical fiber, are expected to play a key role in next-generation data-center connectivity. By leveraging existing CMOS manufacturing and 3D assembly infrastructure, the hybrid CMOS silicon photonics platform enables high integration density and reduced power consumption, as well as high yield and low manufacturing cost. Combined with WDM capability, highly scalable single-mode optical transceivers can be constructed, satisfying the growing need for interconnect bandwidth in next-generation cloud infrastructure.

Imec's transceiver comprises a



silicon photonics (SiPh) chip, flip-chip integrated with a low-power 40nm CMOS chip. The SiPh chip, fabricated on Imec's 25Gb/s silicon photonics platform (iSiPP25G), comprises an array of four compact 25Gb/s ring modulators, coupled to a common bus waveguide to allow WDM transmission. On the receive side, a ring-based, low-loss (2dB) demultiplexing filter with 300GHz channel spacing is implemented and further connected to an array of four 25Gb/s germanium (Ge) waveguide photodetectors. Both the ring modulators and the ring WDM filters include highly efficient integrated heating elements to tune their resonant wavelengths to the desired WDM channels. The CMOS chip includes four differential 20Gb/s ring modulator drivers and four 20Gb/s trans-impedance amplifiers (TIAs). A 12-channel single-mode fiber array is packaged

onto the grating coupler array on the chip, using a planar approach developed at Tyndall National Institute.

Error-free operation was demonstrated in a 20Gb/s loop-back experiment for all four WDM channels as well as with

two channels running together. The dynamic power consumption of the transceiver, including the CMOS driver and receiver, was less than 2pJ/bit. Thermal tuning of the WDM channel wavelengths consumed only 7mW/nm per channel. The transceiver can be further scaled to higher bandwidth capacity by adopting more advanced CMOS technology and by adding more WDM channels, enabling optical modules for 100GbE, 400GbE and beyond for future data-center interconnects, says Imec.

The work was supported by Imec's optical I/O core partner program. The iSiPP25G technology can be accessed through the Europractice service, while silicon photonics packaging services are available through Tyndall National Institute.

www.imec.be

www.europractice-ic.com

www.isscc.org

GigOptix inaugurates Japan headquarters and appoints director of Asia Pacific Sales

GigOptix Inc of San Jose, CA, USA (a fabless supplier of analog semiconductor and optical communications components for fiber-optic and wireless networks) has opened its GigOptix-Japan office in Tokyo, and appointed Yoshi Koizumi as Asia Pacific (APAC) sales director.

"With our rapidly expanding business in the APAC region over the last few years, it is exciting to add a high-performance optical

communications and wireless industry veteran with Koizumi's experience and track record to our team," comments Dr Raluca Dinu, GigOptix' senior VP of global sales & marketing. "We have added yet another impact player with a proven ability to realize our growth aspirations leading our sales efforts in Asia Pacific territory."

Prior to joining GigOptix, Koizumi managed the sales operations of

TriQuint Semiconductor in Japan. His experience includes participation in both 40Gbps and 100Gbps optical driver design-in as well as point-to-point MMIC design-in with major Japanese telecoms corporations. Prior to his lengthy tenure with TriQuint, Koizumi managed the structured ASIC sales & marketing effort at NEC Electronics.

www.gigoptix.com

Ghent University, imec and Max Planck Institute extend frequency comb light sources towards mid-IR

Belgium's Ghent University (UGent) and nanoelectronics R&D center Imec in Leuven have joined forces with the Max Planck Institute in Germany and New Zealand's Auckland University to realize a frequency comb light source in the mid-infrared wavelength band (B. Kuyken et al, 'An octave spanning mid-infrared frequency comb generated in a silicon nanophotonic wire waveguide', *Nature Communications*, 6(6310), (2015)). Frequency comb light sources with an extended spectrum can be used for real-time, extremely high-resolution spectroscopy, for example to measure the presence and concentration of gas molecules in analytes.

A frequency comb source is a light source with a spectrum containing thousands of laser lines. Their development has allowed the construction of a link between the optical part of the electromagnetic spectrum and the radio frequency part, allowing researchers to determine optical frequencies with an unprecedented precision. Frequency comb light sources have also been used in optical clocks, enabling precise time keeping.

The impact of frequency comb light sources on science was highlighted in 2005, when the Nobel Prize for physics was awarded to professor T. Haensch and professor J. Hall for their work on optical frequency metrology using frequency combs.

Lately, frequency combs have been used to target more real-life applications. Several experiments have shown that the specific properties of the sources can be used to do fast, high-resolution spectroscopy over a broad spectrum. However, traditional comb sources are not at the right wavelength spectrum for doing spectroscopy.

Ghent University, Imec, the Max Planck Institute for Quantum Optics in Garching and the Auckland University in New Zealand have developed mid-infrared frequency combs, working in the mid-IR molecular fingerprinting region of the electromagnetic spectrum. In this wavelength region, many molecules have specific absorption bands that can be used in spectroscopy to determine the presence and concentration of these molecules in samples.

The researchers realized the broad frequency combs by combining the strong light-matter interaction in

silicon with its broad transparency window. By fabricating nanowire silicon photonics waveguides to confine the light in a very small-area waveguide, they further enhanced the strong light-matter interaction, allowing them to broaden the spectrum of the frequency combs into the mid-infrared. The achievements were possible through the use of a unique pump laser source, previously developed by Spain's Institut de Ciències Fòniques Barcelona (ICFO).

The results are reckoned to be an important step towards a small-footprint chip-scale mid-IR frequency comb source. Such sources could act as sensitive cheap gas sensors in the mid-infrared. These would be important for example for environmental monitoring for measuring air-pollution or in medical diagnostics as a cheap tool for breath analysis.

The reported work is the result of collaboration between three European Research Council (ERC) grants: Multicomb, Miracle and InSpectra.

www.nature.com/ncomms/2015/150220/ncomms7310/full/ncomms7310.html

Avago's 25G VCSEL shipments surpass 1 million channels

Avago Technologies Ltd (a designer and supplier of III-V-based analog components for communications, industrial and consumer applications) says it has now shipped more than 1 million channels of 25G vertical-cavity surface-emitting lasers (VCSELs) to the enterprise optical networking market.

Leveraging the firm's broad portfolio of VCSEL intellectual properties, the 25G VCSEL technology drives a wide range of high-performance fiber-optic transceiver modules for next-generation Ethernet, Infiniband and high-performance computing (HPC) applications.

"Given the growing demands of optical links within the data center, there is a pressing need for new high-speed VCSEL solutions to support high data bandwidth requirements," says Philip Gadd, senior VP & general manager of Avago's Fiber Optics Product Division. "25G VCSEL technology will be a cornerstone for next-generation short-reach optical networking protocols and applications such as Ethernet, Infiniband, Fiber Channel, PCIe, and SAS. With a proven 25G VCSEL technology and a broad portfolio of high-speed fiber-optic solutions, Avago is well positioned

to serve a variety of customers and applications," he believes.

"This is an exciting milestone for VCSEL technology, the workhorse of optical datacom for many years," comments Dale Murray, principal analyst for LightCounting Market Research. "While we have increased our projections for 25G VCSEL-based modules in the latest market forecast report, it comes as a pleasant revelation that Avago has already shipped a million 25G channels. This bodes well for the long-term future of VCSELs," he adds.

www.avagotech.com/fiber

MACOM unveils upstream and downstream DOCSIS 3.1-compliant CATV amplifiers

M/A-COM Technology Solutions Inc of Lowell, MA, USA (which makes semiconductors, components and subassemblies for, RF, microwave, millimeter-wave and photonic applications) has launched a portfolio of high-performance cable TV (CATV) amplifiers designed for compliance with the DOCSIS 3.1 standard for high-bandwidth data transfer over existing hybrid fiber-coaxial (HFC) infrastructure. "With this new portfolio of DOCSIS 3.1-compliant amplifiers, MACOM is enabling network equipment designers to meet DOCSIS 3.1 specifications in both the up and downstream bands"

Covering both upstream and downstream bands and complementing MACOM's recently introduced portfolio of DOCSIS 3.1-compliant passives, the new ampli-

fiers are suited to head-end, node, system and line access equipment requiring broader bandwidth, high output power and low distortion. The new active components are available in integrated multi-stage and single-stage configurations, allowing system designers the flexibility to achieve the desired performance, says the firm. MACOM's offerings span a range of compact, industry-standard packaging options supporting thermal management attributes that ensure high reliability.

The new upstream single-ended, push-pull and variable gain amplifiers (VGAs) support frequency splits up to 300MHz, offering what is claimed to be excellent linearity, modulation error ratio (MER), low noise figure and high gain. The new downstream, single-ended, push-pull and

variable gain amplifiers cover the extended 45–1225MHz frequency range with a variety of gain and output power levels while delivering high linearity, output power and small-signal performance.

"With this new portfolio of DOCSIS 3.1-compliant amplifiers, MACOM is enabling network equipment designers to meet DOCSIS 3.1 specifications in both the up- and downstream bands," says Graham Board, director carrier networks at MACOM. "MACOM's comprehensive offering of single-ended and push-pull upstream and downstream amplifiers coupled with our extensive portfolio of passives and filters helps to deliver superior end-to-end RF amplifier performance in HFC access amplifiers," he claims.

www.macom.com/products/amplifiers/catv-amplifiers

Oclaro ramps production of 100G LR4 CFP4 transceivers

Oclaro Inc of San Jose, CA, USA (which provides components, modules and subsystems for optical communications) is ramping up production of its 100G LR4 CFP4 client-side transceivers.

Oclaro says that, having previously delivered CFP and CFP2 solutions in high volume, the latest announcement reaffirms its commitment to deliver 100G pluggable MSA form-factor products to address the need for high-bandwidth connectivity for data-center and packet optical transport applications.

The 100G LR4 CFP4 enables high-end core router and packet-optical transport systems to quickly and cost-effectively increase their front-panel density to meet the higher bandwidth demands of data-center interconnects and network operators. These benefits are achieved through the transceiver's small-form-factor design and low power consumption, says Oclaro.

The CFP4 can deliver high-quality Ethernet and OTU4 data-rate performance while only consuming a typical 4W of power, which is equal to or better than other CFP4 solutions based on directly modulated laser (DML) technology, it is claimed.

The CFP4 is also backwards compatible with existing Oclaro CFP and CFP2 LR4 designs and leverages its proven indium phosphide (InP) 28G core electro-absorption modulated laser (EML) technology for what is claimed to be superior performance at both standard 100GbE and OTU4 data rates. The EML, together with Oclaro's own Lens-Integrated PIN Photodiode (LIPD) array, are vertically integrated out of Oclaro's wafer fab facility in Japan, enabling a cost-effective solution and shorter lead-time to customers, the firm adds.

"Oclaro not only has one of the broadest and most comprehensive

CFP portfolios in the market, but it also has a proven history of delivering reliable and high-performance CFP MSA designs in volume production," says Yoshikazu Era, general manager, Oclaro Japan Module Division. "We will continue to deliver to our customers' leading-edge performance while offering the benefits of the smaller and power-efficient CFP4 transceiver so they can meet their market requirements for increased front-panel density, backwards compatibility and high performance at Ethernet and OTU4 rates."

The LR4 CFP4 transceiver is compliant with the 100G Ethernet (100GbE) 100GBASE-LR4 and ITU-T G.959.1 4I1-9D1F as well as the CFP4 MSA standards.

Oclaro's 100G LR4 CFP4 is now shipping to key customers and is expected to be in volume production in second-quarter 2015.

www.oclaro.com

Finisar reports quarterly revenue up 3% to \$306m, as 40–100Gb/s datacom growth outweighs slow telecom carrier spending

New optical engine's low yields hit margins, but OpEx cuts boost income

For its fiscal third-quarter 2015 (ended 25 January), fiber-optic communications component and subsystem maker Finisar Corp of Sunnyvale, CA, USA has reported revenue of \$306.3m, up 3.1% on \$297m last quarter (which had been the firm's first decline in two years) and up 4.2% on \$294 a year ago. Growth was driven mainly by demand for 40 and 100Gb/s transceivers for datacom applications, as well as transceivers for wireless applications. The sole 10%-or-greater customer (Cisco) represented 56.1% of total revenue (up on 55.8% last quarter).

Datacom product revenue was \$234.4m, up 8.5% on \$215.9m last quarter and 11.5% on \$210.3m a year ago, driven mainly by demand for 40 and 100Gb/s transceivers for datacom applications, as well as transceivers for wireless applications.

Telecom product revenue was \$71.9m, down 11.3% on \$81.1m last quarter, due mainly to the impact of one month of the annual telecom price reduction (that typically takes effect on 1 January) and the decrease in demand for transceivers for telecom applications driven by sluggish carrier capital expenditures. This was also down 14% on \$83.7m a year ago.

On a non-GAAP basis, gross margin fell further, from 31.1% last quarter to 30% (below the expected 31%). This was due mainly to the annual telecom price reduction plus a 75-

basis-point impact from substantial yield loss for a new optical engine product for supercomputing applications that began to ramp into production. This is down from 37.2% a year ago, when Finisar's CFP 100G LR4 product was still an early entrant for 100 Gigabit Ethernet (with 85–90% market share, due to having the only fully functional IC in the industry) and hence on allocation for several quarters, according to executive chairman Jerry Rawls. However, after merchant semiconductor companies corrected the errors in their chips and produced functional chips, competitors entered the market at substantially lower prices, so Finisar had to cut its prices (reducing margins).

"Although our gross margins declined primarily as a result of our annual telecom price reductions and low yields on a new optical engine product, we significantly decreased our operating expenses [by a more-than-expected \$2.2m, from \$67.3m last quarter to \$65.1m], resulting in a minimal impact to our earnings," says CEO Eitan Gertel.

Operating income hence rose from \$25m (8.4% of revenue) last quarter to \$26.9m (8.8% of revenue), although this is down on \$46.3m a year ago (15.7% of revenue). Net income rose from \$23.5m (\$0.23 per diluted share) last quarter to \$26.7m (\$0.25 per diluted share), although this is down on \$45m

(\$0.44 per diluted share) a year ago.

Capital expenditure was \$31.7m, back up from \$28.4m last quarter (due to a delay of about a quarter in completing construction of the second building of the new factory in Wuxi, China) but down from \$35.4m a year ago (and less than the forecasted \$40m). During the quarter, cash, cash equivalents and short-term investments rose by \$11.4m, from \$477.4m to \$488.9m.

For fiscal fourth-quarter 2015, Finisar expects revenue to rise to \$310–\$330m. Gross margin should be flat at about 30%, due to the impact of a full three months of the annual telecom price reductions. Operating margin is expected to be 8–9%. Earnings per diluted share should be \$0.22–\$0.28.

Capital expenditure is expected to rise further, back to \$35m, driven by continuing construction of the second building in Wuxi. "We expect the second building to be completed by the end of the fourth quarter and we expect to have all remaining volume manufacturing move from Shanghai to Wuxi and re-qualified with the customers by the end of our second quarter of fiscal 2016," says executive VP & chief financial officer Kurt Adzema. "We will continue to perform R&D and NPI [new product introduction] manufacturing work in Shanghai as well as some corporate functions," he adds.

www.finisar.com

Inphi receives NeoPhotonics' Supplier of the Year award

Inphi Corp of Santa Clara, CA, USA, a supplier of high-speed mixed-signal ICs for communications, data-center and computing markets, has received the 2014 Supplier of the Year award from NeoPhotonics, recognizing it as an "outstanding supplier for its contribution in service, support and

innovative leading-edge technology".

"It reflects our uncompromising commitment to delivering leading-edge next-generation 100G solutions," says Charlie Roach, VP, worldwide sales.

The award is in recognition of Inphi's "high standards of quality, performance and customer service,"

says Ben Sitler, NeoPhotonics' senior VP for worldwide sales. "Inphi's technology-leading integrated circuits for 100G applications have been very helpful to NeoPhotonics in introducing and ramping our 100G optical products."

www.inphi.com

NeoPhotonics reports record Q4 revenue of \$79m, despite pruning low-margin products, driven by growth in 100G

Cost control and product portfolio optimization yield record income

NeoPhotonics Corp of San Jose, CA, a vertically integrated designer and manufacturer of both indium phosphide (InP) and silica-on-silicon photonic integrated circuit (PIC)-based modules and subsystems for high-speed communications networks, has reported record revenue of \$79m for a Q4, down 3.2% on \$81.6m third-quarter 2014 but up 6.2% on \$74.4m for fourth-quarter 2013 (and near the high-end of the guidance range of \$74-80m). Full-year revenue has risen by 8.5% from \$282.2m in 2013 to \$306.2m in 2014.

Two customers comprised more than 10% of revenue: Ciena (16%, down from 17% last quarter) and China's Huawei Technologies 42% (up from 35%). Of total revenue, China hence rose strongly from 50% to 55%, whereas the Americas fell from 25% to 23%, Japan from 5% to 4% and the rest of the world from 20% to 18%.

Revenue from the Access product group was \$15.3m (19% of total revenue), down 10% on \$17m (20.5% of total revenue) last quarter and 12% on \$17.4m (23.3% of total revenue) a year ago. Revenue from the Speed & Agility product group was \$59.3m (75% of total revenue), down slightly by 2% on \$60.6m (74% of total revenue) last quarter but up 16% on \$51.8m (69% of total revenue) a year ago.

For full-year 2014, Access products were 20.2% of total revenue (down from 23% in 2013). Speed & Agility products were 73.5% of total revenue, up from 69% of total revenue in 2013. "Driven particularly by 100G products and deployments, our underlying business remains strong and growing.

On a non-GAAP basis, full-year gross margin has fallen from 26% in 2013 to 25% in 2014. However, Q4 gross margin was 30.3%, up from 26.5% last quarter and 27.5% a year ago (and above the

guidance range of 24-27%). Also, gross margin expanded by 8.4 percentage points from Q1 to Q4 as a result of lower overall manufacturing costs, vendor cost reductions and a favorable mix shift, partly due to pruning of lower-margin products. Operating expenses have been cut further, from \$23.2m a year ago and \$20.3m last quarter to \$19.2m.

Net income was a record \$6.3m (\$0.19 per diluted share), an improvement on \$1.4m (\$0.04 per diluted share) last quarter and a loss of \$1.8m (\$0.06 per diluted share) a year ago (and above the high-end of initial guidance of a \$0.13-0.01 loss). Full-year net loss has been cut from \$14.2m (\$0.46 per diluted share) for 2013 to \$9.2m (\$0.29 per diluted share) for 2014.

Profitability is "a direct result of our focus on cost control and product portfolio optimization," says chairman & CEO Tim Jenks.

NeoPhotonics generated \$9.5m of cash inflow from operations. Capital expenditure was \$1.9m (down from \$3.2m last quarter, leading to full-year CapEx of \$11m, less than the normal run-rate of 5% of revenue). Free cash flow was hence \$7.6m (up from \$5.7m last quarter, totaling \$13.3m for second-half 2014). During the quarter, cash and cash equivalents and restricted cash and investments rose by \$6.4m, from \$57.9m to \$64.3m.

After the end of Q4/2014, NeoPhotonics restructured its debt with new arrangements from Comerica Bank and Bank of

By the end of Q2 and in comparison to one year ago, we will have pruned products with historical revenues of \$5-10m per quarter in total, which will improve gross margin and profitability

Tokyo-Mitsubishi UFJ Ltd, which have effectively increased current unrestricted cash by about \$22m and increased the firm's available borrowing capacity by about \$9m.

Taking into account seasonal declines in average selling process (ASPs), product pruning and the addition of the tunable laser products acquired from Emcore on 5 January, for first-quarter 2015 NeoPhotonics expects revenue of \$75-81m, gross margin of 26-30%, and diluted income/loss per share of a loss of \$0.09 to earnings of \$0.02.

"We intend to maintain our focus on the highest-speed optical network applications and on achieving sustainable profitability," says Jenks.

"We are continuing actions to prune certain products that are not contributing to profitability," says chief financial officer Ray Wallin. "By the end of the second quarter and in comparison to one year ago, we will have pruned products with historical revenues of \$5-10m per quarter in total, which going forward will lower our annual revenue while improving gross margin and profitability," he adds. "On a year-over-year basis and comparing full-year 2014 to full year 2015, we will not be selling in 2015 certain products, which contributed revenues of approximately \$25m in calendar year 2014. These products, which are in the end-of-life, had 10% or below gross margins and are in a last-time-buy process with customers currently." These products are expected to contribute only \$5m of revenue in first-half 2015, then no revenue in second-half 2015. "Nonetheless, we are confident in our ability to execute on our roadmap of a 100G growth, expanding gross margins, tightening expenses and improving cash flow," concludes Wallin.

www.neophotonics.com

Infinera introduces photonic integrated circuits to support new Layer C and Layer T network model

Sliceable enhanced ePIC-500 for hub and application-optimized oPIC-100 for spoke locations target scalable and flexible transport network

Infinera Corp of Sunnyvale, CA, USA, a vertically integrated manufacturer of digital optical network systems incorporating its own indium phosphide-based photonic integrated circuits (PICs), has introduced two PICs for new optical transport applications as scale and virtualization drive changes in network architectures. The new photonic integrated circuits include the sliceable enhanced PIC (ePIC-500) and the application-optimized PIC (oPIC-100).

Emergence of Layer C & Layer T

Infinera says that, now that Cloud services are growing quickly and high-capacity connectivity is paramount, service providers must scale, simplify and increase the flexibility of their networks. Network function virtualization (NFV) provides a means to address these needs for the upper layers of the network through the migration of network functions from dedicated appliances to software services on x86 hardware within Cloud data centers. This Cloud services layer supports NFV plus other Cloud-delivered services (Layer C). In order to support Layer C, Cloud data centers and end users need to be interconnected by a highly scalable and flexible transport network (Layer T).

Scalable photonics is the foundation of Layer T and must provide more capacity per line-card and system while simplifying the network - fewer boxes, fibers and modules, and less space, power and fewer manual processes. Infinera says that PICs are integral to the evolution of the transport network, providing significant benefits when integrated into a packet-optical DWDM transport system for an efficient Layer T, ultimately allowing Layer C to thrive.

Sliceable photonics for metro

Infinera's new sliceable photonics technology provides a large pool of capacity in a PIC that can be divided at a granular optical level, with each slice capable of being routed in a different direction as it exits the line-card or the system housing it, usually at the hub. The recipient of the individual slice is a line-card or system that matches the capacity, usually at the spoke. The ePIC-500 provides sliceable 500G capacity at the hub location, while the oPIC-100 provides 100G capacity at the spoke location. While these two new PICs are applicable across all network locations, they were developed specifically to support Layer T in the metro.

Infinera modeled a wide range of applications from metro aggregation to regional long-haul where hub-and-spoke, mesh or ring topologies are common. When using the new PICs, these models showed an estimated average reduction of 28% in modules, 31% in power and 45% in bandwidth inefficiencies compared with conventional, commercial off-the-shelf technologies that deliver single-wavelength or super-channel solutions for 100G, 200G or 400G, reckons the firm.

"We find the Infinera sliceable photonics

The ePIC-500 provides sliceable 500G capacity at the hub location; the oPIC-100 provides 100G capacity at the spoke location. While these two new PICs are applicable across all network locations, they were developed specifically to support Layer T in the metro

technology to be very relevant for network architectures and have already tested this in our lab," comments Telefonica's senior manager Juan Pedro Fernández-Palacios. "As Cloud services take off, it is imperative that transport networks be scalable yet granular and simple to operate. Enhancing the super-channel technology with sliceability is the right approach to satisfy these needs simultaneously," he adds.

"Infinera continues to leverage its expertise in photonics to provide operators tools to build optimized Transport Layer infrastructure," comments Rick Talbot, principal analyst at market research firm Current Analysis. "We view sliceable photonics provided by the ePIC-500 and oPIC-100 as a significant step in providing flexible wavelength granularity for super-channels, allowing operators to lower the costs and complexities of transport while handling enormous traffic growth," he adds.

"Infinera has been shipping PICs in transport systems, that have been designed from the ground-up, for over a decade," notes Infinera's co-founder & president Dave Welch. "During this time the technology has surpassed over 1.5 billion hours of field operations," he adds. "Sliceable photonics allows our customers to build networks with scale and flexibility for a wide variety of applications, ranging from the metro to the long-haul. It provides a comprehensive tool-set for us to be nimble and build market-specific platforms for Layer T as our customers' needs continue to evolve."

The new PICs are being developed for line-cards and systems that are scheduled for delivery later this year.

www.infinera.com.com/go/pic

JDSU to spin off CCOP business as Lumentum by Q3/2015; NE, SE and OSP businesses to become Viavi

CFO Rex Jackson to leave on 30 September after spin-off

JDSU of Milpitas, CA, USA has filed a registration statement with the US Securities and Exchange Commission (SEC) in connection with the spinoff of its Communications and Commercial Optical Products (CCOP) business (announced in September), which will result in two independent, publicly traded companies. CCOP will become Lumentum Holdings Inc. At the time of this separation (expected by third-quarter 2015), JDSU's Network Enablement (NE), Service Enablement (SE) and Optical Security and Performance Products (OSP) businesses will be renamed Viavi Solutions Inc.

"We are creating two unique brands — both representing well-established expertise and market leadership — and positioning them with greater customer focus and agility," says president & CEO Tom Waechter.

Lumentum focusing on optical communications and commercial lasers

Shares of Lumentum common stock will be distributed on a pro rata basis to JDSU stockholders in a manner intended to be tax-free for US federal income tax purposes. Lumentum intends to apply to list its shares on the Nasdaq Stock Market under the ticker 'LITE'.

Lumentum will specialize in optical components and subsystems for the telecoms market, with high-growth opportunities in data communications, driven by the rapid expansion of cloud networking and data-center infrastructure, and in high-performance lasers for both macro and micro materials processing applications. Lumentum will also focus on growing its 3D sensing and commercial lasers business and expanding into other market segments that can benefit from optical and laser technologies.

Alan Lowe will be CEO of Lumentum. He joined JDSU in September 2007 as senior VP of the Lasers business

and in 2008 he became president of JDSU's newly formed CCOP business segment (combining the firm's Optical Communications and Lasers businesses). Lowe led the transformation of the combined business by focusing on the customer, investing in market-leading innovation, and streamlining and improving operational execution, says JDSU.

Aaron Tachibana will be Lumentum's chief financial officer. He joined JDSU in November 2013 as VP of finance and corporate controller, responsible for driving financial close process improvements, enhancing organizational performance, and reducing operating expenses. Prior to JDSU, he was CFO at Pericom Semiconductor Corp.

Viavi Solutions focusing on network and application visibility

JDSU says that its new Viavi brand has a track record of collaboration with service providers and enterprises worldwide through periods of intense network trans-

formation. The firm has the ability to provide solutions for end-to-end network and application visibility from a portfolio of instruments, software and services, addressing customers' needs to profitably scale to meet the demands of the fast-growing volume of

connected devices and applications, and to transition to virtualized, software-based networks.

Viavi's OSP business is said to be a leader in anti-counterfeiting solutions for currency authentication and high-value optical components and instruments for security, safety, electronics and other applications.

Leading Viavi will be Tom Waechter, who became president & CEO of JDSU in January 2009 and executed a strategy to enhance investment in market-based innovation. He joined JDSU as president of Communications Test and Measurement (the predecessor to JDSU's NE business) in October 2007.

JDSU CFO to leave firm after separation

Also, following the expected completion of the CCOP spinoff and necessary fiscal year-end filing of an annual report (on Form 10-K) for Viavi, chief financial officer Rex Jackson will leave JDSU at the end of September. He joined JDSU in 2011 as senior VP, business services, and was promoted to CFO in January 2013. Prior to JDSU, he was CFO of Symyx Technologies. JDSU will initiate a search for Jackson's replacement in due course.

"Rex has provided outstanding leadership during an eventful period of change at JDSU, played a key role in charting the bright futures for Viavi and Lumentum, and strengthened our finance, information technology and other shared services operations," comments Waechter.

Current JDSU stockholders will own shares in both corporations following the separation. The spin-off is subject to the satisfaction or waiver of a number of conditions, including the registration statement on Form 10 for Lumentum common stock being declared effective by the SEC. Approval by JDSU's stockholders is not required for completion of the separation.

www.jdsu.com

Lumentum will specialize in optical components and subsystems for the telecoms market, with high-growth opportunities in data coms, driven by the rapid expansion of cloud networking and data-center infrastructure, and in high-performance lasers for both macro and micro materials processing

Sol Voltaics doubles GaAs nanowire array solar efficiency record to 15.3%

Efficiencies above 27% targeted using tandem junctions on silicon cells

Sol Voltaics AB of Lund, Sweden, which provides nanomaterial technology for enhancing solar panels and other products, has demonstrated a 1-sun photovoltaic (PV) solar energy conversion efficiency of 15.3% using a gallium arsenide nanowire array (NWA), as verified by Germany's Fraunhofer ISE (Institute for Solar Energy Systems).

This exceeds the existing efficiency record for a III-V NWA solar cell — of 13.8%, set in 2013 by Lund University, using indium phosphide (InP) NWA technology — and specifically

doubles the record for GaAs NWA technology (7.58%, set in 2014).

Sol Voltaics says control of the high density of surface states of native GaAs is essential for PV applications, and that the new results prove that it has resolved this challenge in the growth of solar cell nanowires.

"The efficiency of our GaAs nanowires is a critical component of our low-cost film," says CEO Erik Smith. "The use of III-V materials in the PV industry has always been a goal, but the costs have been prohibitive," he adds. "Using

Sol Voltaic's Aerotaxy nanowire production methodology allows our III-V film to be produced at competitive cost at efficiencies that are industry changing."

Sol Voltaics reckons that its GaAs NWA solar cell represents a significant step towards an efficiency-boosting tandem film. "We look forward to working with industrial partners on the integration of our technology on to silicon cells so they may make the leap to 27% efficiency and beyond," says Smith.

www.solvoltaics.com

First Solar and SunPower file for IPO of JV 8point3

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 solar panel and system maker SunPower Corp of San Jose, CA, USA have announced that 8point3 Energy Partners LP, a limited partnership formed by the firms (as a joint 'YieldCo') to own and operate a portfolio of selected solar generation assets, has filed a registration statement with the US Securities and Exchange Commission (SEC) for an initial public offering of Class A shares.

The name 8point3 is derived from the average amount of time it takes light from the sun to reach the earth (8.3 minutes).

The number of shares to be offered and their IPO price have not yet been determined, but the aim is to raise \$50m. 8point3 Energy Partners will apply to list the shares on the NASDAQ Global Market.

The preliminary prospectus for the IPO (available from Goldman, Sachs & Co and Citigroup, which are acting as lead book running managers) states that 8point3's initial portfolio is 432MW. Of this, 87% (377MW) consists of six utility-scale solar energy projects in the USA (four of

which are operational and two of which are in late-stage construction) mostly in California (including First Solar's 150MW Solar Gen 2 project and SunPower's 108MW Quinto project). The remaining 13% (55MW) of the portfolio consists of 5900 rooftop installations (residential and industrial) from SunPower.

Also, YieldCo has right-of-first-offer (ROFO) agreements for 1131MW of projects (most of which will be finished in 2015–2016). Of this, 82% of the projects are in the USA, 17%, in Chile, and 1% in Japan. Also, 87% of them are utility-scale; the rest are commercial/residential.

www.firstsolar.com

First Solar completes Atlas 25+ testing program

Atlas Material Testing Technology LLC of Mt. Prospect, IL, USA, which provides weathering technology and services, says that First Solar has completed the Atlas 25+ Comprehensive PV Durability Testing program and received test result certification from Atlas' inspection, verification, testing and certification partner SGS.

The Atlas 25+ protocol is a propri-

etary multi-dimensional durability test program designed to subject PV modules to the environmental degradation stresses that can be expected over long-term service. The firm provides manufacturers with the data needed to demonstrate long-term durability and to support warranty and performance claims, while reducing the costs of after-market product failure.

The Atlas 25+ program exposes solar panels to a series of stresses, including UV-A/UV-B exposure, salt spray corrosion, condensing humidity, solar/thermal humidity cycle, solar/thermal humidity freeze cycle, Arizona and Florida solar tracking — including peak summer — and initial, final and multiple interval measurements.

www.atlas-mts.com

Oxford PV secures £8m in first-tranche round B funding

UK-based Oxford Photovoltaics Ltd has raised a first-tranche B-round of funding of over £8m (more than targeted) from both new investors (in the UK, USA, Asia and Europe) and its existing investors (University of Oxford, MTI Partners Ltd, Longwall Venture Partners LLP, Parkwalk Advisors Ltd and a range of angel investors).

"In a very difficult market for solar investments, we exceeded our expectations and broadened our shareholder base," says CEO & co-founder Kevin Arthur.

Oxford PV's technology involves forming a tandem solar cell using perovskite materials as the wide-bandgap solar absorber (with a bandgap energy of about 1.55eV) on top of a conventional silicon solar cell (with a bandgap of 1.1eV).

The new funds more than double the equity raised by Oxford PV to date and will be used to accelerate development of its technology and IP portfolio towards full-scale production and commercial deployment. Reflecting the progress made by the firm, the funds were raised at a

substantial increase to the valuation achieved in the previous round.

Oxford PV reckons that the quality and breadth of its shareholder base is a key demonstration of global support for its technology and will be a key strength as the firm builds towards commercialization worldwide.

"With this additional funding, we will be able to follow through with the many opportunities we have built and accelerate towards commercial deployment," says chief financial officer David Smyth.

www.oxfordpv.com

Ascent Solar re-hires former senior vice president of sales & marketing as chief operating officer

Ascent Solar Technologies Inc of Thornton, CO, USA, which makes lightweight, flexible copper indium gallium diselenide (CIGS) thin-film photovoltaic modules integrated into off-grid applications and its EnerPlex series of consumer products, has appointed Rafael Gutierrez as senior VP & chief operating officer.

Gutierrez was formerly Ascent's senior VP of sales & marketing from 2009 to 2011. Prior to that, during 18 years with Seagate Technologies (from 1991 to 2009), he held executive positions including general manager of Consumer Electronics, executive director of Strategic Marketing, and director of Advanced

Concepts and Product Development.

After Gutierrez left Ascent in 2011, he held positions with Ampt LLC as a senior VP of sales & marketing, and subsequently with Micron Technologies as enterprise business development lead before returning to Seagate in 2013 as strategic business development lead for its SSD division.

"He is an industry veteran and is perfectly suited to lead the continued rapid expansion of our entire sales operation globally," comments Ascent Solar's CEO Victor Lee. "He brings a wealth of large corporate C-level experience in the technology and consumer electronics sectors, and his depth of knowledge in both

international and domestic sales, as well as his comprehensive understanding of the marketing and product development cycles of consumer-oriented businesses and PV applications, are invaluable assets as we continue to accelerate our growth," he adds.

"The market opportunities for flexible PV power solutions in emerging markets such as Internet of Things (IoT), consumer wearables and drone applications create a unique and promising near-term opportunity for Ascent Solar and EnerPlex solutions," says Gutierrez.

www.goenerplex.com

www.AscentSolar.com

Stion completes 228kW commercial rooftop solar project

Stion Corp of San Jose, CA, USA, which makes nanostructure-based CIGS (copper indium gallium sulphur-diselenide) thin-film solar modules and provider of turnkey photovoltaic solutions, has completed a 228kW commercial rooftop solar project at US Continental Marketing Inc of Corona, CA, USA, which is a vertically integrated provider of leather and fabric care products for more than 20 years.

Stion's project development arm Stion Energy Services was selected by US Continental Marketing to provide a turn-key solution for the project, which was commissioned at the end of December. The solar installation will offset a significant portion of the electricity used by the company for its manufacturing operations.

Powered by 1690 modules, the rooftop system will generate about 390,000kWh per year.

"The solar installation, which was completely permitted and installed in less than five months, will help to stabilize growing energy costs, and the resulting savings benefits are an important component of our efforts to improve operational efficiencies," comments US Continental Marketing's chief financial officer Steve Toloday.

www.stion.com

www.uscontinental.com

Solar Frontier's residential and commercial systems chosen for UEI's self-consumption storage device

Tokyo-based Solar Frontier — the largest manufacturer of CIS (copper indium selenium) thin-film photovoltaic (PV) solar modules — and energy provider Unendo Energia Italiana (UEI) of Milan, Italy are collaborating to provide solar energy systems that combine Solar Frontier's residential PowerSets and commercial PowerSaver with Unendo's storage solutions.

Already a distributor of Solar Frontier's PowerSets, Unendo Energia Italiana now supplies residential customers by combining Solar Frontier's optimized systems with its CU-Q storage solution, enabling homeowners to generate and consume up to 93% of their own electricity.

Commercial customers benefit from similar advantages through Solar Frontier's PowerSaver, optimized PV solutions for self-consumption adapted to the specific needs of each business. Projects in Italy implemented by UEI are said to show the advantage of combining these with Unendo's energy supply solutions: higher independence from grid-sourced electricity and, consequently, lower energy bills.

"In the last few years and especially since the end of the 'Conto Energia V' [Italian feed-in premium], energy



Solar Frontier's residential PowerSet solution.

self-consumption has become increasingly important," says UEI's managing director Giuseppe Pirola. "In such a market environment, systems that generate the highest possible energy output have become the main focus," he adds. "Our experience shows that Solar Frontier offers the maximum level of optimization between modules and electrical components. On top of that, customers benefit from Solar Frontier's CIS technology, which generates high output even in unfavorable conditions. Combined with our intelligent storage device, CU-Q, our customers now have the opportunity to be independent, day and night, from external energy suppliers and price

deviations."

Strengths that distinguish CIS from other technologies include high performance under low light conditions and partial shading, high temperature stability, and a boost in power output after initial exposure to sunlight (the 'light soaking effect'). The configuration of Solar Frontier's PowerSystems is designed to leverage these strengths, enabling CIS systems to start working earlier

in the day and shutdown later in the evening, so that more energy is produced under real conditions, it is claimed.

"Customers are realizing the benefit of optimized solutions in which components complement each other, resulting in the highest possible yields," says Wolfgang Lange, managing director of Solar Frontier Europe GmbH of Munich, Germany. "The combination of our PowerSystems with Unendo's intelligent storage devices represent the optimal solution for residential and commercial customers, as they can generate their own energy at a lower price than offered by external providers," he claims.

<http://unendoenergia.it>

Solar Frontier to supply 100MW to India's Welspun Renewables

Solar Frontier has signed an agreement to supply 100MW of modules to independent solar energy project developer Welspun Renewables Energy Pvt Ltd of New Delhi, India. The modules will be used in upcoming solar power projects in India at sites with high levels of solar irradiation.

"The government of India has set a target of 175GW of renewable energy by 2022, of which 100GW will be solar energy," says Welspun Renewables' director Sindoor Mittal. "Welspun Renewables is com-

mitted to achieving high-level quality benchmarks at all of its project sites, and because of this we prefer to work with tier-1 technology providers," he adds. "We have worked with Solar Frontier on multiple projects before, and we do so again based on the proven high electricity yield and quality of its CIS technology, on top of the company's close support."

The supply agreement follows a recent spate of power purchase agreements (PPAs) that Welspun Renewables has signed with

multiple state governments in India. The firm aims to commission more than 1GW of solar and wind capacity in fiscal 2015. Welspun is present in nearly all states in India.

"This is a landmark agreement for Solar Frontier as we continue to develop our presence in key international markets with companies that are sustainable and show willingness to work closely together," says Solar Frontier's CEO Atsuhiko Hirano.

www.welspunrenewables.com
www.solar-frontier.com

Solar Frontier acquiring 280MW US project pipeline from Gestamp Solar

Gestamp's US operation joins Solar Frontier Americas

Tokyo-based Solar Frontier — the largest manufacturer of CIS (copper indium selenium) thin-film photovoltaic (PV) solar modules — has agreed to acquire a 280MW solar power project pipeline in the USA from Gestamp Solar of Madrid, Spain (the photovoltaic energy division of Gestamp Renewables), a global developer and operator of utility-scale solar power plants.

As part of the transaction, the development team leading Gestamp Solar's US operations will join Solar Frontier's US subsidiary Solar Frontier Americas. Solar Frontier has already established itself as a project developer in Japan, where it sells completed solar power plants to investors. Through this transaction, it is now bringing these broader market solutions to the USA, providing it with a catalyst to scale business in the Americas.

"The US downstream expansion is part of Solar Frontier's growth strategy to accelerate our business in key global markets through 2015

and beyond," says Solar Frontier's Atsuhiko Hirano. "The company has achieved world-class production costs and delivered exceptional product performance in Japan, a country recognized globally for demanding the highest quality in solar," he adds. "We plan to bring that same quality and performance to our fully integrated business in the US and the Americas."

Backed by the \$13bn multinational industrial holding group Corporacion Gestamp, Gestamp Solar has projects in Spain, Italy, France, South Africa, Mexico, Japan, Peru, Chile and the USA. It has developed more than 600MW worldwide and, most recently, commissioned projects that include 30MW in South Africa and 40MW in Peru.

"Solar Frontier's financial strength and high-performance products — combined with the experienced development team — is sure to enable successful completion of this US pipeline," reckons Gestamp Solar's CEO Jorge Barredo Lopez.

"We believe that this vertical integration is a major advantage in future development in the US market," he adds.

"This transaction will uniquely position Solar Frontier and its new world-class team to execute on the 280MW pipeline, thereby strengthening our global presence and allowing us to better leverage our performance advantages to achieve higher returns for our project investors," says Solar Frontier Americas' chief operating officer Charles Pimentel. "This also enables our team to build a more sustainable presence for Solar Frontier in the Americas."

Solar Frontier has supplied nearly 3GW of CIS modules to commercial and utility-scale clients around the world, including an 82.5MW solar power plant in California (the world's largest CIS installation). Solar Frontier's development operations in the USA will be based in San Francisco.

www.gestampsolar.com

www.solar-frontier.com

Solar Frontier sells its first owned-and-operated megasolar plant

Solar Frontier is selling its 2MW Kunitomi Megasolar power plant in Miyazaki Prefecture, Japan, to a trust account managed by Mitsubishi UFJ Trust and Banking Corp (MUTB). The agreement includes the transfer of all related facilities, contractual positions, rights and obligations. Kunitomi Megasolar, which started operating in March 2013, was the first megasolar power plant owned and operated by Solar Frontier.

Solar Frontier provides one-stop solar energy solutions in Japan, from manufacturing and selling CIS thin-film PV modules to project development, funding and O&M (operation & maintenance). It also builds, operates and sells



The right-hand portion of the megasolar plant is to be sold.

megasolar power plants in Japan. As part of this business model, it sells electricity as an independent power producer (IPP) with the

option to sell completed power plants to investors that wish to avoid construction-related risks.

Following this transaction, Solar Frontier will continue to be involved in the operation of Kunitomi Megasolar as the project's O&M provider.

Solar Frontier says that it aims to use the expertise it has gained by developing and operating the Kunitomi Megasolar power plant as it continues to

advance its megasolar business through projects in Japan and overseas.

www.solar-frontier.com

High-temperature and concentrated photovoltaic performance of GaInN wells

Strong potential seen for material system as active collecting junction and spectral filter for lower thermal load in conventional solar junctions.

Rensselaer Polytechnic Institute in the USA has developed nitride semiconductor solar cells with high quantum efficiency for short wavelengths (370–450nm) and concentrated photovoltaics at temperatures up to 400°C [Liang Zhao et al, Appl. Phys. Lett., vol105, p243903, 2014].

The researchers see the cells as being potential 'top cells' of multi-junction and hybrid devices. Although the bulk of solar radiation intensity occurs at shorter wavelengths, the absorption of the higher-energy shorter wavelengths can be a significant source of heating, raising solar cell temperatures and degrading performance.

The solar cells structures were grown on c-plane sapphire using metal-organic vapor phase epitaxy. The active region consisted of 2.5nm multiple quantum wells (MQWs) of gallium indium nitride (GaInN) separated by 20nm gallium nitride barriers. The wells contained an 8% molar fraction of InN. The MQWs were grown on 2μm n-GaN on the

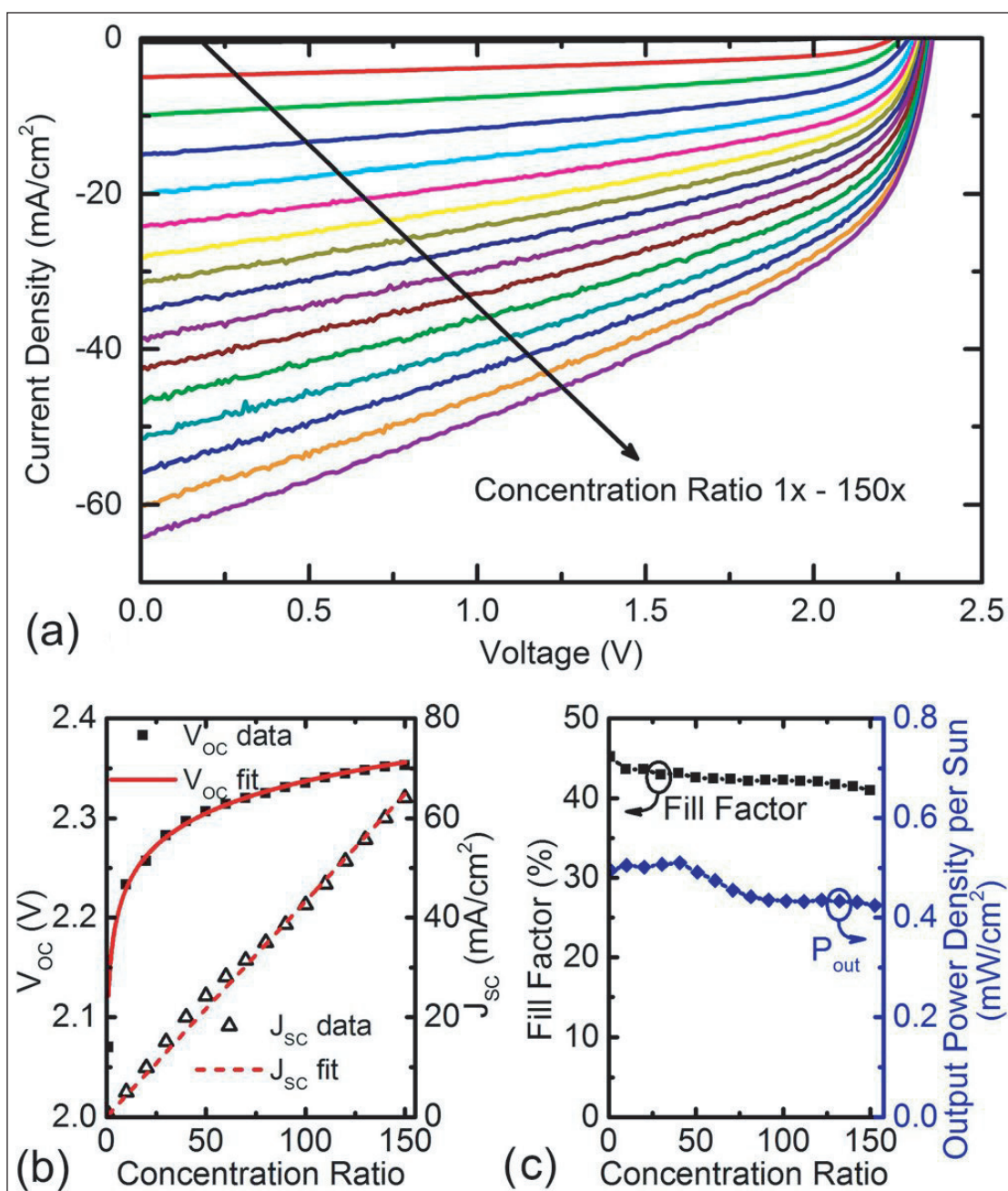


Figure 1. (a) Current-voltage behavior of 25-well cell passively cooled on aluminium chuck under concentrated illumination up to 150 suns. (b) V_{oc} and J_{sc} as functions of concentration ratio. (c) Fill factor and output power density per sun as functions of concentration ratio.

substrate. The p-type top layers consisted of 20nm aluminium gallium nitride (AlGaIn) and finally 200nm GaN.

The cell fabrication consisted of etching $350\mu\text{m} \times 350\mu\text{m}$ mesas and depositing semi-transparent nickel/gold as the p-contact and titanium/aluminium/titanium/gold for the n-contact. The researchers report that they did not make any special effort to improve the light coupling into the devices.

Devices with 8, 25 and 40 quantum wells were produced. In testing under AM1.5G solar simulated radiation (Table 1), the 40-QW device showed degraded performance in terms of open-circuit voltage (V_{OC}) and leakage current. This was attributed to V-defects that began to appear when more than 20 quantum wells were grown.

The researchers believe that this problem could be resolved in future development aimed at controlling and avoiding V-defect formation. The hopeful result of such development

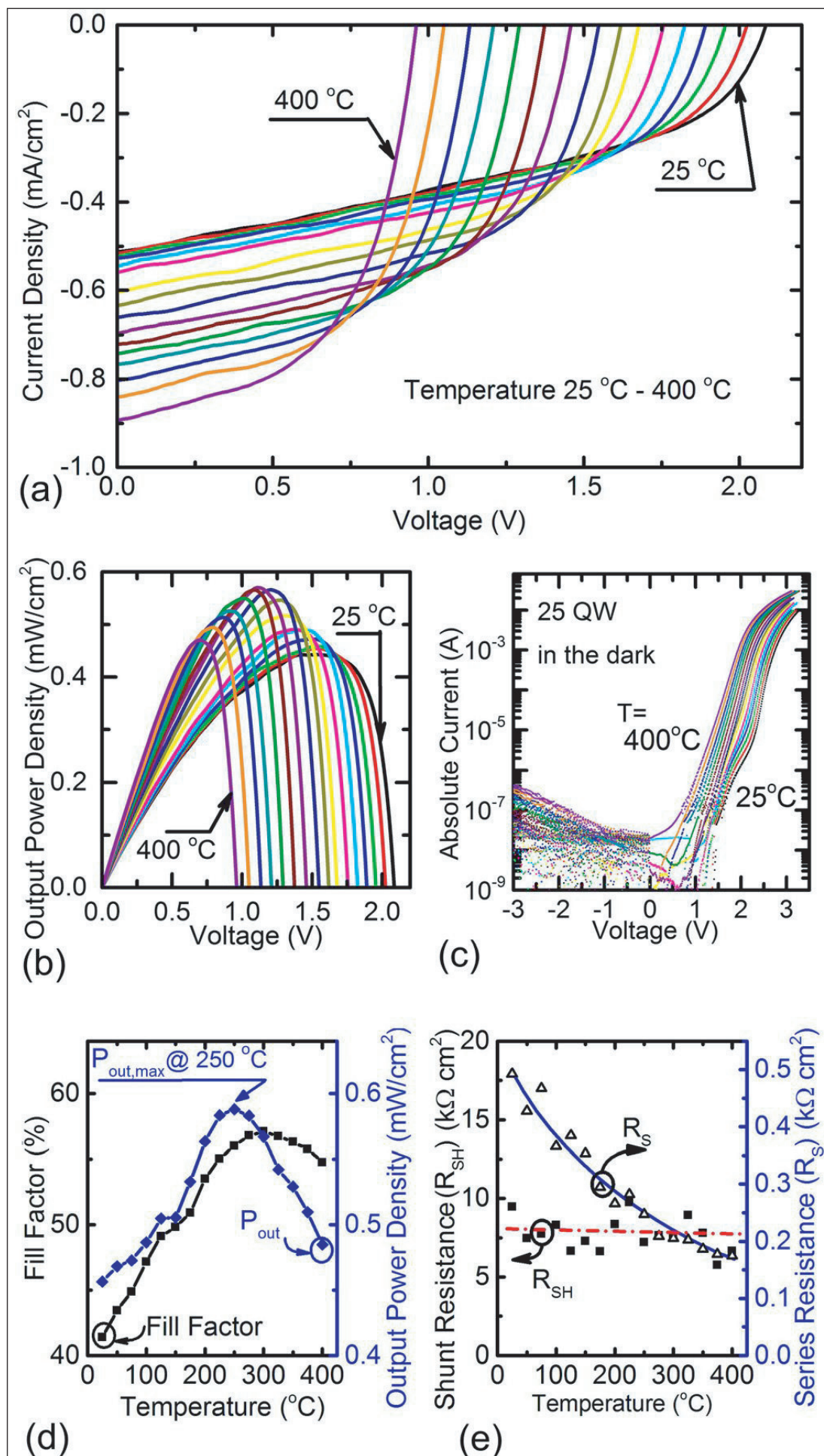


Figure 2. Junction current-voltage performance under elevated chuck temperature up to 400°C (25 QW structure) under illumination (a) and in the dark (c). (b) Output power density versus voltage, (d) fill factor and maximum output power density as functions of temperature, and (e) series resistance and shunt resistance all as functions of temperature.

Table 1. Short-circuit current density (J_{sc}) and open-circuit voltage (V_{oc}) under 1-sun AM1.5 illumination.

QWs	J_{sc}	V_{oc}
8	0.26mA/cm ²	2.12V
25	0.51mA/cm ²	2.07V
40	1.35mA/cm ²	0.86V

Table 2. Performance of 25-well device at 25°C and 400°C.

	25°C	400°C
V_{oc}	2.08V	0.96V
J_{sc}	0.51mA/cm ²	0.89mA/cm ²
$P_{out,max}$	0.46mW/cm ²	0.48mW/cm ²
FF	43.4%	56.2%

would be a short-circuit current density (J_{sc}) more than 1mA/cm² with V_{oc} more than 2V. In fact, the team believes that 40 wells are needed for 'full absorption' of the short-wavelength (370–450nm) radiation.

Estimates of the internal quantum efficiency (IQE) gave a 94% peak at 434nm for the 8-well structure. The 25-well cell showed a broader plateau of ~70% in the narrow 370–450nm range. Internal power conversion efficiency was put at 42.0% for the 8-well and 38.6% for the 25-well structures.

The 25-well cell was also subjected to concentrated

AM1.5G illumination up to 150 suns (Figure 1). The ratio of maximum output power to the product of J_{sc} and V_{oc} – the 'fill factor' – decreased slightly from 45% to 41% as the number of suns increased. The maximum output power density per sun initially peaked at 0.51mW/cm² for 40-sun illumination. The values at 1-sun and 150-suns were 0.49mW/cm² and 0.42mW/cm², respectively.

The researchers comment: "With a value above 0.4mW/cm² and an overall loss of not more than 14% for the partial spectrum performance (350–450nm) up to concentrations of 150 suns without any active cooling, these results demonstrate the strong potential of the material system as an actively collecting junction and spectral filter for a lower thermal load in secondary conventional solar junctions."

The 25-well structure was also tested for performance at temperatures up to 400°C (Figure 2, Table 2). The higher temperature increases J_{sc} at the cost of reducing V_{oc} . The peak output power density of 0.59mW/cm² occurred at 250°C. The fill factor increased to 57.1% at 300°C.

The improved output power and fill factor at higher temperatures is attributed to a temperature-induced shift of the cell sensitivity to longer wavelengths where there is more solar radiation. However, the maximum power at 250° compares with previous work by others where the maximum occurred at 70°C. ■

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Photonic crystal improves light output of InGaN LED by 42% at 350mA

Low-cost polystyrene nanosphere lithography has been used to produce an array of holes at the interface between p-GaN and a silver reflector.

Researchers at Chinese Academy of Sciences' Institute of Semiconductors have achieved a 42% enhancement in light output from flip-chip indium gallium nitride (InGaN) light-emitting diodes (LEDs) by incorporating a photonic crystal (PHC) structure at the interface between the device and a silver reflector (Figure 1) [Aigong Zhen et al, Appl. Phys. Lett., vol105, p251103, 2014].

The photonic crystal structure was achieved through lithography using 600nm-diameter polystyrene nanospheres. The spheres were arranged in a single-layer close-packed array, creating a mask for etching hexagonal patterns of holes in the p-type GaN contact layer. The holes were 600nm pitch, 410nm diameter, and 78nm depth. The fill factor of holes was 0.42.

The researchers see their method of producing photonic crystals as more cost effective compared with technologies needing further crystal growth of zinc oxide nanorods or other materials. With InGaN LEDs without light extraction enhancements, some two-thirds of the produced photons can be reflected back into the device, where the energy may be lost through re-adsorption.

The epitaxial material for the LEDs was grown on c-plane sapphire through metal-organic chemical vapor deposition (MOCVD). The epitaxial layers included a 30nm GaN nucleation layer, a 2μm undoped u-GaN buffer layer, a 2μm silicon-doped n-GaN layer, a 180nm InGaN/GaN 450nm-wavelength-emitting multiple quantum well (MQW) layer, a 20nm AlGaIn electron-blocking layer, and a 200nm magnesium-doped p-GaN layer.

The epitaxial material was fabricated into 45milx45mil mesa LEDs with a nickel/silver/platinum/gold p-electrode/reflector and chromium/platinum/gold

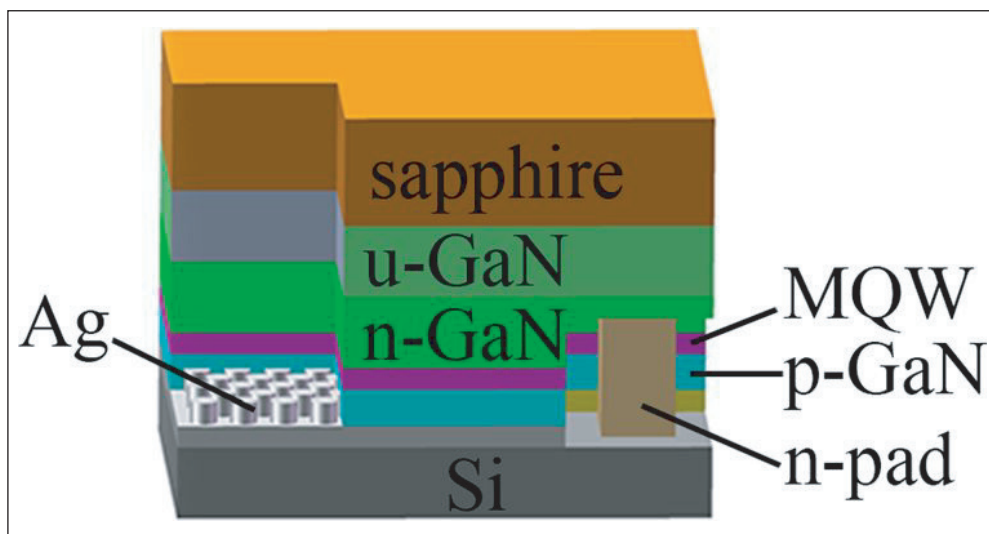


Figure 1. Schematic illustration of FCLED with embedded PHC at the interface of p-GaN and silver (Ag) reflector.

n-electrode. Singulated chips were flipped onto a silicon submount with gold interconnects.

The electroluminescence from the device showed a 42% enhancement in light output power (LOP) at 350mA current injection over a reference 'planar' flip-chip LED (FCLED) without photonic crystal. The researchers comment: "The significant improvement in the LOP is mostly attributed to the guide-light diffraction by the embedded PHC structures."

The divergence angle of half intensity of the PHC LED was 145°, compared with 163° for the planar device. The researchers believe that this indicates that the embedded PHC structure serves as a diffraction layer, redirecting light to angles where photons can escape from the top of the chip.

The light extraction efficiency (LEE) enhancement of the fabricated devices was less than suggested by simulations. The researchers comment that this may be due to two factors: "First, the lateral surface of holes is not smooth, which will enhance absorption. Second, the periodicity defects of the PHC structure could weaken the interaction between PHC and guide-light." ■

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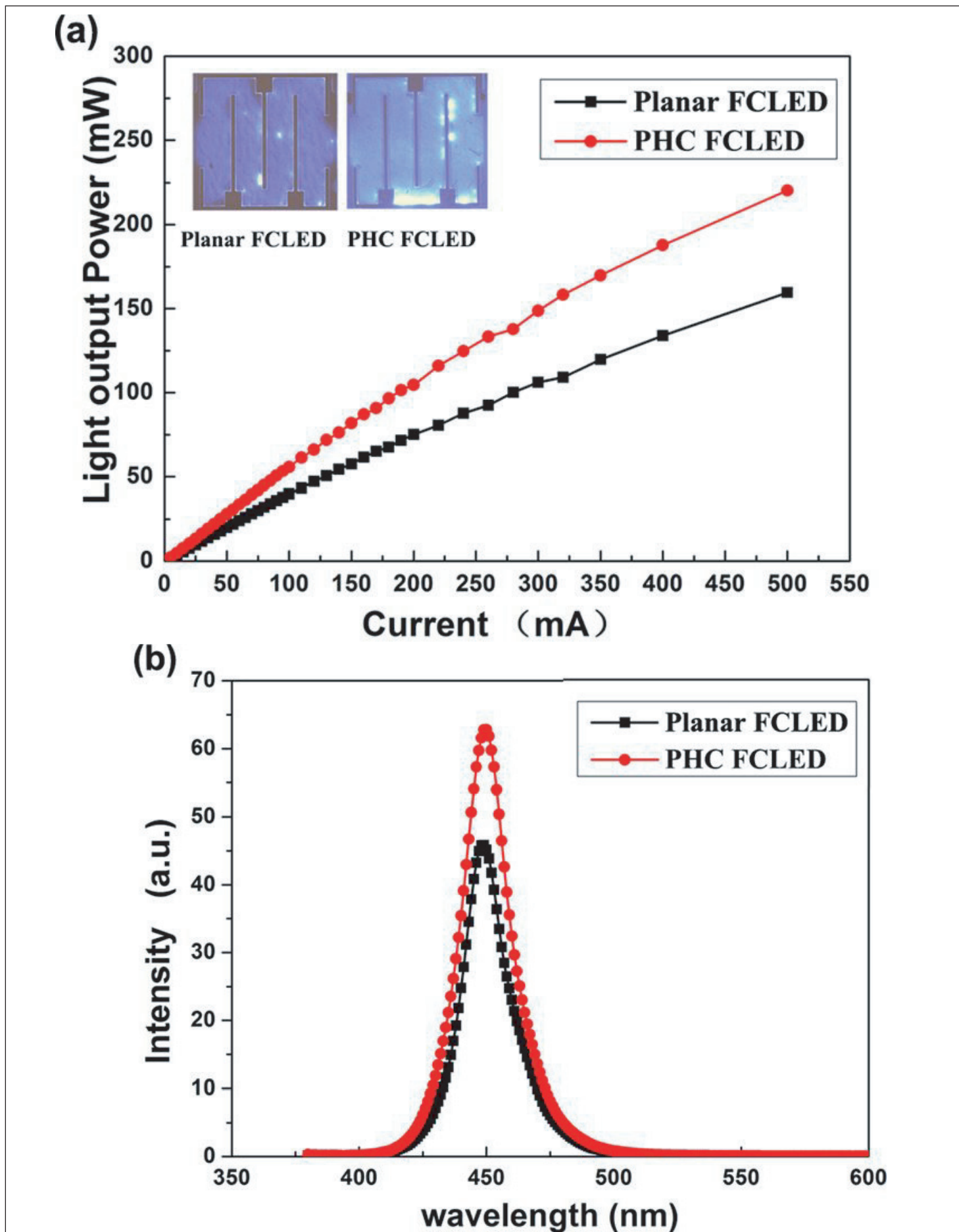


Figure 2. (a) Light output power of PHC FCLED and planar FCLED versus injection current; (b) EL emission spectra of PHC FCLED and planar FCLED at 350mA drive current.

Plasma-assisted molecular beam epitaxy of indium gallium nitride

Taiwan research develops two-step process for high indium content and high-intensity green light emission.

National Tsing Hua University, Taiwan, has been developing plasma-assisted molecular beam epitaxy (PAMBE) of indium gallium nitride (InGaN) for green light emission [W. C. Yang et al, J. Appl. Phys., vol117, p015306, 2015].

Improving the green emission of InGaN is a strategic aim of many researchers for creating high-quality white and colored light in equipment based on light-emitting diodes and laser diodes. Green light falls in the wavelength range 495–570nm.

Single quantum wells of InGaN sandwiched between GaN barriers were produced on GaN templates. The well was of the order 3nm thick, sandwiched between a 300nm GaN buffer and a 45nm GaN cap.

The InGaN layer was grown in two steps (Figure 1). First, all three species — In, Ga, N — were available, resulting in InGaN with 10% indium and a couple of monolayers of accumulated In atoms. The V/III flux ratio was 1 and the In/Ga flux ratio was 1.33. The indium source was then shut off and the residual indium atoms were incorporated in the remainder of the InGaN layer with up to 30% indium incorporation, dependent on growth temperature. The InGaN compositions were determined by secondary-ion mass spectroscopy (SIMS) and x-ray diffraction analysis.

The templates were produced on 2-inch patterned sapphire substrates (PSS) to improve crystal quality. The researchers used a Veeco MBE system with nitrogen RF plasma source, and In and Ga effusion cells. The growth mode of PAMBE InGaN has been found to be liquid- rather than vapor-phase epitaxy. Liquid Ga mixed with In and N accumulates on the surface of the substrate during epitaxial growth.

The back-sides of the substrates were coated with 1µm of titanium to give uniform, efficient heat transfer from the substrate heater. The templates were

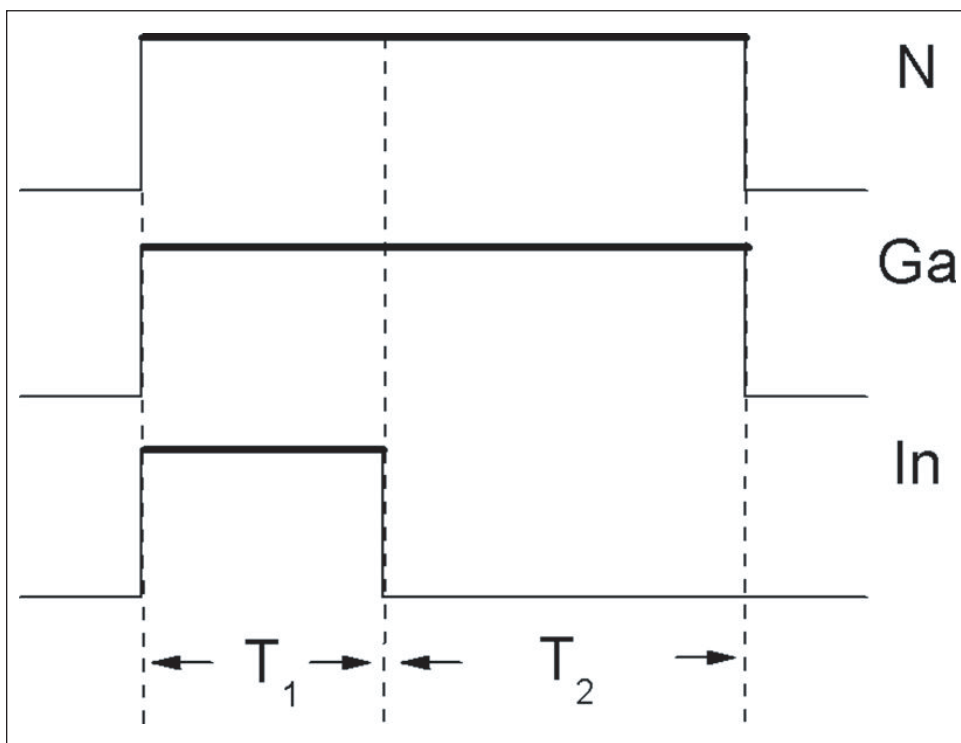


Figure 1. Scheme of source shutter sequences used in two-step PAMBE growth of InGaN SQWs.

Increasing the growth temperature initially increased the indium content of the wells, increasing the PL wavelength toward the green region of the visible spectrum. However, beyond 650°C, the indium atoms begin to evaporate from the liquid layer from which the crystal grows

decreased before loading in the MBE system.

Before deposition the substrates were heated to 830°C in the reactor for thermal cleaning. The main deposition was carried out at 600–750°C. The growth rate was affected by the partial pressures of the In/Ga in the system. Most of the samples were processed at a “moderate growth rate” of 3.6nm/minute. However, four samples were grown at a higher rate of 5.6nm/minute.

The researchers found that increasing the growth temperature initially increased the indium content of the wells, increasing the photoluminescence (PL) wavelength toward the green region of the visible spectrum (Figure 2). However, beyond a certain point ($\sim 650^{\circ}\text{C}$), the indium atoms begin to evaporate from the liquid layer from which the crystal grows, saturating incorporation and the wavelength increase.

As indium content increases, InN becomes immiscible in GaN and phase separation occurs. The wells in high-indium-content samples were thicker ($\sim 4.5\text{nm}$), leading to quantum-confined Stark effects from electric fields across the well, reducing emission intensity. The researchers therefore view

650°C as the optimal growth temperature. Also, the moderate growth rate of 3.6nm/minute is preferred.

They suggest "one way to extend the emission peak wavelength while maintaining a high emission intensity of the InGaN SQW is to minimize polarization effects by using non-polar substrates while increasing the

SQW thickness."

The longest wavelength with strong PL emission was achieved with 30% indium content and 506nm wavelength (Table 1). ■

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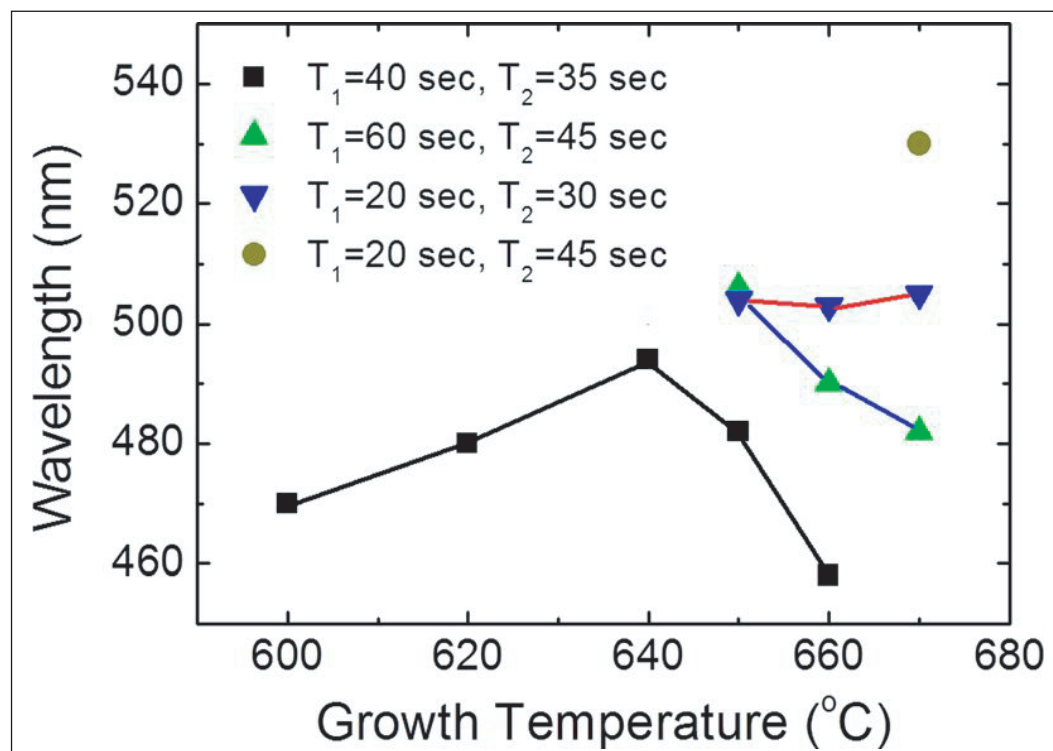


Figure 2. Trend of achieved PL wavelength for all samples grown under various growth conditions. Samples grown at a moderate rate of $\sim 3.6\text{ nm/min}$, square and triangle; faster rate of $\sim 5.5\text{ nm/min}$, circle and inverted triangle.

Table 1. Indium accumulation time (T_1), indium incorporation time (T_2), and growth temperature (T_G) used to grow InGaN/GaN SQW samples and their PL peak wavelengths, relative intensities, and indium content. All samples were grown at $\sim 3.6\text{ nm/min}$, except N, O, P and Q, at $\sim 5.5\text{ nm/min}$.

Sample	T_1 (s)	T_2 (s)	T_G ($^{\circ}\text{C}$)	PL peak wavelength (nm)	Relative PL intensity (a.u.)	In content (%)
A	40	25	600	460	5.11	...
B	40	35	600	470	2.41	17.8
C	40	45	600	500	2.22	...
D	40	35	620	480	3.36	22.5
E	40	35	640	494	3.44	28.1
F	40	35	650	482	8.26	23.1
G	40	35	660	458	8.67	12.2
H	40	45	640	500	5.23	...
I	40	45	650	480	8.12	...
J	40	60	640	516	3.03	28.6
K	60	45	650	506	10.53	30.2
L	60	45	660	490	8.88	...
M	60	45	670	480	11.63	...
N	20	30	650	504	6.1	...
O	20	30	660	503	10.7	...
P	20	30	670	505	8.4	31.8
Q	20	45	670	530	1.2	32

Silver nanowires and compound semiconductor optoelectronics

Mike Cooke reports on recent research into transparent conducting layers that incorporate silver nanowires as a possible replacement for indium tin oxide.

A large range of electronics chemical suppliers offer silver nanowires in various solvents — water, ethanol, isopropyl alcohol, etc. These companies market AgNWs mainly for touchscreen and other transparent conductive electrode (TCE) applications offering flexible electronics. Recent research has focused more generally on the possibility of using AgNWs to replace expensive indium tin oxide (ITO) TCEs.

The AgNW solutions are generally spin-coated onto target device structures. Spin-coating could be a low-cost alternative to TCE processes using ITO or more complex techniques such as graphene deposition on metal foil and transfer. Although AgNWs potentially suffer from long-term stability/degradation problems, these could be overcome with suitable encapsulation and packaging.

Here we look at attempts to combine AgNWs into TCE structures for compound semiconductor optoelectronics.

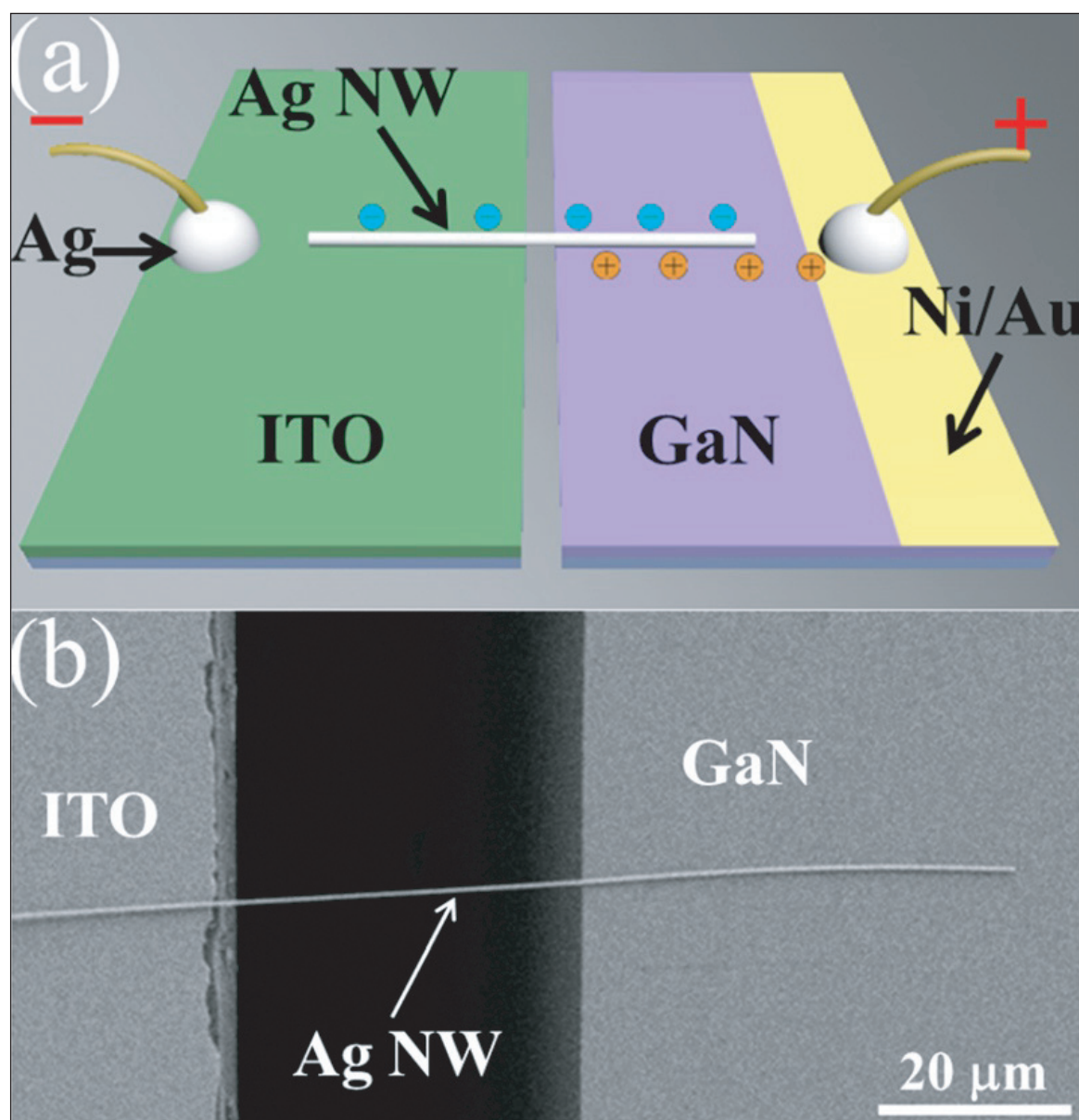


Figure 1. (a) Single AgNW/p-GaN ST-LED. (b) SEM image of as-fabricated device.

Schottky UV-LEDs

China's Zhejiang University and the UK's University of Cambridge have jointly developed ultraviolet light-emitting diodes (UV-LEDs) based on metal-semiconductor

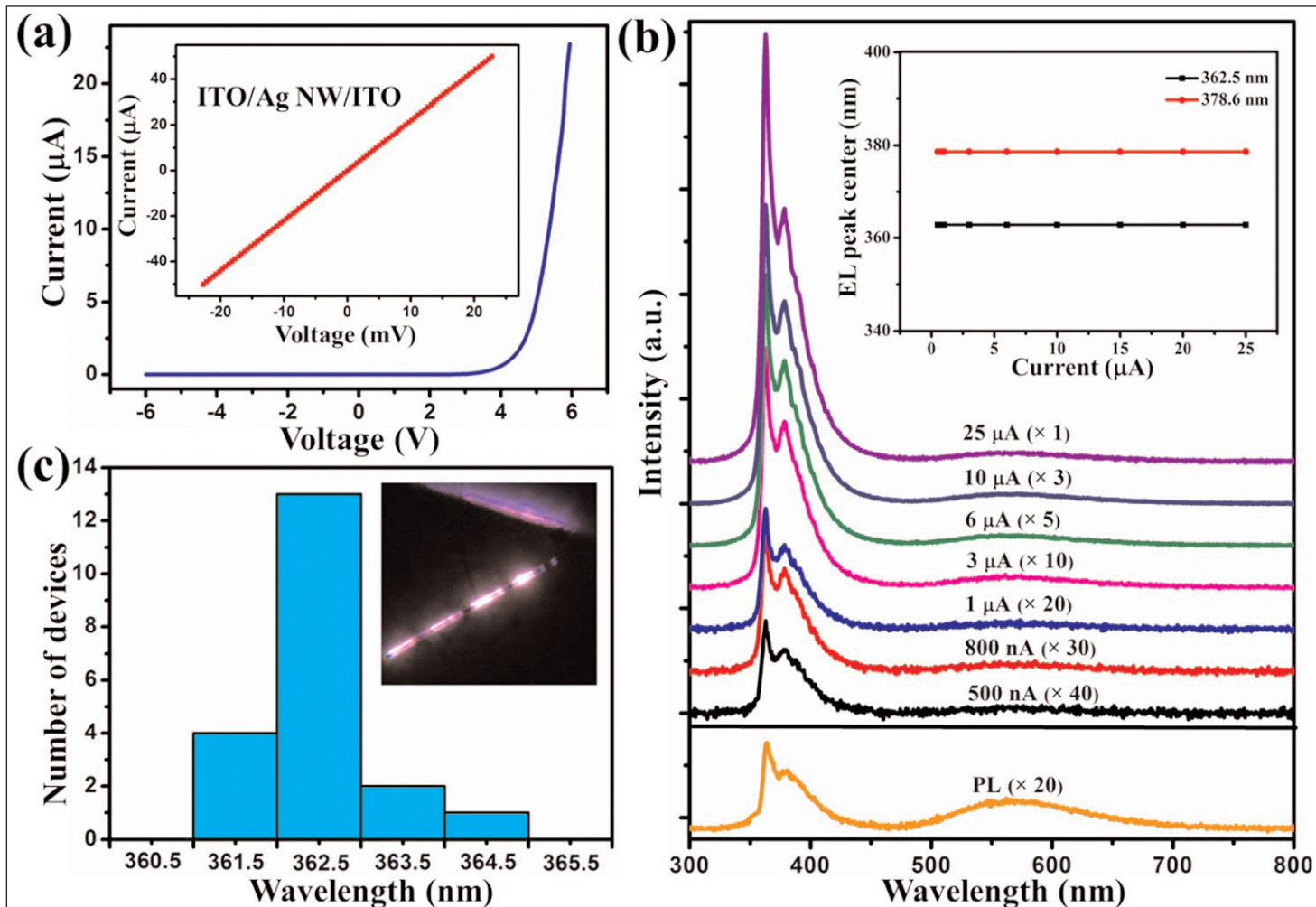


Figure 2. (a) Current versus voltage (I–V) characteristics of an as-fabricated device. Inset: ohmic contact behavior of ITO/AgNW/ITO structure. (b) EL spectra of device under various injection currents and the photoluminescence (PL) spectrum of p-GaN under 355nm pulsed laser excitation. Inset: EL peak position (362.5nm and 378.6nm) versus different forward currents of same device. (c) Dominant emission peak distribution of 20 devices. Inset: typical optical microscope image of emission.

Schottky junctions between silver nanowires (AgNWs) and gallium nitride (GaN) [Y. Wu et al, Appl. Phys. Lett., vol106, p051108, 2015].

The external quantum efficiency (EQE) for radiation around 362.5nm wavelength was as high as 0.9%. The researchers comment: "The EQE of our device is the highest reported to date for UV LEDs based on a Schottky junction."

UV-LEDs are being developed for a wide range of applications such as high-density information storage, water purification, the disinfection of medical tools, UV curing, phototherapy, and medical diagnostics.

The researchers see three advantages of Schottky-type LEDs (ST-LEDs) over conventional multiple quantum well (MQW) devices: "First, ST-LEDs do not require complex processing such as those required for MQWs. Second, the device operation does not rely on a p–n junction, reducing the difficulties associated with doping of semiconductors. Finally, it does not require the deliberate introduction of an intrinsic layer to reduce leakage current and to accumulate carriers

near the interface, which is a key process in [metal-insulator-semiconductor] MIS LEDs."

Conventional ST-LEDs suffer a tradeoff from the metal layer absorbing a significant percentage of the LED output, reducing overall efficiency. The use of nanowires reduces this blocking of radiation.

The Zhejiang/Cambridge devices have a simple structure (Figure 1) that the researchers believe has "the potential to be a cost effective alternative to traditional UV-LEDs and can also be integrated into nano-optoelectronic systems".

The semiconductor material for the device was p-GaN grown on sapphire by metal-organic chemical vapor deposition (MOCVD). The diode fabrication began with cleaning and etching to remove native oxide from the GaN surface. After rinsing and drying, the nickel/gold p-electrode (anode/p-contact) was deposited by thermal evaporation. The cathode (n-contact) was an indium tin oxide (ITO) covered sapphire substrate micro-manipulated to give a gap of less than 0.35 μm from the GaN substrate.

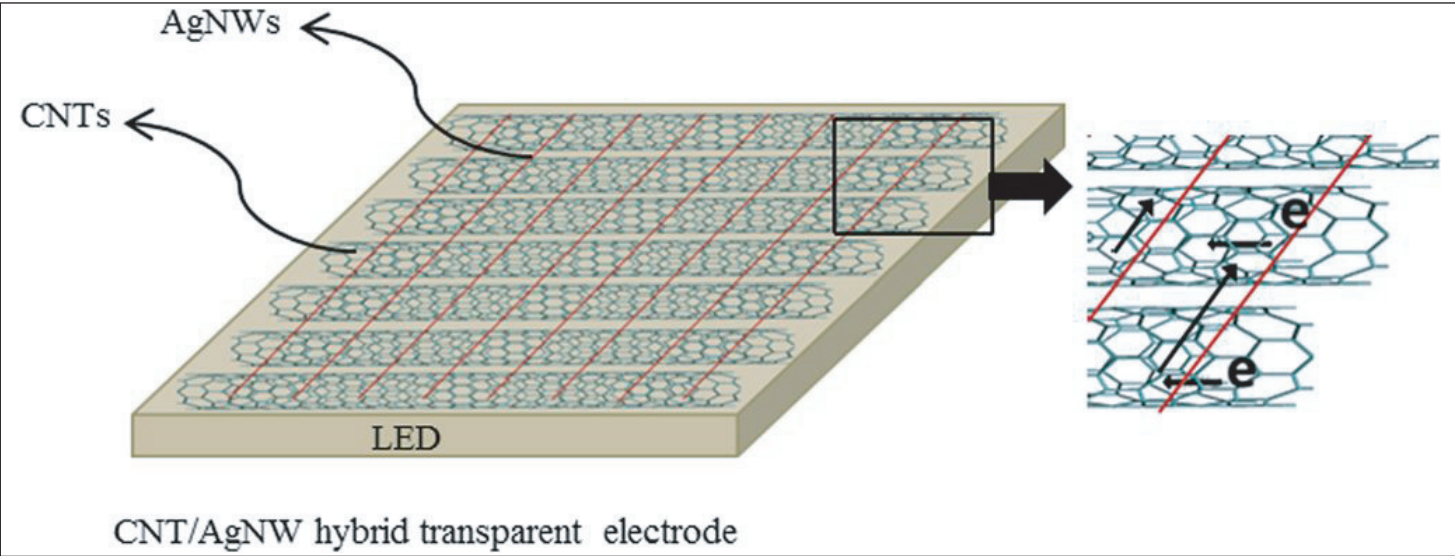


Figure 3. Schematic of LED with CNT/AgNW hybrid film as transparent conducting layer.

► The gap between the p-GaN and ITO was bridged by silver nanowires produced by ‘soft self-seeding’. The nanowires were generated from silver nitrate reduced with ethylene glycol (EG) in the presence of polyvinyl pyrrolidone (PVP). The resulting wires had a diameter of 120–500nm and a length of more than 50µm. The nanowires were purified in several cycles by immersing in ethanol, centrifuging and then rinsing in deionized water.

The nanowire suspension was deposited on clean glass. Single nanowires were then transferred to bridge the gap between the ITO and GaN substrates. The AgNWs were held in place by van der Waals forces.

The current–voltage curve of the device was rectifying with a forward bias onset at 4.8V (Figure 2). The silver-ITO and GaN-nickel/gold contacts were found to be ohmic in separate tests. The diode behavior was therefore a result of the Ag/p-GaN contact.

Electroluminescence (EL) was observed for forward currents as low as 500nA. The UV emission included two contributions: a main peak at 362.5nm with 7nm full-width at half maximum (FWHM) and a second peak at 378.6nm with 30nm FWHM.

The researchers attribute the main peak to recombination through an exciton state (electron–hole bound state). The second peak was assigned to isolated magnesium atoms from the p-GaN doping. There was also weaker defect-related emission from the visible range 480–710nm.

Much of the emission was trapped in the GaN because of total internal reflection from the GaN/air interface refractive index contrast. Trapped light was emitted from the edge of the device. The light output intensity increased as a 1.24 power of the current injection. The ‘superlinear’ behavior of the intensity is attributed to the changing balance of radiative and non-radiative recombination mechanisms. At 25µA injection the EQE was estimated to be 0.9%.

The team attributes the relatively high efficiency to the reduced blocking of the light by the nanowires compared with the usual metal electrodes. “The performance is also comparable to those of UV-LEDs based on NW/thin film p-n hetero-/homo-junctions and MIS junctions, with a simpler device architecture and potentially lower fabrication cost,” the researchers add.

The highest efficiency was obtained for nanowires of 250nm diameter. Beyond that self-heating effects reduced the performance to 70% of the maximum EQE with 170nm diameter. (The current injection was not pulsed to avoid self-heating effects.) Narrower wires are less able to transmit heat away from the AgNW/GaN junction.

Enhancing carbon nanotube layers

Researchers in China have developed a hybrid AgNW/carbon nanotube (CNT) current spreading layer for aluminium gallium indium phosphide (AlGaInP) LEDs [Bai Liu et al, Appl. Phys. Lett., vol106, p033101, 2015].

The team based at Beijing University of Technology, Beijing University of Chemical Technology and Tsinghua University used the AgNWs to redistribute carriers between the CNTs (Figure 3). Without the NWs, the rate of carrier transfer between CNTs is low due to a high inter-tube contact resistance.

The researchers comment: “The hybrid film takes advantage of the extremely high mobility and conductivity of individual CNTs and avoids the high inter-tube contact resistance of CNT networks by including AgNWs. The carriers are not only transported along the CNTs but also between CNTs through the AgNW bridges in a vertical direction, providing a symmetric carrier distribution.”

The AlGaInP LEDs consisted of an 800nm active region with 60-period $(\text{Al}_{0.5}\text{Ga}_{0.5})_{0.5}\text{In}_{0.5}\text{P}/(\text{Al}_{0.1}\text{Ga}_{0.9})_{0.5}\text{In}_{0.5}\text{P}$ multi-quantum well. The active region was sandwiched

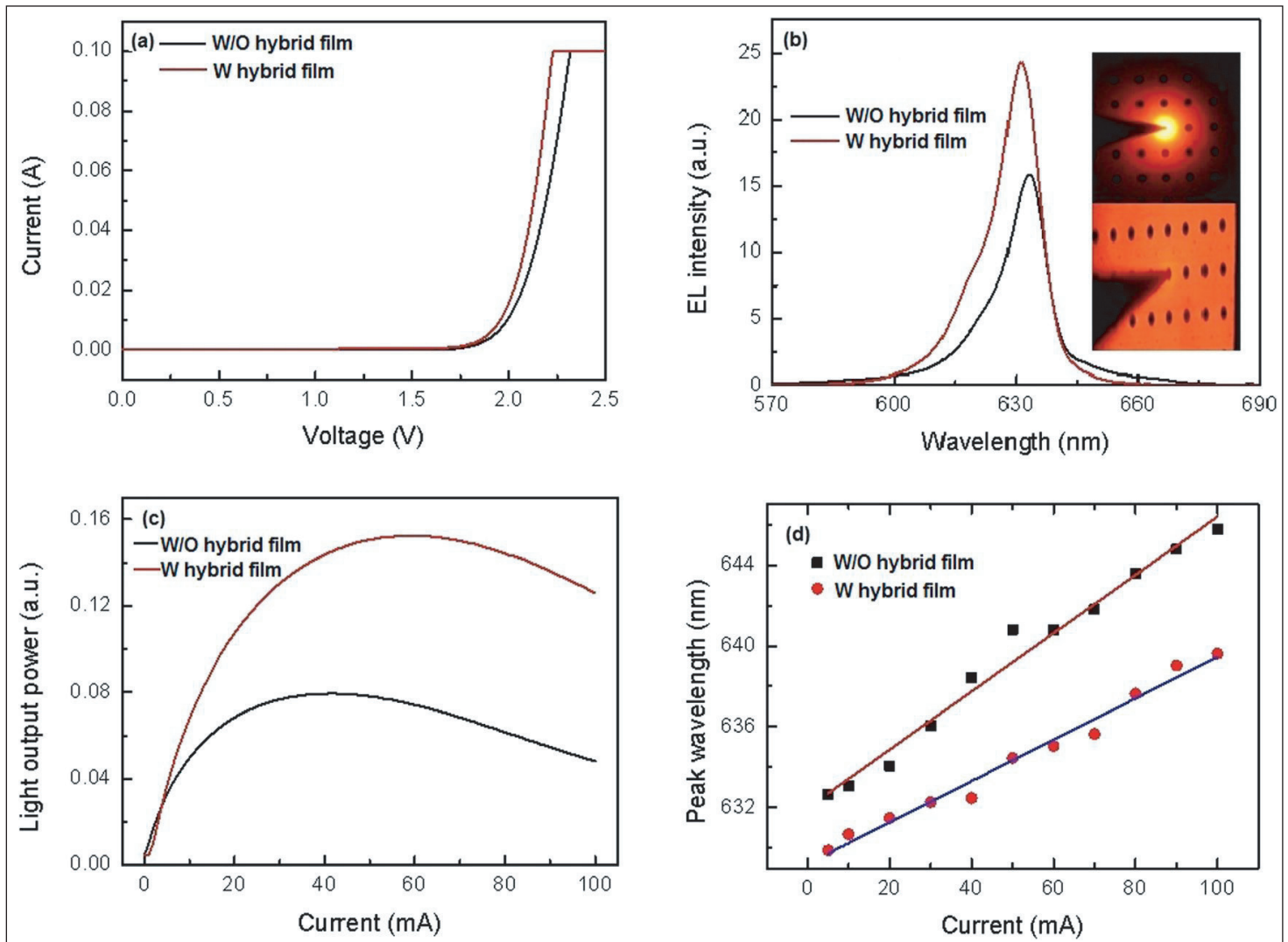


Figure 4. (a) Current versus voltage, and (b) EL spectra at 20 mA (inset: EL images at 2.5mA of 2.5μm x 2.5μm area around electrodes of control and hybrid-film LED wafers), and dependence of (c) light output, and (d) peak wavelength on injection current of AlGaInP LEDs with and without AgNW/CNT hybrid film.

between n- and p-type cladding layers of $(\text{Al}_{0.7}\text{Ga}_{0.3})_{0.5}\text{In}_{0.5}\text{P}$. The LED heterostructure was grown on a distributed Bragg reflector consisting of 15 layer pairs of $\text{Al}_{0.6}\text{Ga}_{0.4}\text{As}/\text{AlAs}$ on a 100nm gallium arsenide (GaAs) buffer. The growth substrate was n-GaAs. The structures also included a final 500nm p-GaP window layer.

The p-electrode consisted of a 100μm-diameter region of gold/beryllium-gold/gold. The n-electrode was gold-germanium-nickel/gold sputtered onto the back-side of the growth substrate. The CNTs were drawn continuously from multi-walled CNT arrays, adhering through Van der Waals forces. The process resulted in 'a super-aligned CNT (SACNT) film', according to the researchers. Titanium/gold was deposited and patterned on the p-electrode to make sure the SACNT film remained in place. The resulting LED chips were 300μm x 300μm.

Optical transmission of 550nm wavelength through the SACNT was about 85%. To increase the light transmission the researchers used a 30-second oxygen plasma etch to decrease the density of tubes, increasing

transmission to 96%. After the etch, the AgNWs were spin-coated onto the CNTs. The structure was then annealed at 200°C for 10 minutes to improve the electrical contact between the AgNWs and CNTs.

By varying the AgNW concentration in the spin-coating process, the light transmission ($T_{550\text{nm}}$) could be traded off against sheet resistance (R_s). "For AgNW concentrations of 0.25mg/ml and 0.5mg/ml, $T_{550\text{nm}}$ (R_s) of the hybrid films was 93% (88Ω/square) and 90% (23Ω/square), respectively," the researchers report. The sharp drop in resistance is attributed to a typical percolation threshold effect, where a small increase in connectivity of a random network creates conduction paths across a space.

One effect of the AgNW/CNT hybrid film was to slightly reduce the LED forward voltage at 20mA from 2.1V to 2.0V (Figure 4). This indicates a reduced series resistance loss.

The electroluminescence was 'greatly enhanced' at 20mA by the presence of the hybrid AgNW/CNT current-spreading layer, despite an estimated 10%

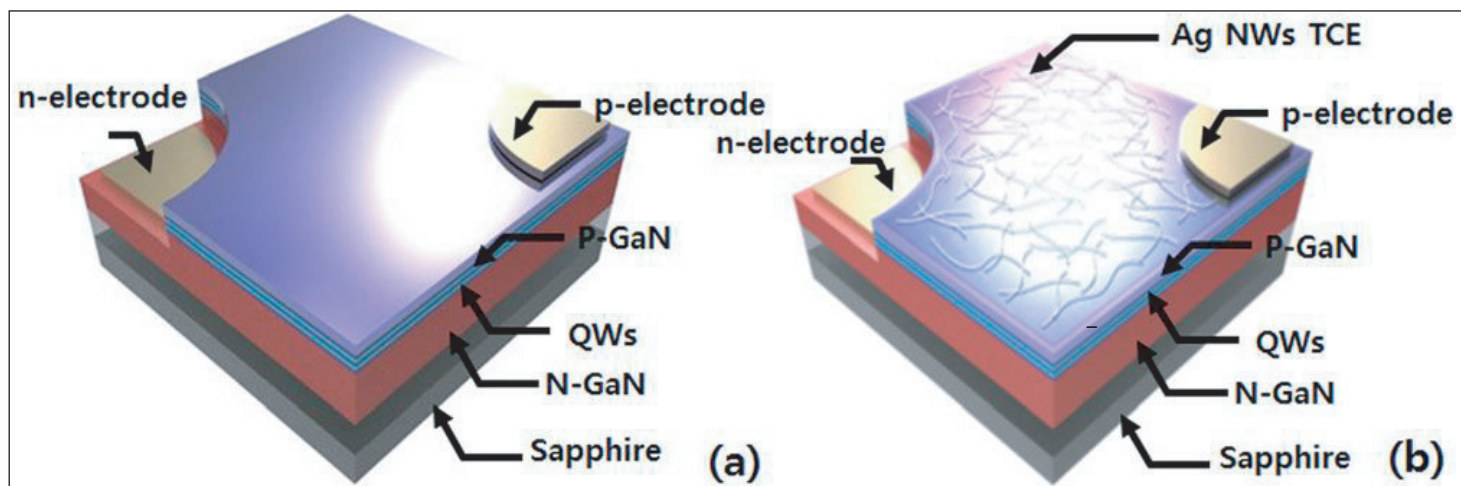


Figure 5. Schematics of conventional InGaN LED (a) and LED with AgNWs as transparent conductive electrode (b).

optical loss. The researchers add, "The high surface roughness of the hybrid film further increased the light output of the LED." This was presumably due to better transmission of light — rather than reflection — from the device-air interface.

The emission pattern of the LED chip without hybrid film showed current crowding around the p-electrode. By contrast, the emission from the LED with hybrid film was bright and uniform across the chip. The integrated intensity of the hybrid-film LED was 1.6x that of the control device at 20mA. The 1.6 enhancement factor continued up to 60mA injection. Beyond that the enhancement was limited by self-heating effects. The researchers say the current spreading effect was reduced by the higher temperature in the film.

With increased current injection, the emission peaks of both devices red-shifted — at the rates 0.1nm/mA and 0.15nm/mA for the hybrid-film and control devices, respectively. At 100mA, the corresponding total redshifts were 9.7nm and 13.11nm.

InGaN LEDs

Researchers have also investigated the use of just AgNWs as TCE. In Korea, a team based at Korea Polytechnic University and Chonbuk National University has used spin-coated AgNWs to improve the performance of InGaN LEDs [Gyu-Jae Jeong et al, Appl. Phys. Lett., vol106, p031118, 2015].

The researchers say that before their work "there have been no reports detailing the use of only AgNWs in GaN-based LEDs as TCEs, with the exception of graphene/AgNW hybrid films." The team believes improved LED performance was due to better current spreading and thermal dissipation via the AgNWs.

The InGaN heterostructures were grown on sapphire by metal-organic chemical vapor deposition. The LED material consisted of a GaN buffer (2μm) and n-contact (3μm), 5-period $\text{In}_{0.15}\text{Ga}_{0.85}\text{N}$ wells in GaN barriers, and GaN p-contact (0.1μm).

The epitaxial material was fabricated into 'ultra-large-

size' 5mmx5mm mesa-structure LEDs (Figure 5). Conventional mesa-LEDs typically measure on the order of 1mmx1mm. The electrodes consisted of indium/tin.

The AgNWs were spin-coated for 40 seconds at 800 rotations per minute from a suspension supplied by Korean company Nanopyxis Inc [<http://nanopyxis.com>]. The nanowire source solution was sonicated for 6 minutes and shaken well before application. The deposited film was annealed for one minute at 100°C, giving a sheet resistance of 15Ω/square.

The researchers report that the coating process resulted in networks of randomly oriented AgNWs with less than 50nm height variation — "sufficiently planar to form a p-type electrode in LEDs". The average NW diameter was 25nm. The lengths were of the order of tens of microns.

The open regions without NWs constituted about 84% of the surface. The optical transmittance of LED material with AgNWs was about 6% less than without. However, photoluminescence was decreased about 32.5% by having NWs.

The researchers describe the electroluminescence emission as 'strong' in the blue region around 460nm with and without AgNW contact layers. The peak at 20mA was at 457.8nm with AgNWs and at 452.7nm without AgNWs. Increasing the current injection between 10mA and 100mA led to a large shift in wavelength of 3.5nm for the LED without AgNWs. Over the same range, the LED with AgNWs shifted only 0.3nm. The more stable behavior of the device with AgNWs was attributed to better current spreading leading to a decrease in the effective current density through the device.

The researchers comment: "The band-filling effect of the LED without AgNWs appeared to be dominant compared to the LED with AgNWs due to decreased carrier density, resulting in the longer emission wavelength of LEDs with AgNWs than LEDs without AgNWs. Moreover, at increasing injection current, this also likely contributed to the lower blue-shift of LEDs with AgNWs than LEDs without AgNWs."

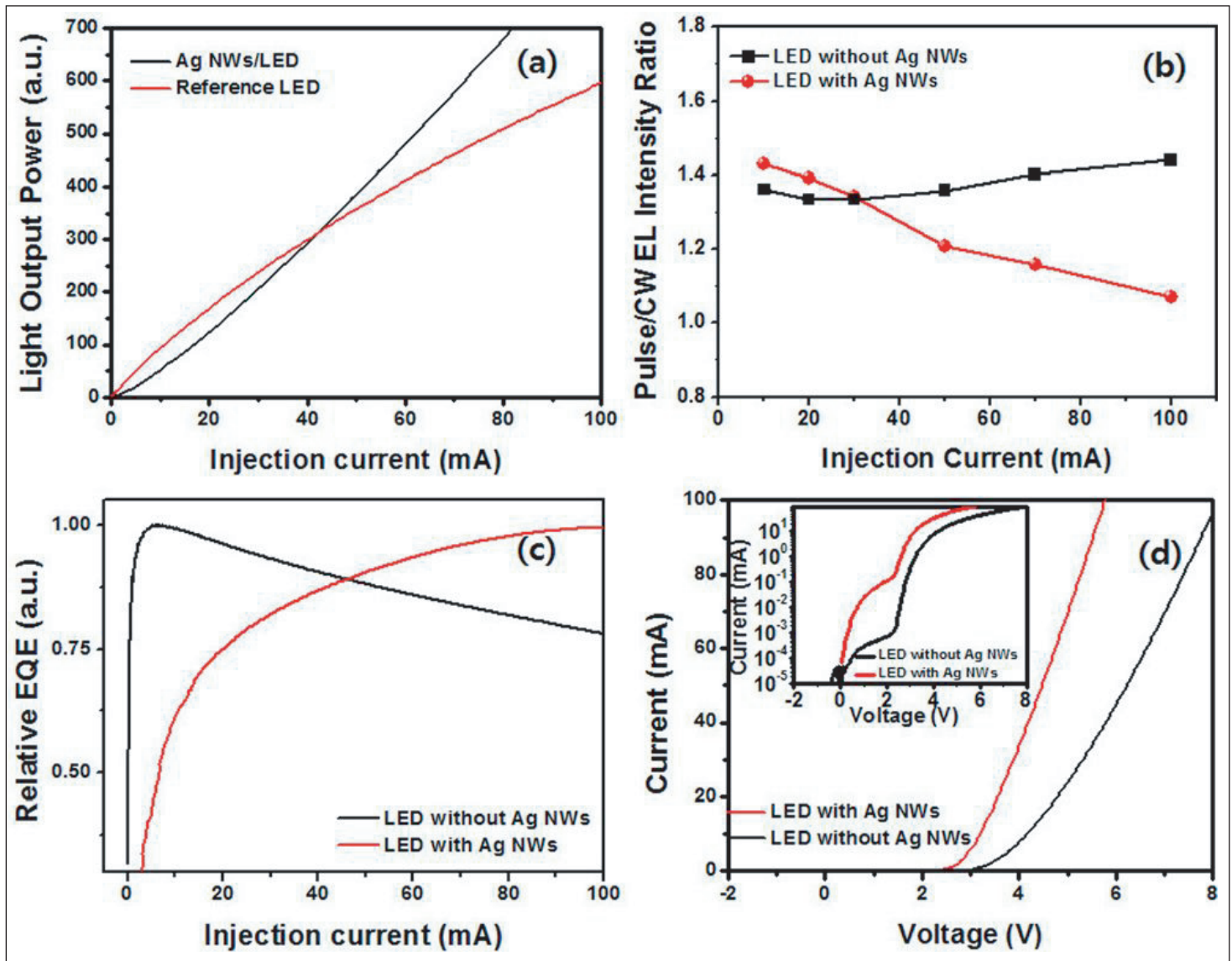


Figure 6. Light output power (a), pulse/continuous wave (cw) EL intensity ratio (b), and relative EQE (c) of GaN-based LEDs without/with AgNWs as a function of injection current. Current-voltage characteristic (d) of LEDs with/without AgNWs.

The spectral line was also narrower for the LED with AgNWs — around 15nm full-width at half maximum (FWHM), compared with ~20nm for the LED without current spreading. Although the FWHM increased in both devices at higher currents, the ~5nm difference was maintained. The researchers attributed the difference to the lower junction temperature (46.8°C at 50mA, compared with 70.5°C) in the device with AgNWs.

"We surmised that the narrower FWHMs of the EL spectra originated from a decreasing thermal heating effect due to improved heat dissipation afforded by the AgNWs," the researchers write.

At low injection currents the LED without AgNW current spreading emitted more intense light, but above 45mA the device with AgNWs performed increasingly better (Figure 6). Self-heating effects also adversely affected the light output power of the LED without AgNWs more than for the device with AgNWs. The team comments: "Because AgNWs were effective at

dissipating the thermal heat from LEDs, the cw EL intensity of LED without AgNWs was drastically decreased under the high injection current region (>30mA), leading to an increase in the pulse to cw EL intensity ratio."

The EQE of the LED without AgNWs peaked at a very low current, while the efficiency increased over the range up to 100mA for the device with AgNWs. The AgNWs also reduced the turn-on voltage of the diode (2.72V versus 3.22V), also contributing to improved efficiency. Below turn-on the AgNW LED showed a higher series resistance, indicating problems with surface currents. However, above turn-on the series resistance was lower for the AgNW LED. ■

Author:

Mike Cooke is a freelance technology journalist who has worked in the semiconductor and advanced technology sectors since 1997.

More absorbent 2D stacks through layer transfer rather than epitaxy

Randomly oriented 2D semiconductor structures have been fabricated that are as functional as those with perfect alignment.

Researchers based in the USA have found that randomly oriented molybdenum disulfide (MoS_2) on tungsten disulfide (WS_2) has a similar photoluminescence (PL) response to aligned epitaxial structures [Yifei Yu et al, Nano Letters, published online 3 December 2014].

"This work demonstrates that, by stacking multiple two-dimensional (2D) materials in random ways, we can create semiconductor junctions that are as functional as those with perfect alignment," says Dr Linyou Cao, senior author of the paper and assistant professor of materials science and engineering at North Carolina State University. The other institutions involved in the research were University of North Carolina at Charlotte and Oak Ridge National Laboratory.

Less stringent alignment of semiconductors could

lead to an order-of-magnitude lower-cost manufacturing processes, Cao believes.

Yu et al have found that absorption of light in a certain spectral range increased two orders of magnitude over that of single layers of the disulfide materials. Absorption-based photonic devices include photovoltaics/solar cells, solar fuels, photodetectors, optical modulators, and photocatalysts.

Transition-metal dichalcogenides (TMDCs) 2D semiconductors such as MoS_2 and WS_2 have excited much research interest in the past year. Semiconductor structures usually need to be precisely aligned with matched lattice structures for efficient operation. "But we found that the crystalline structure doesn't matter if you use atomically thin, 2D materials," Cao comments. "We used molybdenum sulfide and

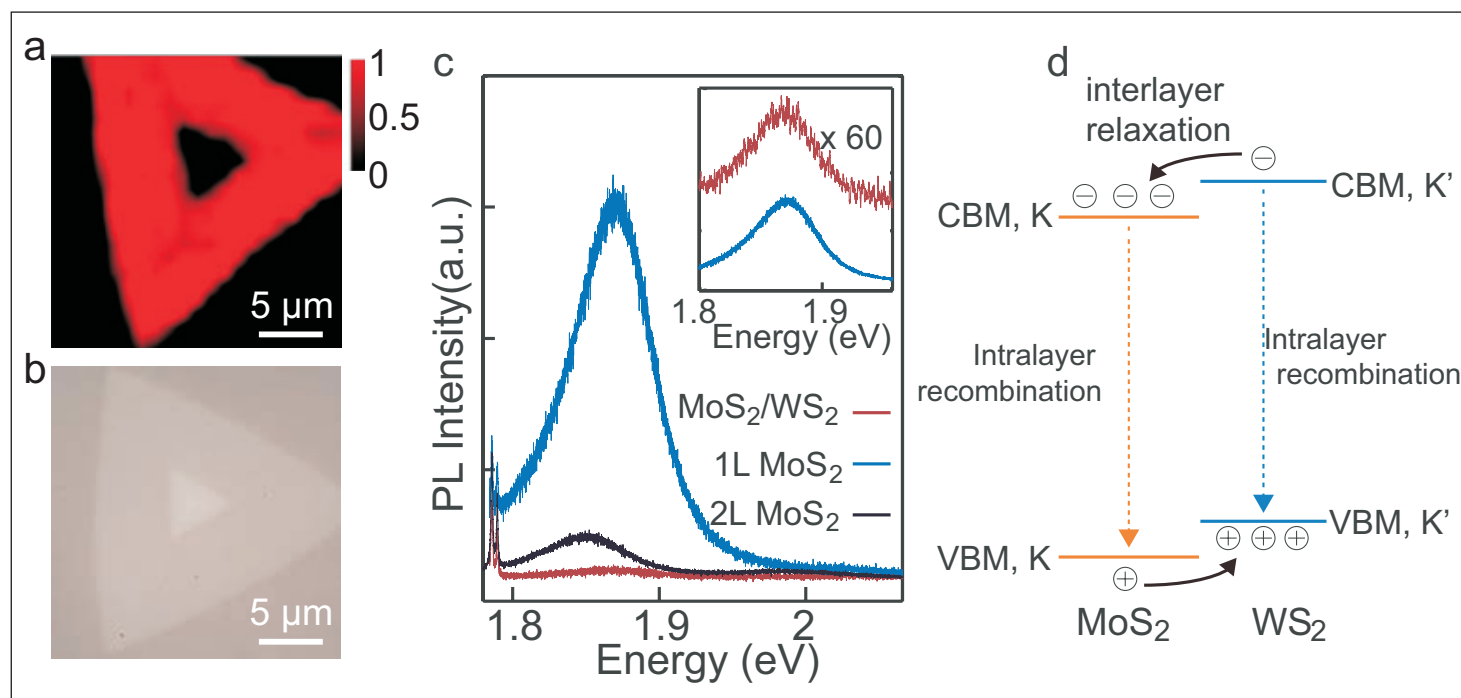


Figure 1. (a) PL mapping of typical epitaxial MoS_2/WS_2 heterostructure. (b) Optical image of heterostructure mapped in (a). (c) PL spectra collected from monolayer (1L) MoS_2 area (red curve) and MoS_2/WS_2 heterostructure area (blue curve). PL from MoS_2 bilayer (2L) is also given (black curve). Inset: comparison of PL from MoS_2 and MoS_2/WS_2 areas, where PL from MoS_2/WS_2 area is scaled by factor of 60. (d) Schematic illustration of bandstructure alignment of heterostructure. K-point of MoS_2 coincides with the K'-point of WS_2 . Interlayer relaxations and intralayer recombination are also shown.

tungsten sulfide for this experiment, but this is a fundamental discovery that we think applies to any 2D semiconductor material. That means you can use any combination of two or more semiconductor materials, and you can stack them randomly but still get efficient charge transfer between the materials.”

The epitaxial MoS₂ and WS₂ heterostructure was produced through chemical vapor deposition (CVD) in a tube furnace with sulfur and molybdenum and tungsten oxide precursors (MO₃, WO₃). Epitaxial structures were grown at 950°C with a flow of argon.

The synthesized MoS₂ and WS₂ monolayer 2D crystals formed as large (~25µm) or small triangles (~8µm), respectively. These formed concentric heterostructures (Figure 1). The lattice constants of the two materials were almost identical.

Photoluminescence from regions of MoS₂ away from the heterostructure gave a peak at 1.87eV, consistent with other measurements made on MoS₂ monolayers (Figure 1). In the region of the heterostructure, the peak is reduced by about two orders of magnitude (factor of 100). A bilayer of MoS₂ also showed a reduced intensity peak, but only about an order of magnitude.

The researchers point out that they do not see a 1.4eV peak found by another group in WS₂/MoS₂ heterostructures. The team suggests that differences in WS₂ growth precursors or the different substrates used might explain the different characteristics. The tungsten precursor used by Yu et al was WO₃, while the other group used a combination of tungsten and tellurium. The respective substrates were sapphire and silicon dioxide/silicon. Yu et al attribute the PL suppression to interlayer exciton relaxation.

Non-epitaxial structures were fabricated by manually combining separate WS₂ and MoS₂ layers. The separate layers were grown at lower temperatures – 750°C for MoS₂ and 900°C for WS₂. For the WS₂ process, 5% hydrogen was added to the argon carrier.

The MoS₂ layer was delaminated from the growth substrate through a surface-energy-assisted transfer process involving polystyrene and water. The polystyrene/MoS₂ was handled with tweezers and trans-

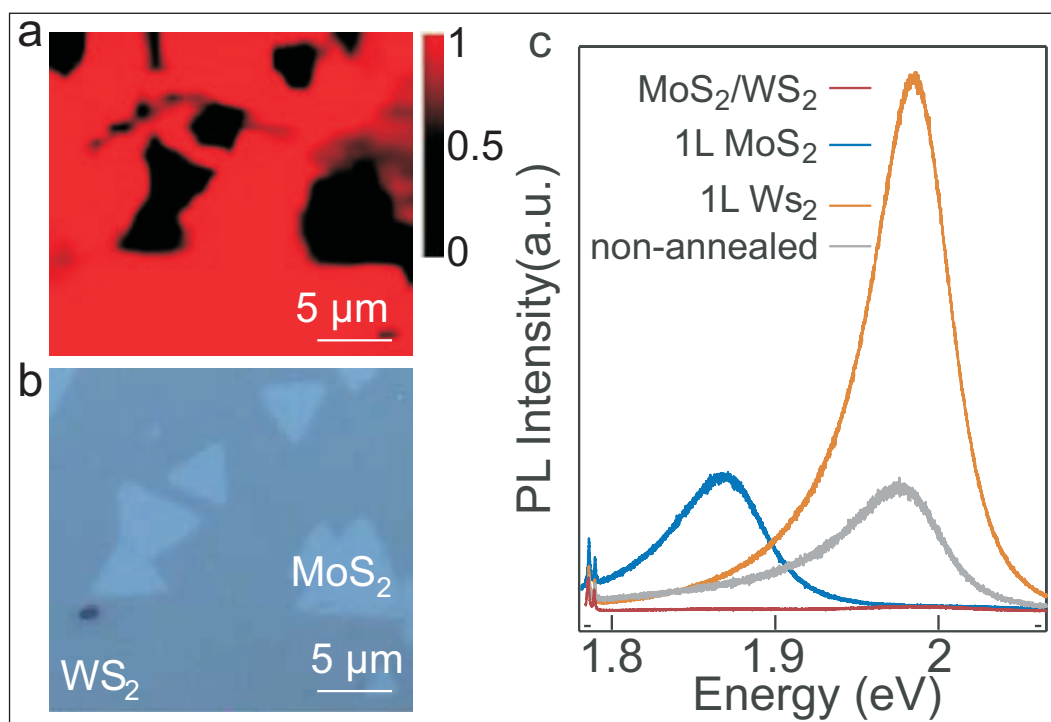


Figure 2. (a) PL mapping of typical non-epitaxial MoS₂/WS₂ heterostructures. (b) Optical image of heterostructure mapped in (a) with multiple MoS₂ monolayers (small triangles) randomly distributed on top of big WS₂ monolayer. (c) Spectra PL collected from non-epitaxial MoS₂/WS₂ heterostructure (red curve), MoS₂ monolayer (1L) (blue curve), and WS₂ monolayer (1L) (brown curve). PL of unannealed non-epitaxial MoS₂/WS₂ heterostructure is also given (grey curve).

ferred onto WS₂. The polystyrene was removed with toluene. Annealing was carried out on some samples at 200–250°C for 10–30 minutes in argon.

The MoS₂ was around 5µm, stacked on ~50µm WS₂. The annealed non-epitaxial structures showed similar two-order of magnitude decreases in PL intensity in overlap regions. Without annealing, the decrease is less significant. The researchers comment: “The low-temperature annealing process may remove the residue of solvent and water molecules left between the two monolayers during the transfer process, which may subsequently facilitate the interlayer exciton relaxation.”

The researchers also say that the PL response is independent of the crystal orientation of the stacked layers. They add: “The independence of the efficient interlayer exciton relaxation in MoS₂/WS₂ heterostructures on the epitaxy and orientation of the stacking suggests a strong electron–phonon coupling in 2D materials. The electron–photon coupling could be so strong that it is able to efficiently compensate for any momentum mismatch of the charge transfer between the monolayers.”

Other groups have measured much less decrease of the PL — around a factor of three. The team suggests that this could be due to the different layer transfer processes used that can cause damage or leave organic residues. Also, the substrates may again be to blame. ■

<http://pubs.acs.org/doi/abs/10.1021/nl5038177>

Author: Mike Cooke

Prospect of accurate p-type silicon-doped gallium arsenide antimonide

MOCVD at increased temperature shifts conductivity from n- to p-type.

Researchers at Japan's NTT Device Technology Laboratories have used silicon (Si) doping to achieve p-type conduction in gallium arsenide antimony (GaAsSb) produced with metal-organic chemical vapor deposition (MOCVD) on indium phosphide (InP) [Haruki Yokoyama and Takuya Hoshi, Jpn. J. Appl. Phys., vol54, p015506, 2015]. Yokoyama and Hoshi write: "This is the first time that p-type doping into GaAsSb layers has been achieved by MOCVD using silicon as a dopant."

These researchers believe that the resulting p-GaAsSb could be useful for heterojunctions with InP and InGaAs with improved device performance in heterojunction bipolar transistors (HBTs), tunnel diodes and tunnel field-effect transistors.

Alternative p-dopants for GaAsSb suffer from high levels of diffusion, which makes accurate doping profiles difficult to achieve. Carbon (C) is also a p-dopant for GaAsSb with a relatively low diffusion rate, but the precursor used to supply C atoms, tetrabromomethane (CBr₄), has an etching effect on GaAsSb, again compromising doping profiles.

Silicon also has a low diffusion coefficient, but previous work producing Si-doped GaAsSb by MOCVD has resulted in n-type conduction. Although Si is an n-type impurity in GaAs, it is a p-type impurity in GaSb.

Yokoyama and Hoshi hoped that different growth conditions might lead to p-type conduction from Si-doped GaAsSb. Previous work reported by others in 1988 with molecular beam epitaxy (MBE) supported this: GaAsSb showed a shift from n-type to p-type conductivity as the growth temperature increased. MOCVD processes tend to be preferred by manufacturers.

Yokoyama and Hoshi used MOCVD carried out in a close-coupled showerhead reactor on (001) semi-insulating iron-doped InP wafers. The source materials

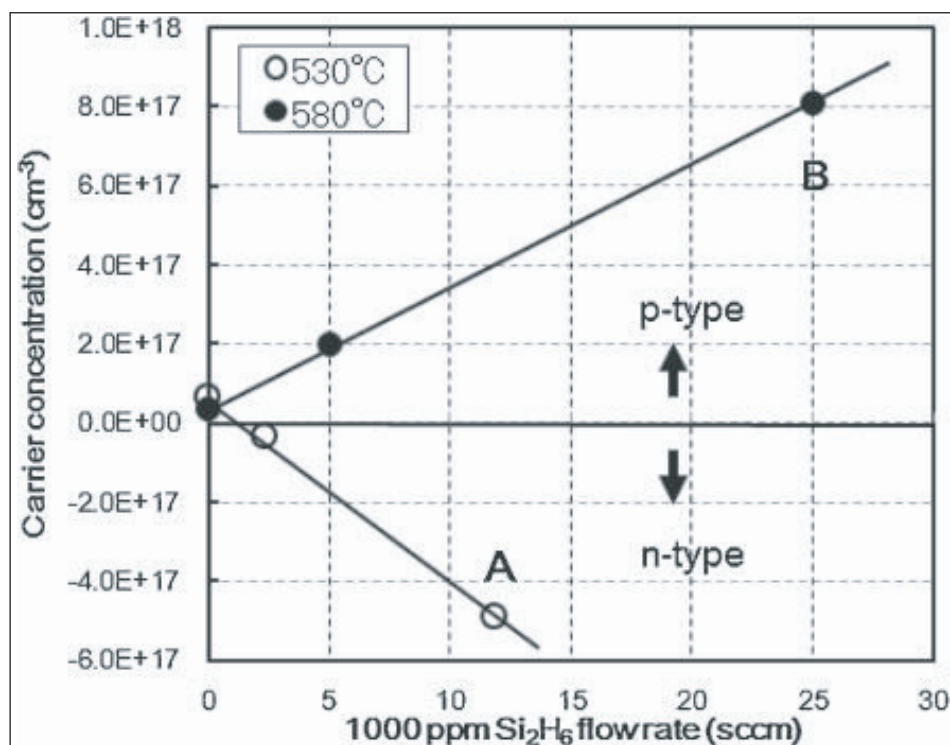


Figure 1. Si₂H₆ flow rate dependence of carrier concentration in silicon-doped GaAsSb layers.

were triethylgallium (TEGa), arsine (AsH₃) and trimethylantimony (TMSb) in hydrogen carrier gas. The silicon doping was achieved with disilane (Si₂H₆). The growth pressure was 125mbar.

Undoped lattice-matched GaAsSb/InP samples were found to have p-type conductivity. However, silicon doping shifted this to n-type when MOCVD was carried out at 530°C (Figure 1). At 580°, silicon doping instead increased the hole density, giving stronger p-type behavior.

Yokoyama and Hoshi comment: "These results confirm that there is a proportional relationship between the Si₂H₆ flow rate and carrier concentration, regardless of conductivity type. This indicates that precise control of p- and n-type carrier concentration in Si-doped GaAsSb layer is possible."

The mobility behavior of the samples was similar to that achieved for GaAsSb samples produced using MBE

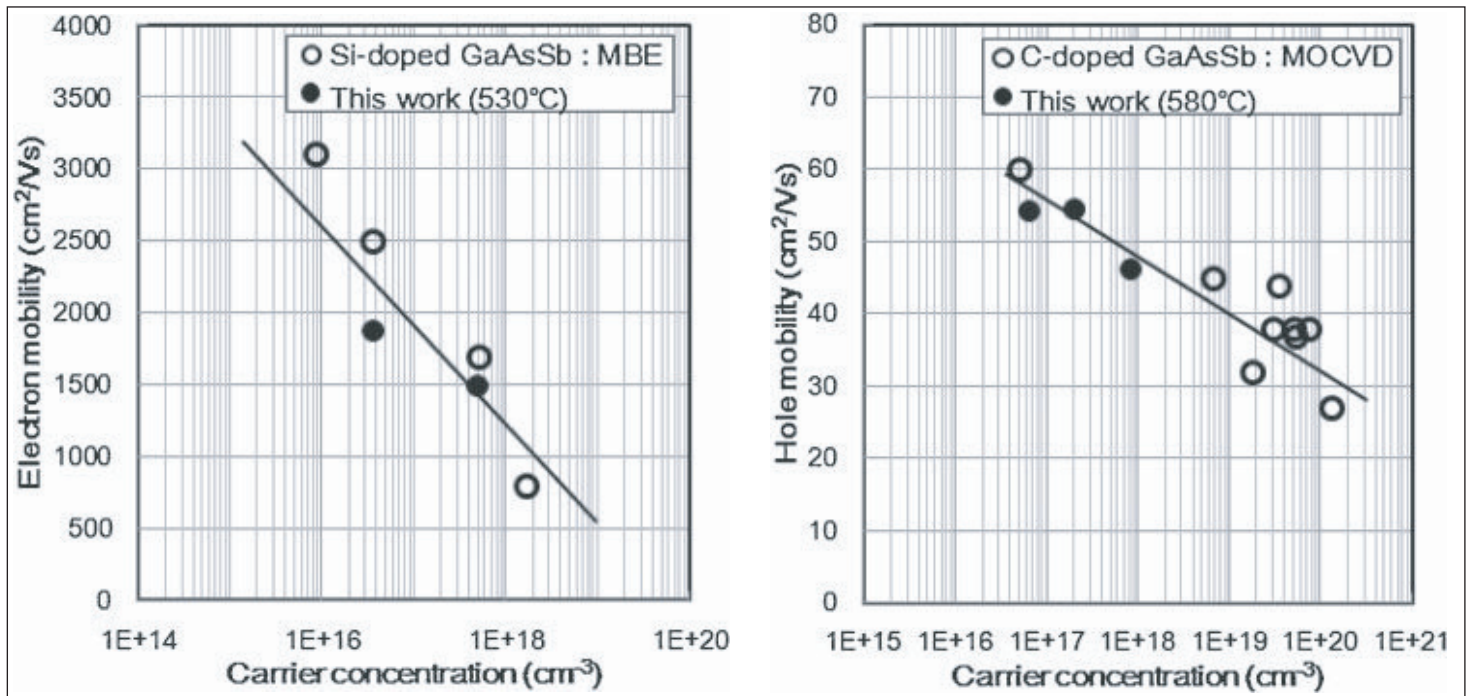


Figure 2. (a) Relationship between electron mobility and electron carrier concentration in Si-doped GaAsSb layers grown at 530°C, compared with MBE GaAsSb:Si. (b) Relationship between hole mobility and hole carrier concentration in Si-doped GaAsSb layers grown at 580°C, compared with MBE GaAsSb:C.

(Figure 2). Comparison was made with silicon-doped MBE GaAsSb for the n-type low-temperature MOCVD material and with carbon-doped MBE GaAsSb for the p-type layer.

Secondary-ion mass spectrometry (SIMS) showed that the silicon doping concentration was constant through the deposited layers. The activation ratio of electron carrier concentration to silicon concentration was 0.33 for a 530°C GaAsSb layer with $1.5 \times 10^{18}/\text{cm}^3$ doping density. The hole/silicon ratio was 0.27 for

580°C GaAsSb with $3 \times 10^{18}/\text{cm}^3$ silicon density.

Si-doped MBE GaAsSb has been reported with 0.392 activation of $1.27 \times 10^{18}/\text{cm}^3$ doping. C-doped MBE GaAsSb activation has been measured close to 1. The low activation of Si-GaAsSb does not impact the mobility performance (Figure 2b). "Since alloy scattering becomes dominant in GaAsSb, it may eliminate the effect of inactivation," write Yokoyama and Hoshi. ■

<http://dx.doi.org/10.7567/JJAP.54.015506>

Author: Mike Cooke

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Diamond-like carbon used to improve performance of GaN HEMTs

Diamond-like carbon and micro-machining reduces thermal resistance from 13.6K/W to 5.3K/W.

Researchers based in Taiwan have used micro-machining and diamond-like carbon (DLC) layers to improve the thermal performance of nitride semiconductor high-electron-mobility transistors (HEMTs) on silicon substrates [Hsien-Chin Chiu et al, Appl. Phys. Express, vol8, p011001, 2015].

HEMT performance tends to degrade when the temperature increases due to self-heating or when

operated in harsh environments. Thermal management can be expensive, requiring external cooling equipment. Reducing the need for such measures requires high-thermal-conductivity materials and structures.

The team from Chang Gung University, Feng Chia University and RiteDia Inc used micro-machining to remove part of the substrate from under HEMT-based circuits, along with thermally conductive layers of DLC

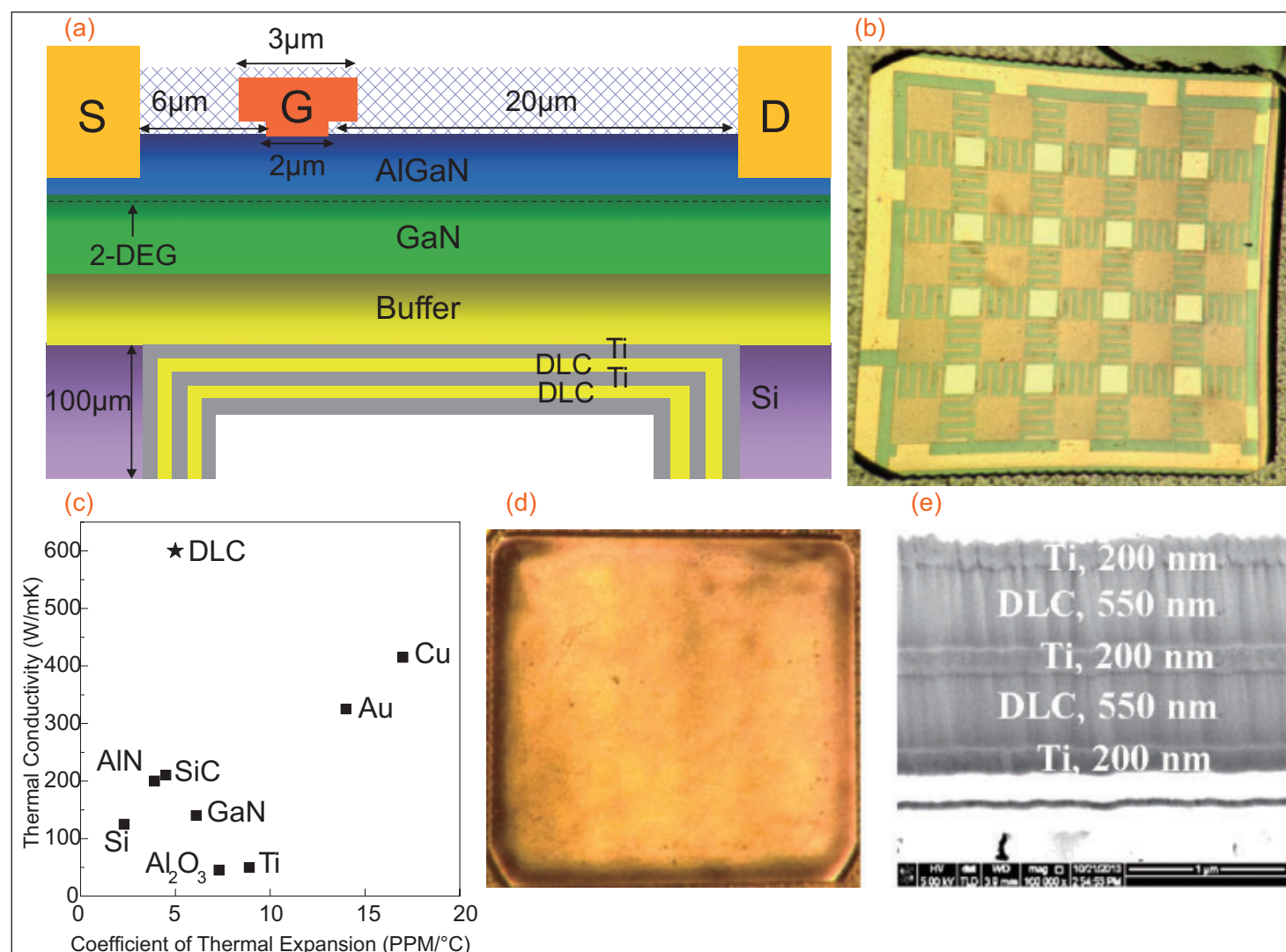


Figure 1. (a) Cross-section of AlGaIn/GaN HEMT with DLC heat-dissipation layer. (b) Backside view of M-HEMT. (c) Material coefficient of thermal expansion (CTE) and thermal conductivity. (d) Backside view of M-HEMT with DLC heat-dissipation layers. (e) SEM image of DLC/Ti layers.

and titanium to improve breakdown voltages and increase maximum drain currents.

DLC has a high thermal conductivity and a similar coefficient of thermal expansion to gallium nitride (GaN). Materials with mismatched expansion coefficients can delaminate when thermally processed or when operated at varying temperatures.

The epitaxial material for the HEMT (Figure 1) was grown on p-type (111) silicon through metal-organic chemical vapor deposition (MOCVD). The 2µm buffer layer consisted of a series of layers of GaN and AlGaIn. The GaN channel layer was 1µm thick. The 18nm Al_{0.27}Ga_{0.73}N barrier was sandwiched between the channel and a 1nm GaN cap.

The HEMT structure was fabricated with a 300nm-high mesa etched from the epitaxial layer, titanium/aluminium/nickel/gold ohmic contacts, 100nm silicon dioxide passivation, and Schottky gate. The gate was T-shaped to give a field-plate to reduce current collapse under pulsed operation. The gate had a 2µm footprint and 3µm T-head.

The layout of the devices was an air-bridged matrix (ABM) designed to improve heat distribution. The gate zigzagged between interdigitated source/drain electrodes. The active device area was 1.25mmx1.25mm. Micro-machined HEMTs (M-HEMTs) were compared with standard HEMTs without micro-machining. The gate width of the M-HEMT was 22.8mm. The standard device had a wider gate of 40mm (1.25mm/finger, 32 fingers).

After the HEMT fabrication, the substrate was thinned to 100µm from 625µm. For the micro-machining step, the silicon under the active region was removed using sulfur hexafluoride plasma etch. Further etching with boron trichloride/chlorine plasma cut partially into the transition/buffer layers.

DLC films were sputtered from a metal hydrocarbon target of tungsten carbide. Titanium layers were also applied for film adhesion and improved electrical conductivity. The DLC/titanium was applied in two pairs of thickness 200nm and 550nm, respectively, to give a total DLC thickness of more than 1µm.

The three-terminal off-state breakdown of the devices was measured in Fluorinert liquid to avoid surface flashover. The 1mA/mm breakdown of the M-HEMT with DLC/titanium film at -8V gate potential occurred with a source-drain bias of 637V. The standard HEMT broke down at 450V. Two-terminal breakdown of the buffer occurred for the M-HEMT with DLC/titanium film at 1400V and the standard HEMT at 1100V.

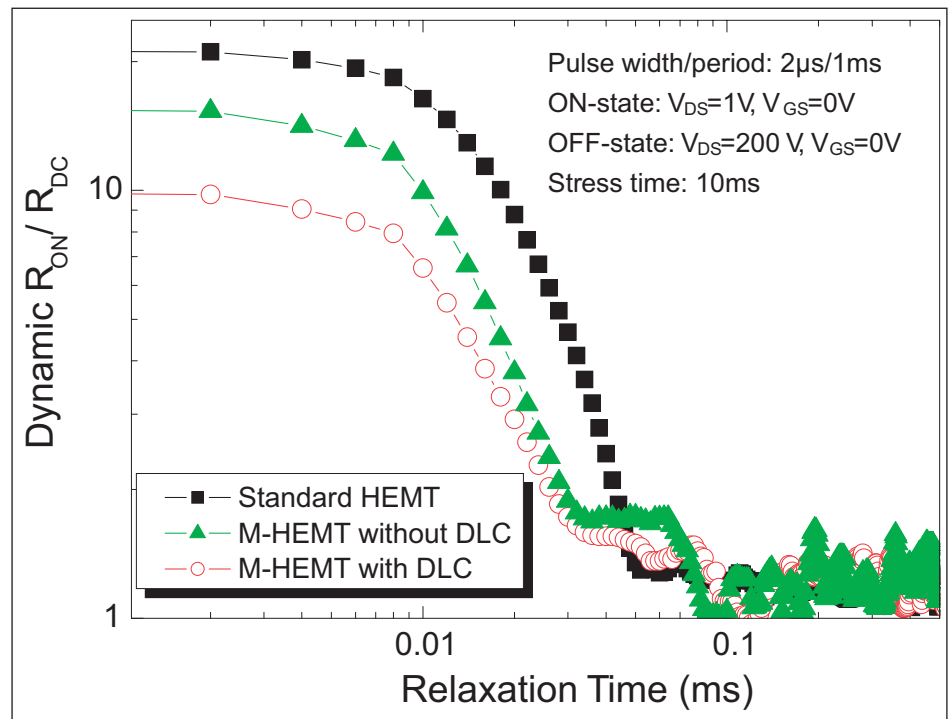


Figure 2. Dynamic switching performance of standard HEMT, M-HEMT without DLC layers, and M-HEMT with DLC layers.

The M-HEMT/DLC/titanium structure also improved the transistor performance. The saturated drain current was 4.97A, compared with 2.18A for the standard device. The threshold voltage was -2.3V for both devices. Bending strain of 0.01% was found to reduce the maximum current 30% for the standard HEMT, but only 5% for the M-HEMT with DLC/titanium. The researchers attribute the relative insensitivity-to-bending to thermal effects and removal of silicon from under the buffer.

The increase of on-resistance with temperature up to 200°C was slower for the M-HEMT with DLC/titanium at 1.51mΩ/°C, compared with 2.77mΩ/°C for the standard HEMT. The researchers estimate the thermal resistance of the standard HEMT structure at 13.6K/W, compared with 5.3K/W for the M-HEMT with DLC/titanium layers.

Thermographs with devices with drain current at 1A with a 10V bias showed the standard HEMT to be running hotter at up to 172°C, compared with 90°C for the M-HEMT. Another M-HEMT, but without the DLC/titanium layers, had a peak temperature of 125°C.

The dynamic on-resistance under pulsed operation was also tested. Again, the M-HEMT with DLC/titanium layers showed improved performance (Figure 2). The poorer performance of the standard HEMTs was attributed to deep-level capture in buffer/transition layer traps and parasitic effects from the silicon substrate. Reduction of device thermal resistance is believed to be beneficial for relaxing and conducting the carriers from ON-state operation. ■

<http://iopscience.iop.org/1882-0786/8/1/011001/article>

Author: Mike Cooke

Reducing gate leakage and current collapse in GaN HEMTs on silicon

UK research team combines sulfuric acid treatment and silicon nitride deposition to passivate devices.

The University of Sheffield and the University of Cambridge in the UK have developed an optimized passivation for gallium nitride (GaN) high-electron-mobility transistors on silicon substrates

(HEMTs) using sulfuric acid (H_2SO_4) treatment and silicon nitride (SiN) deposition [Z. H. Zaidi et al, J. Appl. Phys., vol116, p244501, 2014]. The researchers compared separate passivation

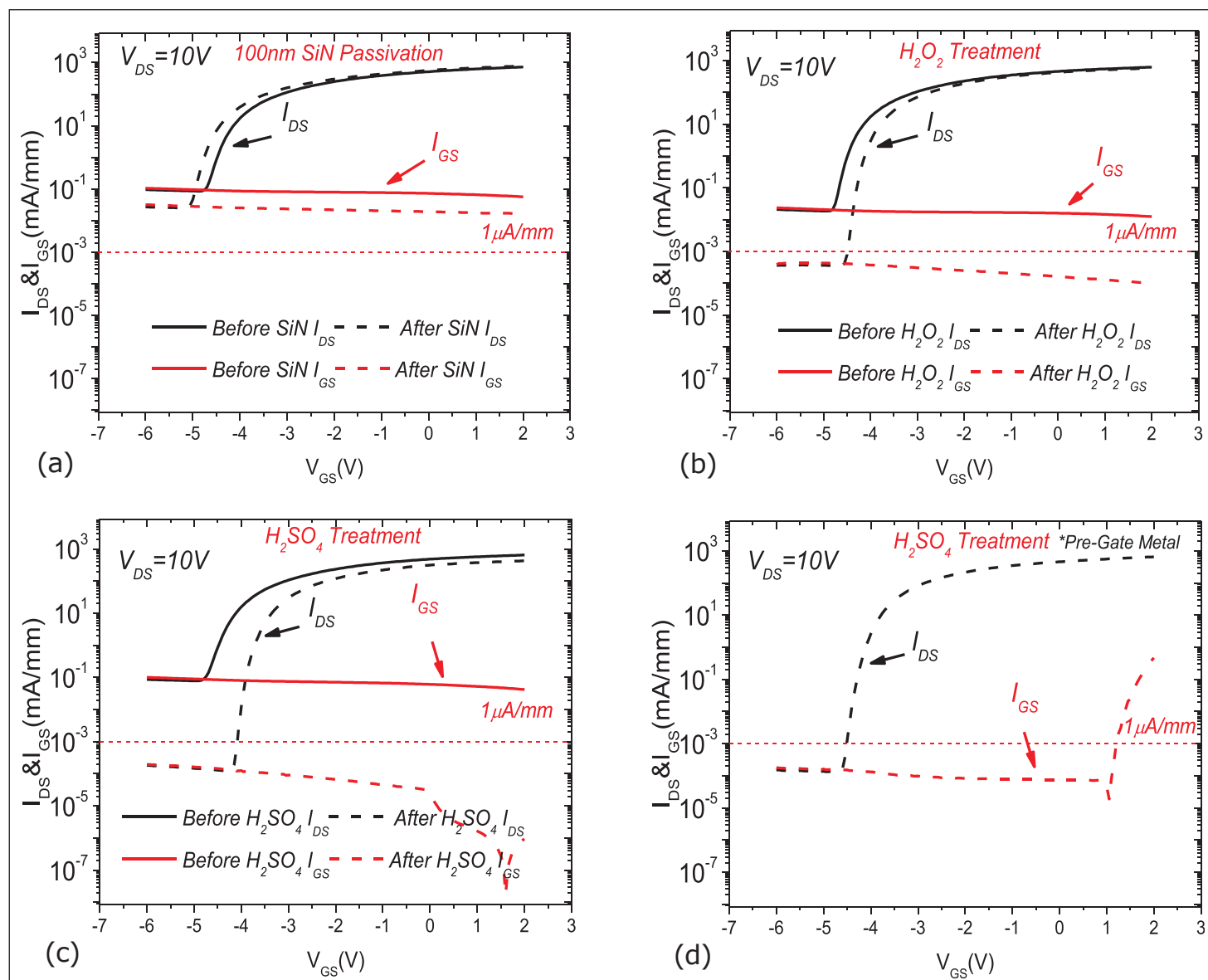


Figure 1. Gate transfer characteristics of AlGaIn/GaN HEMTs before and after (a) 100nm SiN post-gate metal passivation, (b) H_2O_2 post-gate metal treatment, (c) H_2SO_4 post-gate metal treatment, and (d) H_2SO_4 pre-gate metal treatment.

efforts with sulfuric acid or hydrogen peroxide (H_2O_2) treatments, or 100nm silicon nitride deposition. They were particularly keen to tackle gate leakage currents and current collapse under pulsed operation with a view to power electronics applications.

The chemical treatments — hydrogen peroxide solution or sulfuric acid — reduced gate leakage current to less than $1\mu\text{A}/\text{mm}$, improved the subthreshold swing (SS), and increased the on/off current ratio to around 10^7 (from 10^4 – 10^5), compared with silicon nitride deposition at 10V drain bias (see Figure 1). The researchers add: “Although the untreated devices showed a range of gate leakage currents, over the devices studied in this work, H_2SO_4 treatment was found to be the most effective in suppressing the gate leakage current and improving the SS.”

However, the peak drain current was reduced from $647\text{mA}/\text{mm}$ to $427\text{mA}/\text{mm}$ at 2V gate potential after sulfuric acid treatment. This treatment also shifted the threshold voltage furthest in a positive direction, although nowhere near enough to give enhancement-mode, normally-off operation.

The researchers comment: “These results suggest that H_2SO_4 treatment oxidizes the surface and, in the process, consumes some of the barrier layer (AlGaN), which in turn reduces the 2DEG charge. Formation of an oxide layer on the surface has a strong passivating effect and reduces the overall gate leakage current.”

In analyzing the sulfuric acid treatment’s effect on surface states, the researchers concluded that deep-level trap states are introduced that could have a catastrophic effect in normal switching operation, “causing a reduction in the total available drain current (current collapse) due to their sluggish response to changing bias”.

To overcome this problem, the team produced HEMTs with both sulfuric acid treatment and 100nm silicon nitride passivation (Figure 2). “This optimum configuration sustains a low gate leakage ($<1\mu\text{A}/\text{mm}$) with reduced sub-threshold slope ($100\pm 10\text{mV}/\text{decade}$),” the researchers report.

Devices with just sulfuric acid treatment had a poor gate-lag ratio of 0.4 ± 0.2 with 400ns pulses from a -6V gate off-state. The ratio increased to 0.85 ± 0.1 in devices with combined sulfuric acid and silicon nitride passivation. This was almost identical with the performance of just silicon nitride passivation.

The epitaxial material (Figure 3) was grown on 6-inch (150mm) silicon wafers using metal-organic chemical vapor deposition (MOCVD). Standard HEMTs were fabricated with mesa isolation, titanium/aluminium/titanium/gold ohmic source-drain contacts, $1\mu\text{m}$

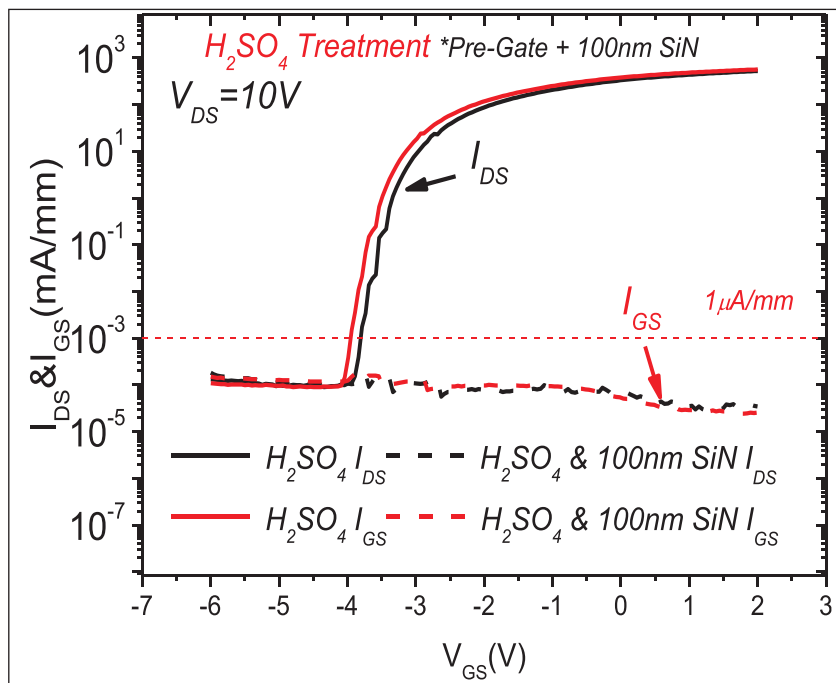


Figure 2. Gate transfer characteristics of AlGaN/GaN HEMTs with H_2SO_4 treatment combined with 100nm SiN passivation. Black curves are for pre-gate metal treatment and red curves are for treatment after gate metal deposition. In both cases SiN was deposited after gate metal.

nickel/gold gates, and titanium/gold bond pads.

The gate was centered in the $7\mu\text{m}$ gap between the source-drain contacts.

The 100nm silicon nitride passivation was achieved using plasma-enhanced chemical vapor deposition (PECVD). The hydrogen peroxide or sulfuric acid treatments were applied in solution at room temperature for around 48 hours. The sulfuric acid treatment was also tried before the gate formation, but then the researchers were naturally unable to compare performance before and after treatment. ■

<http://dx.doi.org/10.1063/1.4904923>

Author: Mike Cooke

Cap	GaN	2nm
Barrier	AlGaN	27nm
Mobility enhancement	AlN	1nm
Buffer/channel	GaN	1.9 μm
	AlN	12nm
Graded transition	AlGaN→GaN	(iron doped)
Nucleation	AlN	250nm

Figure 3. Epitaxial structure for HEMTs with aluminium gallium nitride barrier layer.

Gallium nitride transistors fabricated on cubic silicon carbide on silicon

Devices with gold-free ohmic contacts rival the fastest GaN HEMTs on silicon or silicon carbide with gold-based ohmic contacts, according to researchers in Germany.

Researchers in Germany have developed gallium nitride (GaN) high-electron-mobility transistors (HEMTs) on silicon carbide (SiC) layers on silicon wafers [Wael Jatal et al, IEEE Electron Device Letters, published online 11 December 2014]. The ohmic source-drain contacts were gold-free (Au-free) titanium nitride on titanium (TiN/Ti). The researchers came from Technische Universität Ilmenau and Institut für Mikroelektronik- und Mechatronik-Systeme gemeinnützige GmbH (IMMS GmbH).

GaN-based HEMTs are being developed for radio frequency (RF) power amplification, based on high operating frequencies combined with high output power. The best GaN transistors are generally produced on hexagonal (4H) polytype SiC wafers, which are expensive and are of smaller diameter than is available with silicon.

The substrate used by Jatal et al was low-resistivity ($3\text{m}\Omega\text{-cm}$) (111)Si on which 3C cubic polytype SiC had been deposited. The SiC growth began with 3nm carbonization with ethylene (C_2H_4) precursor. Further SiC was grown by adding silane (SiH_4) as a silicon chemical vapor deposition (CVD) precursor.

Metal-organic chemical vapor deposition (MOCVD) was then used to apply 100nm aluminium nitride (AlN) as an interlayer, and GaN buffer. The barrier structure consisted of $\text{Al}_{0.2}\text{Ga}_{0.8}\text{N}/\text{AlN}$ (design A) or $\text{Al}_{0.35}\text{Ga}_{0.65}\text{N}$ (design B). The AlGaN barrier thickness in both cases was 20nm. The AlN spacer between the AlGaN barrier and GaN buffer of design A was 2nm. The structures

were capped with 2nm GaN.

The epitaxial design A achieved a Hall mobility of $1760\text{cm}^2/\text{V-s}$, compared with $1200\text{cm}^2/\text{V-s}$ for design B. The sheet carrier densities were very similar at $7.5 \times 10^{12}/\text{cm}^2$ for design A and $7.2 \times 10^{12}/\text{cm}^2$ for design B.

The nickel-gold HEMT gate had two fingers of total width $150\mu\text{m}$. The gate was centered in the $2\mu\text{m}$ source-drain gap.

The ohmic contacts for the source-drain regions were applied using magnetron sputtering of titanium. The initial deposition was 20nm titanium followed by 100nm titanium nitride. The titanium nitride was formed through reactive magnetron sputtering in argon/nitrogen atmosphere and annealing at 850°C in nitrogen.

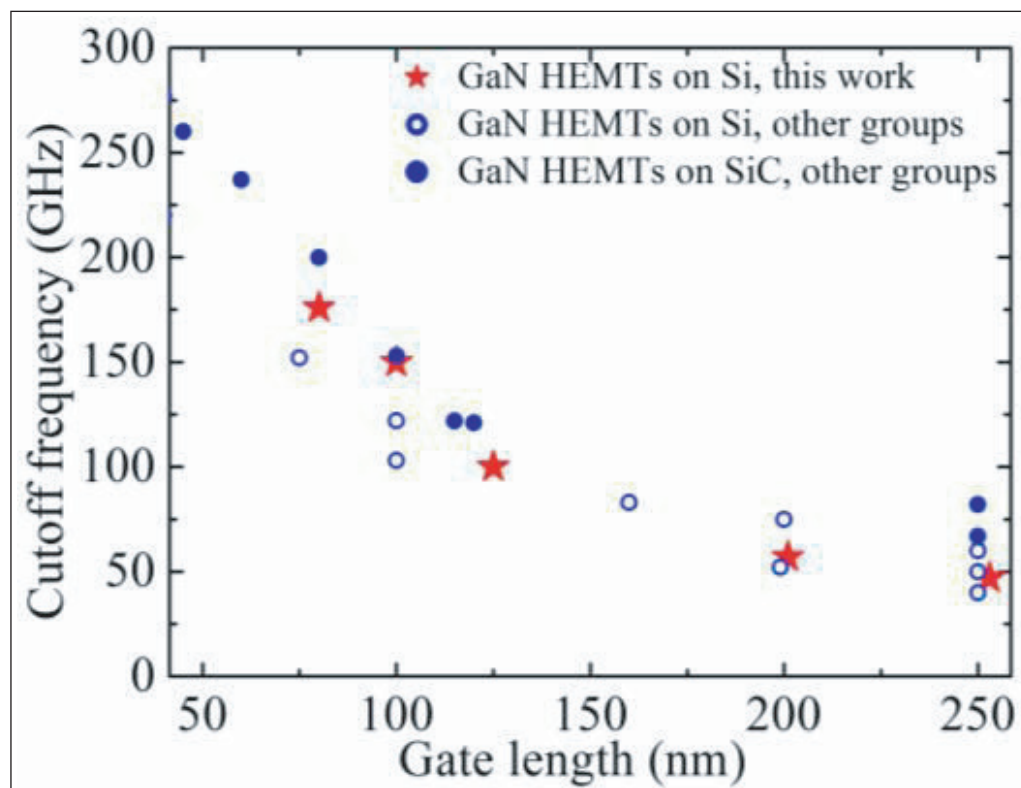


Figure 1. Comparison of cutoff frequencies of GaN HEMTs on silicon with barrier design A with best data reported by other groups for GaN HEMTs on silicon and on SiC.

Table 1. Results of DC and RF characterization of 100nm-gate HEMTs. DC measurements at 10V drain-source voltage (V_{DS}): maximum drain current (I_D) and peak transconductance (g_m). On-resistance (R_{on}) measured at low drain voltage with zero gate potential. Also shown are contact resistance (R_C), sheet resistance (R_S), specific contact resistance ρ_C , and cut-off frequencies (f_T) at 10V and 20V V_{DS} ($-2.75V$ gate potential).

Barrier design	I_D	g_m	R_{on}	R_C	R_S	ρ_C	f_T at 10V	f_T at 20V
A	1.13A/mm	388mS/mm	0.9 Ω -mm	0.13 Ω -mm	169 Ω /sq	1x10 ⁻⁶ Ω -cm ²	115GHz	150GHz
B	0.95A/mm	360mS/mm	1.6 Ω -mm	0.6 Ω -mm	365 Ω /sq	1x10 ⁻⁵ Ω -cm ²	79GHz	107GHz

The specific contact resistance of Ti/TiN structures was $\sim 10^{-6}\Omega\text{-cm}^2$. The contact resistance was 0.13 Ω -mm. The root-mean-square (rms) roughness was 1.8nm. The researchers claim that their Ti/TiN structure is among the best gold-free structures so far.

The researchers comment: "We ascribe the low contact resistivity to the conversion of Ti into TiN causing the formation of nitrogen vacancies in the barrier layer which lead to a high doping level of the AlGaIn underneath the contact."

The team carried out a number of characterizations on a 100nm-gate-length device (Table 1). The researchers attribute the improved performance of design A HEMTs to reduced alloy scattering due to the AlN spacer layer.

The RF measurements were carried out between 0.1GHz and 50GHz. Using extrapolations and de-embedding corrections, the cut-off frequency (f_T) for an 80nm-gate HEMT at 20V drain bias and $-2.75V$ gate potential was estimated at 176GHz. The maximum oscillation frequency (f_{max}) was 70GHz. The low f_{max} was blamed on the simple rectangular

gates and low-resistance substrate that was used. "Significant improvements of f_{max} can be expected by using mushroom gates with reduced gate resistance and high-resistivity substrates," the research team writes.

By contrast, the best 80nm-gate Al_{0.35}Ga_{0.65}N/GaN HEMTs demonstrated a poor f_T of only 115GHz at 20V drain voltage. HEMTs on SiC can achieve f_T values of 200GHz with a 75nm gate length. The corresponding value for HEMTs on silicon is 152GHz.

Comparing their results with those of others (Figure 1), the researchers comment: "It can be seen that our 80nm-gate HEMT shows competitive f_T performance compared to GaN HEMTs on Si (with Au-based and Au-free contacts) reported by other groups. Moreover, our GaN HEMTs on Si with barrier design A rival successfully the best reported GaN HEMTs on SiC substrates in the 80–125nm gate-length range." ■

<http://ieeexplore.ieee.org/xpl/articleDetails.jsp?arnumber=6982198>

Author: Mike Cooke

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Power electronics market grew in 2014 after two years of stagnation

Yole forecasts a compound annual growth rate of 6.9% to \$17bn in 2020, driven by IGBT improvement as well as SiC and GaN adoption.

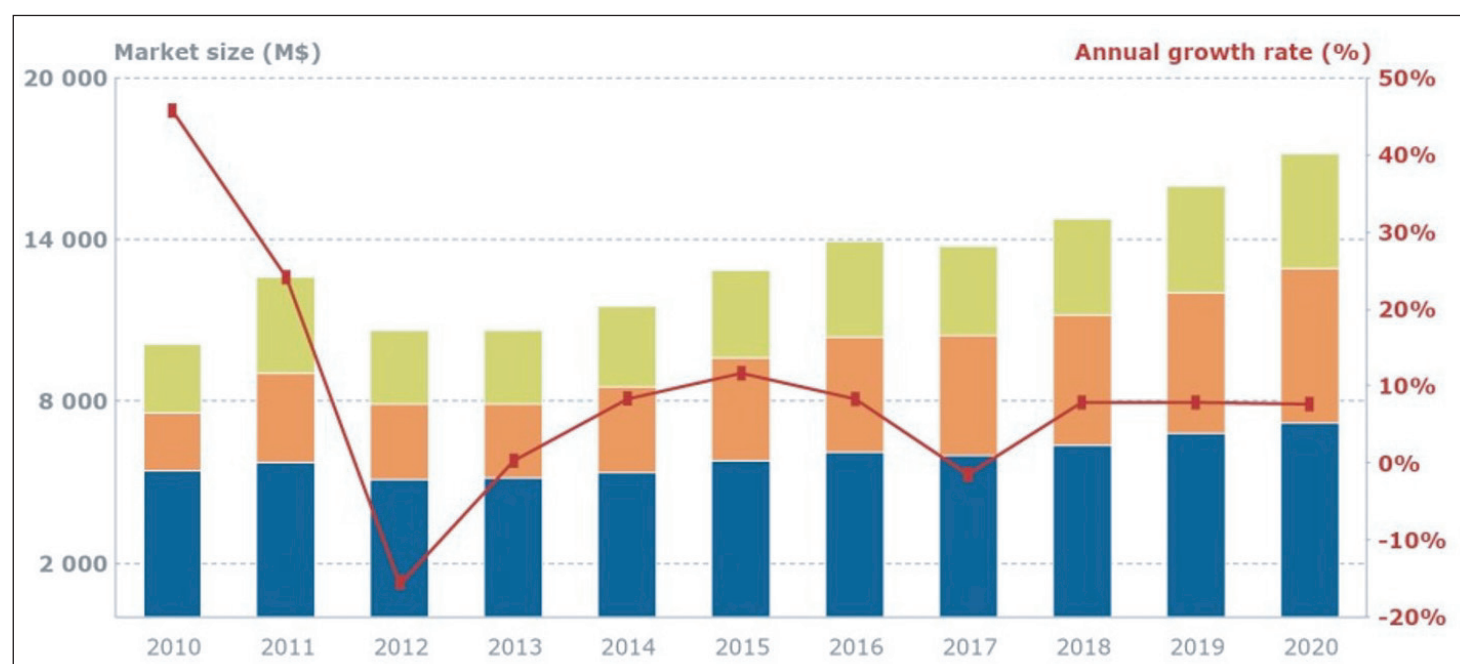
After two tough years of stagnation, in 2014 the power semiconductor device market returned to growth, rising by 8.4% to \$11.5bn, according to the report 'Status of the Power Electronics Industry (February 2015 edition)' from Yole Développement, which presents data for applications such as photovoltaics (PV), wind turbines, transmission and distribution, EV/HEV, rail traction, uninterruptible power supplies (UPS) and motor drives, as well as from different value chain levels spanning wafers, devices, and inverters.

The outlook for the years ahead is also optimistic, says the market research firm. Driven by a significant increase in electric and hybrid-electric vehicle (EV/HEV) sales, as well as the ramp-up of renewable energy and more smart-grid technology implementation, the market will rise at a compound annual growth rate (CAGR) of 6.9% from 2014 to more than \$17bn in 2020.

"Power modules, and more precisely IGBTs [insulated-gate bipolar transistors], will lead this growth," says technology & market analyst Mattin Grao Txa-

partegi. "Modules are expected to reach a CAGR 2014–2020 of 10.3%, compared to 5.1% growth for discrete components. This growth in the demand of IGBT modules is due to their improved overall performance in terms of efficiency and thermal conductivity management," he adds.

"The new wide-bandgap (WBG) device market will also drive growth," says Dr Pierrick Gueguen, business unit manager for Power Electronics & Compound Semiconductor activities at Yole. A lot of industrial firms have been focusing their development on WBG technologies, notes the report. Today, both silicon carbide (SiC) and gallium nitride (GaN) have proved to be powerful solutions, ready to be implemented in numerous applications. They should represent about 5% of the overall market by 2020, recons Yole, even though their presence will still be limited in terms of units. Gueguen and his team are working to identify and analyze the current bottlenecks to implementing WBG technologies in the power electronics industry. ➤



Power device market size (2010–2020), including power ICs, modules and discrettes: 2014, was a year of recovery for the power electronics market.

► **Chinese companies' vertical integration challenging diverse historical market leaders, while Europe and US firms push horizontal integration**

In this context the supply chain is evolving. The power electronics supply chain is very diverse and mostly dependent on applications and local markets, says Yole. European and American players will prioritize horizontal integration, maintaining proven expertise in a specific level of the value chain. Partnerships and joint ventures will therefore be preferred, Yole reckons. The report hence analyzes the major mergers and acquisitions of 2014 (e.g. International Rectifier's acquisition by Infineon) in order to understand their context and purpose.

Some system manufacturers, such as Tesla or BYD, have understood the importance of developing their own power electronics and energy management systems for traction, chargers and batteries in order to offer extended added-value.

Asian companies will prefer to expand vertically in order to be fully integrated and optimize the costs. Japanese players are already vertically integrated and involved in multiple applications simultaneously to benefit from their technologies across different markets. Chinese players are developing this vertical integration in order to create major market leaders in each application segment, such as SunGrow in PV, GoldWind in wind and BYD in EV/HEV. Yole's report focuses especially on the details of the Chinese market, which is driven by Chinese Government policies. In this changing environment, western and Japanese players need to bring high-added-value solutions to be able to compete with Chinese companies, says Yole. The report therefore includes a complete section on the strategies of the main players.

Existing technological disruptions now generating revenue, becoming a challenge for firms that are not involved

Demand for compact products is increasing. Players are therefore obliged to create partnerships between different industries so that they can coordinate and use the synergies of integrated products in order to offer a smaller and higher-performance solution. In

the report, Yole describes several partnerships influenced by this trend. In this direction, the concept of the power stack has recently appeared, and ever more companies will be involved in their development, forecasts Yole.

Technologically, MOSFETs and IGBTs will continue to be the devices in greatest demand, covering low- and medium- to high-voltage applications respectively. Also, the last decade has seen the appearance of new technologies, such as Super Junction MOSFETs, which have raised the MOSFET family into higher-voltage segments (up to 900V), with better performance. In terms of power packaging, ongoing evolution is driven particularly by the EV/HEV industry.

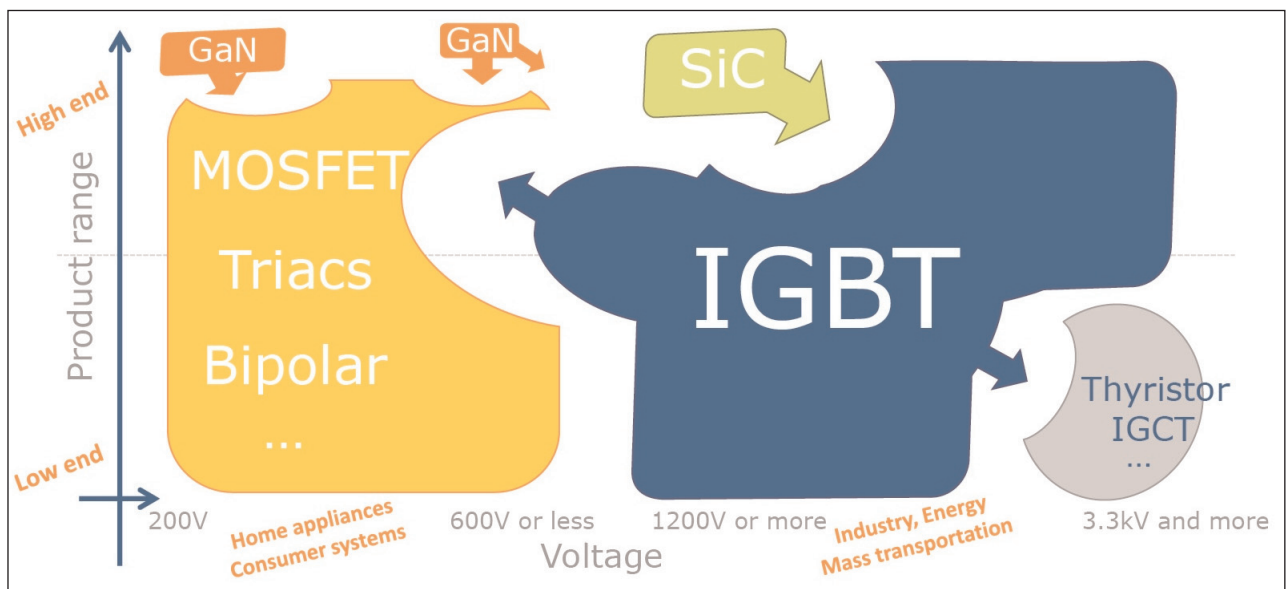
The advance of new wide-bandgap materials is also reshaping the power electronics industry. Compared with silicon devices, SiC- and GaN-based devices are intended for high-voltage (especially SiC), high-frequency and high-temperature applications due to their advanced performance. SiC technology is more mature than GaN, so industry segments such as rail traction and PV inverters have already adopted systems based on WBG devices.

The introduction of SiC into other high-voltage segments — such as wind and high-voltage direct current grids — is also inevitable, says Yole. But the big boost for these new markets should arrive with the implementation of SiC devices in the traction systems of electric cars.

GaN systems are still less prevalent on the market. Some consumer applications, such as laptop chargers, and just-announced PV inverters will be the first market segments to incorporate GaN, says Yole.

Several system manufacturers are also developing further SiC- and/or GaN-based prototypes, so the next five years are going to be decisive for the introduction of WBG devices into different markets, concludes Yole. ■

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Power device technology positioning.

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www.csmantech.org

7–10 June 2015

16th European Workshop on Metalorganic Vapour Phase Epitaxy (EW MOVPE 2015)

Lund, Sweden

E-mail: ewmovpe2015@ftf.lth.se

www.nano.lth.se/ewmovpe2015

15–19 June 2015

2015 Symposia on VLSI Technology and Circuits

Rihga Royal Hotel, Kyoto, Japan

E-mail: vlsi@vlsisymposium.org

www.vlsisymposium.org

16–18 June 2015

SEMICON Russia 2015

Moscow, Russia

E-mail: eweller@semi.org

www.semiconrussia.org/en

23–24 June 2015

Imec Technology Forum Brussels 2015

SQUARE, Brussels Meeting Centre, Brussels, Belgium

E-mail: Olfa.Marzouk@imec.be

www.itf2015.be/ITF-Brussels/Homepage/page.aspx/1790

8–10 July 2015

SEMICON West 2015

Moscone Center, San Francisco, CA, USA

E-mail: semiconwest@semi.org

www.semiconwest.org

13–16 July 2015

Intersolar North America 2015

Moscone Center West Hall and InterContinental Hotel
San Francisco, CA, USA

E-mail: brade@intersolar.us

www.intersolar.us

9–13 August 2015

SPIE Optics + Photonics 2015

San Diego Convention Center, CA, USA

E-mail: customerservice@spie.org

<http://spie.org/optics-photonics1>

26–28 August 2015

IEEE Photonics Society's 12th International Conference on Group IV Photonics (GFP-2015)

Vancouver, British Columbia, Canada

E-mail: m.figueroa@ieee.org

www.gfp-ieee.org

2–4 September 2015

SEMICON Taiwan 2015

Taipei World Trade Center (TWTC), Taipei, Taiwan

E-mail: staiwan2@semi.org

www.semicontaiwan.org

2–5 September 2015

17th China International Optoelectronic Expo (CIOE 2015)

Shenzhen, China

E-mail: cioe@cioe.cn

www.cioe.cn/EN

3 September 2015

1st International Forum on Sapphire Market & Technologies

Shenzhen, China

E-mail: veyrier@yole.fr

www.i-micronews.com/yole-events/eventdetail/40/-/1st-int-forum-on-sapphire-market-technology.html

21–24 September 2015

SPIE Remote Sensing 2015

Centre de Congrès Pierre Baudis, Toulouse, France

E-mail: info@spieeurope.org

<http://spie.org/spieremotesensing>

27 September – 1 October 2015

European Conference on Optical Communication (ECOC 2015)

Feria Valencia, Spain

E-mail: ecoc2015@viajeseci.es

www.ecoc2015.org

4–8 October 2015

28th IEEE Photonics Conference (IPC 2015)

Reston, VA, USA

E-mail: c.c.scott@ieee.org

www.ipc-ieee.org

12–15 October 2015

SPIE Optifab 2015

Joseph A. Floreano Rochester Convention Center,
Rochester, NY, USA

E-mail: customerservice@spie.org

<http://spie.org/spieoptifab>

20–22 October 2015

SEMICON Europa 2015

Messe Dresden, Germany

E-mail: eweller@semi.org

www.semiconeuropa.org

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