EVG®

invent
innovate
implement

www.EVGroup.com

Solutions for

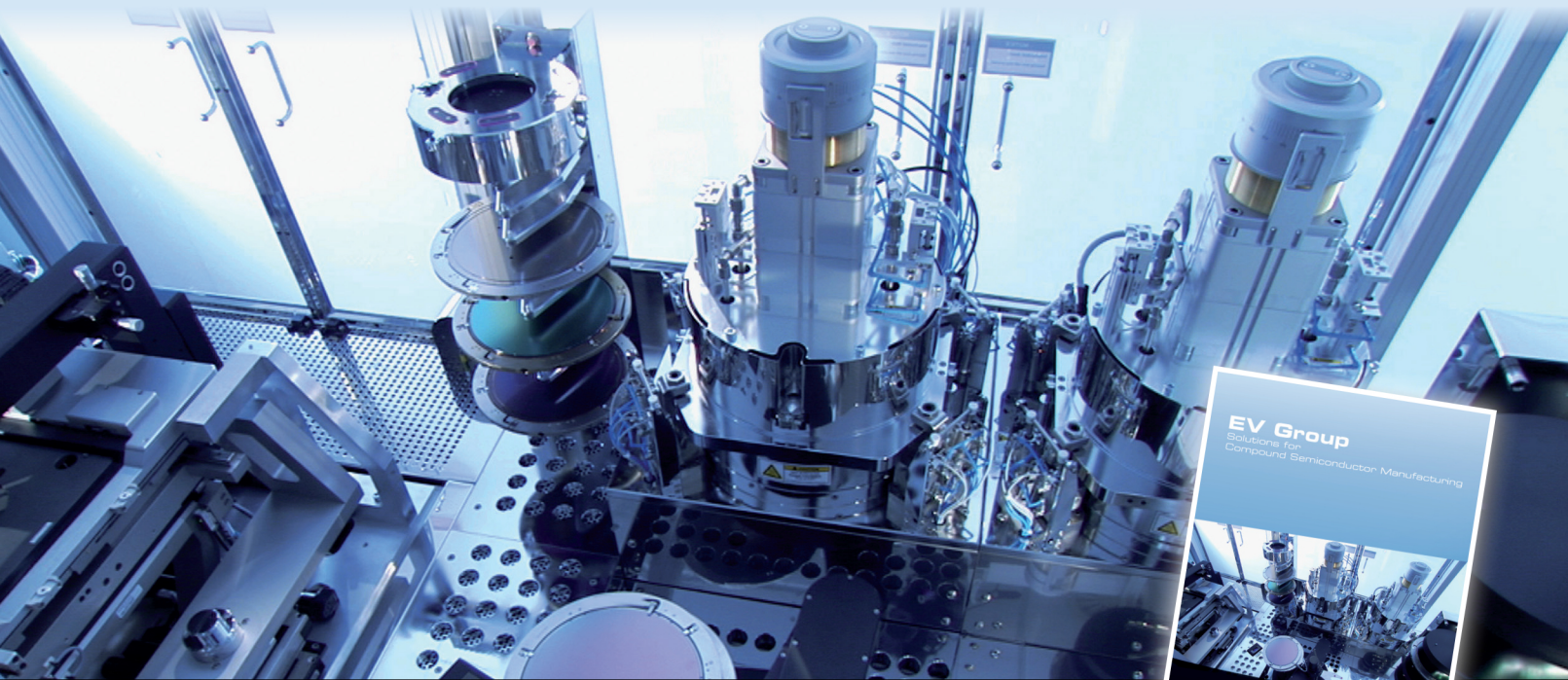
COMPOUND SEMICONDUCTOR MANUFACTURING

Temporary Bonding and Debonding
of Thinned and Fragile Compound Semiconductor Substrates

Spray Coating
for Dielectrics, Thick and Thin Resist Layers and High Topography

Optical Lithography
for Device Patterning and Advanced Packaging

Wafer Bonding
for Layer Transfer and Advanced Packaging



For more information visit **www.evgroup.com/compoundsemi**

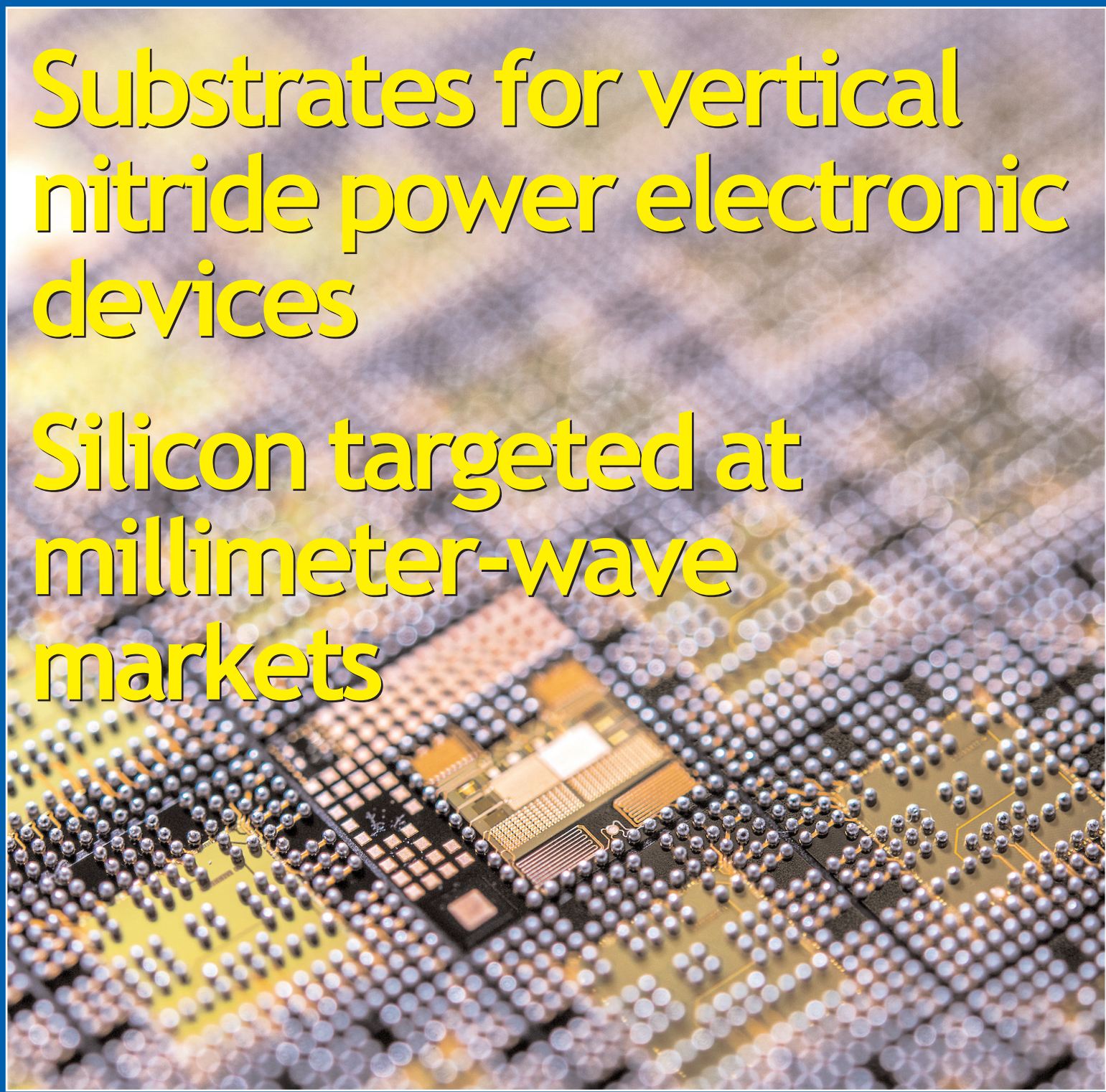
ISSN 1752-2935 (online)

semiconductorTODAY

COMPOUNDS & ADVANCED SILICON

Vol. 10 • Issue 7 • September 2015

www.semiconductor-today.com

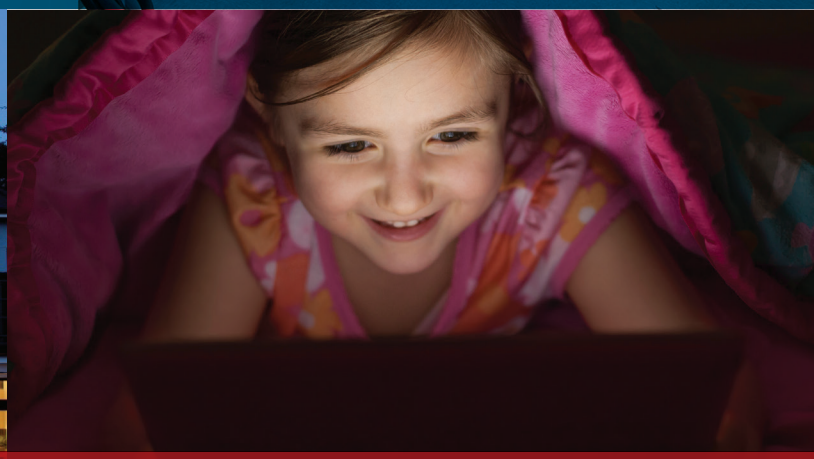


Substrates for vertical nitride power electronic devices

Silicon targeted at millimeter-wave markets

Cree names Power & RF unit Wolfspeed • Finisar's profits fall
Grant for Plessey expansion • GigOptix acquires Terasquare

Lower Cost LEDs



Faster LED Adoption

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

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

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

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

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

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

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

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

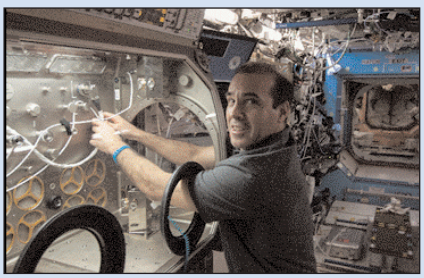
Veeco's New TurboDisc EPIK700 GaN MOCVD System

contents

semiconductorTODAY
COMPOUNDS & ADVANCED SILICON

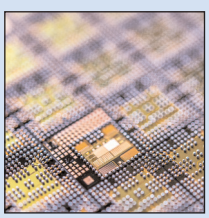
Vol. 10 • Issue 7 • September 2015

p16 Silvaco and Singapore University of Technology and Design collaborate on IC innovation and development.



p40 NASA astronaut using micro-biological test chamber containing Violeds UV-LED sterilizing technology of SETi and Seoul Viosys.

p54 First Solar's new Operations Center in Berlin, managed and operated by subsidiary skytron energy (acquired in mid-2014).



Cover: Infineon's high-frequency radar chip team is nominated for the German President's Award for Innovation in Science & Technology. Infineon claims to be the first firm to develop highly integrated circuits for the 77GHz range based on silicon and SiGe. **p12**

editorial

Power & RF sectors gear up

In pages 74–79 of this issue we focus on substrates for III-nitride vertical power electronic devices. Compared with the integration and reliability challenges of conventional laterally structured transistors and diodes, vertically structured devices promise to handle higher voltage and current in a smaller footprint, along with exhibiting better thermal performance.

Meanwhile, device makers continue to gear up for the growing demand for commercial applications of wide-bandgap gallium nitride (GaN) and silicon carbide (SiC) electronic devices. In early September, Cree Inc of Durham, NC, USA unveiled Wolfspeed as the new name for its Power & RF division (which it announced in May would be separated into a standalone firm by mid-2016). Its GaN-on-SiC high-electron-mobility transistors (HEMTs) and monolithic microwave integrated circuits (MMICs) for radar applications were exhibited under this new identity at European Microwave Week (EuMW) in mid-September (see pages 22–23).

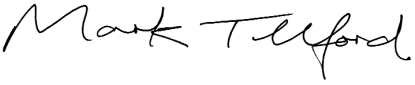
Likewise at EuMW, Germany's Infineon Technologies — a long-time manufacturer of SiC power devices — launched its first devices in a family of GaN-on-SiC RF power transistors, targeting mobile base-station transmitter applications (see page 18). This follows it earlier this year announcing the expansion of its GaN-on-silicon range, resulting from the acquisition of International Rectifier (IR). Even accounting for IR, Infineon has increased its market-share lead in power semiconductors (to 19.2%, from 17.5% for Infineon and IR combined in 2013 — see page 19). While Infineon's power semiconductor sales are mostly silicon-based (IGBTs and MOSFETs), it now spans the SiC, GaN-on-SiC and GaN-on-Si gamut of complementary technologies.

In RF applications, Infineon has just shipped its 10 millionth high-frequency automotive radar chip, which use silicon germanium (SiGe) to operate at 77GHz (see page 13), for which the firm has been nominated for the German President's Award for Innovation in Science & Technology (page 12). Meanwhile, using its 45nm and 40nm low-power process technology, silicon-based GlobalFoundries has partnered with design firm QEOS (also Silicon Valley based) to co-develop what is reckoned to be the first millimeter-wave CMOS platform (demonstrating a 77GHz CMOS design library and an adaptive 60GHz CMOS link for gigabit wireless outdoor connectivity at EuMW) — see page 15. Also, specialty foundry TowerJazz (which has both SiGe and RF-CMOS process technology), together with joint venture analog foundry TowerJazz Panasonic Semiconductor in Japan, has developed what is claimed to be the first 65nm millimetre-wave 110GHz RF-CMOS platform, which it is targeting at applications such as wireless communication (60–77GHz), automotive radar (57–86GHz, mostly 77GHz) and imaging and scanning (100GHz) — see page 14.

Meanwhile, epiwafer foundry IQE has agreed to exclusively license (with an option to subsequently acquire) the Rare Earth Oxide (cREO) technology of Silicon Valley-based Translucent Inc (a subsidiary of Australia's Silex Systems Ltd) — see page 33. The cREO technology is said to be a unique approach to the manufacture of compound semiconductors on silicon, including GaN-on-Si for power switching and RF markets.

So, while CMOS silicon makes inroads into millimeter-wave markets, integration on silicon offers new economies of scale for GaN power devices.

Mark Telford, Editor
mark@semiconductor-today.com



semiconductorTODAY
COMPOUNDS & ADVANCED SILICON

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

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

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

Original design Paul Johnson
www.higgs-boson.com

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

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

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

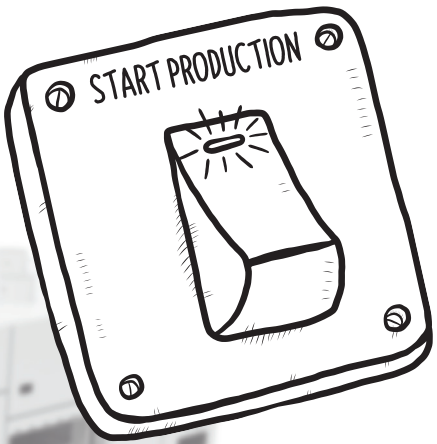
AIXTRON
Our technology. Your future.

YOU THINK,

AIXTRON SYSTEMS SHOULD BE THE EASIEST TO USE.

WE THINK THAT TOO.

THE NEW AIX R6.



DISCOVER THE NEW AIX R6.

Revolutionizing an industry is not about changing everything. It's about making the good even better. Introducing: The new AIX R6. It has everything you expect from the industry's technology leader plus **better usability, better throughput and better cost of ownership.**

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

LED chip market sees oversupply as China accounts for 47% of global MOCVD capacity

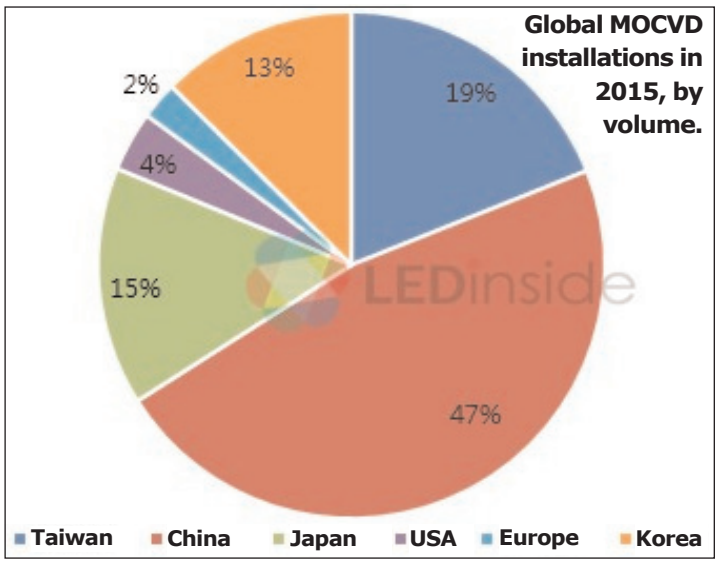
LED chip supply-demand ratio to reach 22% in 2015

Capacity expansion by Chinese LED chip makers has resulted in a supply glut, with this year's LED chip supply-demand ratio reaching 22%, according to the latest '2015 Global LED Industry Supply and Demand Database Report' by LEDinside (a division of TrendForce).

LEDinside also estimates that the global installed volume for metal-organic chemical vapour deposition (MOCVD) in 2015 will grow to 3130 chambers, including 1473 in China accounting for 47% of global capacity (MOCVD systems used in the calculation are of the K465i model).

This year's MOCVD capacity is equivalent to 72.31 million 2-inch LED wafers, up 14% in output volume over 2014, notes research director Roger Chu. Chinese chip makers such as San'an Opto and Changelight in particular are manufacturing using the latest MOCVD systems in their newly built plants in Xiamen. LEDinside projects that monthly wafer capacity during second-half 2015 will rise by as much as 500,000 pieces, making a huge impact on the entire chip industry's supply and demand situation.

Due to government support and fundraising in the stock market in recent years, Chinese LED chip makers are able to expand their capacities to the point of creating a supply glut, notes LEDinside. Therefore the strength of these enterprises cannot be judged by past records. A prime example is China's largest LED chip maker San'an Opto, which in the past few years has been provided with local government subsidies that have comprised 10-14% of the firm's annual revenue. Moreover, San'an Opto's market value has been rising sharply since 2014, and this in turn has attracted more numerous and larger-size investments. In the overall competition, Chinese LED firms have fewer patents and a smaller customer base than their global competitors, but they have significant strength as they are backed by a continuing stream of investments, says LEDinside. In contrast, Taiwanese LED companies have seen their market values falling, followed by an exodus of talent together with fundraising challenges. Consequently, the firms have resorted to layoffs and unpaid furloughs as a means to reduce cash outflow.



Global MOCVD installations in 2015, by volume.

As the oversupply situation remains unresolved, industry participants in future will have to differentiate themselves by developing distinct products or niche applications in order to overcome highly saturated and competitive markets, reckons LEDinside. From this point onwards, their strategies will change from focusing on market scale and market share to generating stable profits to ensure sustainable development, the report concludes.

www.ledinside.com

	2012	2013	2014	1H15
Sales revenue	3,363	3,732	4,580	2,291
Subsidies	471	321	610	17
Subsidies % in revenue	14%	9%	13%	1%
Fundraising	0	0	3237	0
Short-term loan	940	1163	610	601

Total annual subsidies and fundraising (RMB millions).

Slowing demand pushes down LED light bulb and component prices in August

The global average price of 40W-replacement LED light bulbs fell 1.5% in August to US$10.9, while 60W-replacement LED light bulbs fell 2.3% to US$14.9, based on a report by market research firm LEDinside (a division of TrendForce).

According to analyst Allen Yu, the USA was again the regional market that saw the biggest decline in LED light bulb prices after July, as product vendors including Cree and Philips are using package promotion deals and low prices to drive up sales volume and capture market shares.

Furthermore, Chinese LED and chip makers have been gradually expanding their capacities, pushing down component prices during this period of slowing demand. Competition in the LED market on the whole has therefore become more heated.

Yu notes that capacity expansion efforts by many upstream Chinese companies have led to a general supply glut, making price decline inevitable. For example, HC Semitek is raising the metal-organic chemical vapor deposition (MOCVD) capacity of its Souzhou plant, while Changelight's blue and green LEDs have entered mass production at its Xiamen operation. Nationstar is also steadily increasing its chip capacity.

Consequently, in August, prices of 0.2W 2825 LED products fell by 1.36% on average. Prices for 0.5~1W 3030 products fell by 2.15%. In general, Chinese and foreign first-tier package suppliers — Lumileds, Seoul Semiconductor, Osram, Honglitronic and Refond — have all marked down their prices.

After a sharp 14.1% drop on average in July, the prices of 40W-replacement LED light bulbs continued to fall in the US market through August, but with a smaller average decline of 3.7%. Vendors such as Cree and Philips had reduced prices of their products significantly during their promotional campaigns.

Among Cree's products, the price of a pack of six 8.5W 470lm bulbs fell 20% to US$62.26, while a pack of four 6W 450lm bulbs fell more than 30% to US$27. Besides these examples, other vendors including Philips and EcoSmart have also cut prices for their products as part of their sales activities. Many markets outside the USA experienced a gradual price decline in August as well for 40W-replacement products. Prices in Germany and the UK fell 1~2% on average, while China's drop was 1.3%. Japan, however, was an exception to this downtrend as the prices there went up by 0.9% instead.

The USA was also the market where the prices of 60W-replacement LED light bulbs saw the biggest drop.

In July, through their promotional pricing strategies, vendors pushed the average price of these products down 9.5%. Prices fell further in August, with an average monthly decline of 3.9%. Among Philips' products, a pack of four 11W 830lm bulbs fell 20% to US$45.41, and a pack of six 8.5W 800lm bulbs fell 2.57% to US$29.22. A pack of six 13.5W 800lm bulbs from Cree also dropped 20% to US$62.26. In the UK, the price decline of the 60W-replacement LED bulbs grew from 1.1% in July to 3% in August.

However, only a minority of these products saw a significant price decrease. An example of such an extreme case is the price of a Verbatim 10W 820lm bulb, which plummeted nearly 30% to US$18.78 in the UK market. During the same month, prices of 60W-replacement products also fell by 1–3% in other regional markets, including China, Taiwan, Germany and South Korea. Japan was again the exception to the price downtrend, with its 60W-replacement LED bulb market seeing a slight rise of 0.2%.

www.LEDinside.com

Figure 1: Changes in Chinese LED Package Market for August

Package Type	Lumen (lm)	Price (USD/K)			August 2015
		High	Low	Average	MOM
2835	10~24	12.00	4.00	7.23	-1.36%
	54~61	20.00	14.00	16.40	0.00%
5630	36~50	80.00	43.00	59.50	-2.06%
	25~35	65.00	40.00	49.43	-1.98%
3030	100~120	85.00	40.00	60.20	-0.66%

Note: Data are sampled from major package suppliers.

Figure 2: LED Bulb Street Price

Equivalent to 40W Standard Light Bulbs 450~485lm, Warm White (US$)				August 2015	
	High	Low	Average	Change	K-lm, Average
China	16.9	2.1	4.5	-1%	9.2
Worldwide	37.8	1.9	10.9	-2%	22.9

Figure 3: LED Bulb Street Price

Equivalent to 60W Standard Light Bulbs 800~810lm, Warm White (US$)				August 2015	
	High	Low	Average	Change	K-lm, Average
China	43.2	3.2	12.6	-2%	15.5
Worldwide	43.2	3.2	14.9	-2%	18.3

Demand for larger diameters to boost GaN substrate market from $2.2bn in 2014 to $4bn by 2020

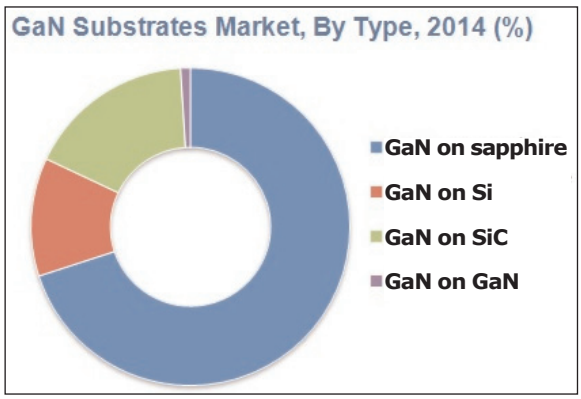
China to dominate market, but quality issues to be addressed

The gallium nitride substrate market will grow from $2.2bn in 2014 to more than $4bn by 2020, forecasts research and consulting firm IndustryARC in the report 'Gallium Nitride (GaN) Substrates Market Analysis: By Type (GaN on sapphire, GaN on Si, GaN on SiC, GaN on GaN); By Products (Blu-ray Disc (BD), Radio frequency amplifiers, LEDs, UV LEDs); By Industry (Consumer Electronics, Telecom, Industrial, Power, Solar and Wind) – With Forecast (2015 — 2020))'.

The GaN substrate market is dominated by foreign substrates, where GaN is grown epitaxially on sapphire, silicon or silicon carbide (SiC). Bulk GaN substrates, i.e. GaN grown on a core GaN substrate, are much lower in volume and are still emerging. Currently, LEDs account for most GaN substrate consumption, with GaN-on-sapphire being the predominant substrate type.

The total market in 2014 comprised mostly 4-inch substrates. However, there is pressing demand for larger-diameter substrates. Making devices on smaller diameters leads to wastage of space and edges whereas larger diameters help to not only prevent wastage but also increase device efficiency.

The USA, Japan, Korea and some European countries are already advanced in adopting larger diameters. Conversely, the leading countries in the LED market (China and Taiwan) are in the transition phase, shifting from 2" to 4" and 6" substrates. LED makers in these countries are now actively making efforts to boost efficiency in production costs and the production process. It is estimated that in China, by 2020, the number of LED-producing metal-organic chemical vapor deposition (MOCVD) reactors making devices on 6-inch substrates will be the highest. Moreover, the production of larger bulk GaN substrates is also estimated to start by 2018 and grow significantly by 2020. Therefore, in the next five years, the market is projected to incline towards larger diameters such as 6" and 8", forecasts the report.



The GaN substrate market is currently led by LED and laser applications. However, over 2015–2020, power electronics are forecast to be the growth segment. In this sector too, players are seeking larger-diameter substrates to yield cost efficiency in production. The market is currently dominated by 2" and 4" substrates. However, as the end-use industries demand devices that can withstand higher powers with low losses, the core components of power electronics are expected to become extra effective and adopt 6-inch substrates.

The Asia-Pacific region is both the major producer and consumer for the GaN substrate market. The Asia-Pacific market in 2014 was almost $1bn. The manufacturers of sapphire, GaN and SiC substrates are located in countries such as Japan, China, and Korea, which contribute to more than 80% of production. Furthermore, bulk GaN substrate production is also dominated by Asia-Pacific players, especially Japan. In the coming years, China is expected to dominate the market, as its cheaper and faster LED production stirred up the LED industry before 2014, positioning China as the major threat to global players. In particular, the cost of gallium material, fabrication and packaging is lower in China than elsewhere, attracting more manufacturers into the market. However, as China-based players take over substrate production and attain global market share, quality remains the major issue to be addressed, forecasts the report.

http://industryarc.com/Report/1264/GaN-substrates-market-research-report.html

Qorvo completes latest $400m share repurchase program

Qorvo Inc of Greensboro, NC and Hillsboro, OR, USA, a provider of RF solutions for mobile, infrastructure and aerospace/defense applications, recently completed its $400m share repurchase program, which was authorized by Qorvo's board of directors just this August.

Under this latest program, Qorvo repurchased about 7.3 million shares of common stock at an average price of $54.75 per share.

Since February, Qorvo has repurchased about $600m of its common stock, with about $500m expended in the quarter to end-September (over a period of about 30 days).

"The Qorvo management team and board of directors believe that the rapid completion of this repurchase program is indicative of Qorvo's strong free cash flow and underscores our commitment to building stockholder value," says president & CEO Bob Bruggeworth.

www.qorvo.com

GENxplor™

Discover The Future

GENxplor's open architecture improves ease-of-use, provides convenient access to effusion cells and is easier to service than other MBE systems

Finally, the Industry's First Fully-Integrated R&D MBE System

You've been asking for a more affordable, flexible, and easy-to-use MBE system, and Veeco has delivered with the GENxplor. Veeco's industry-leading MBE technology features a novel 'all-in-one' design that combines the reactor and electronics on a single frame, making it up to 40% smaller than other MBE systems, so you can save valuable lab space. Its efficient single frame design combines all vacuum hardware with on-board electronics to create high quality epitaxial layers on substrates up to 3" in diameter. The GENxplor allows you to concentrate on the future through cutting edge research for emerging technologies such as UV LED, high-efficiency solar cells and high-temperature superconductors. Discover more at **www.veeco.com/genxplor**

Veeco

Innovation. Performance. Brilliant.

4900 Constellation Drive | St. Paul, MN 55127
Phone: (651) 482-0800 | info@veeco.com

Anadigics launches three small-cell wireless infrastructure power amplifiers

Broadband wireless and wireline communications component maker Anadigics Inc of Warren, NJ, USA has launched three new power amplifiers (PAs) optimized for 3G and 4G small-cell applications, including picocells, enterprise-class femtocells, and high-performance customer premises equipment (CPE). Service providers are expected to increasingly leverage small-cell equipment to improve network capacity and data speeds in densely populated areas. This is exemplified by a recent presentation at LTE World Summit 2015 by Vodafone Netherlands, which discussed planned expansion of its small-cell network and the superior customer experience that it provides.

The AWB7133, AWB7137 and AWB7238 power amplifiers operate in the 2496–2690MHz, 758–803MHz and 791–821MHz frequency band, respectively, delivering a combination of efficiency, linearity, output power and thermal characteristics enabling manufacturers to develop

wireless infrastructure solutions that consume less power and provide higher throughput with greater coverage, the firm claims.

"Anadigics continues to expand its industry-leading small-cell power amplifier family to address the most popular WCDMA, LTE FDD and TD-LTE frequency bands," says Charles Armour, Anadigics' senior director of business development for Wireless Infrastructure Products. "As wireless data consumption continues to break records, our power amplifiers enable the design of high-throughput, reliable, and compact small-cell base stations," he adds. "These solutions enable service providers to economically and pragmatically expand broadband network capacity and coverage."

Anadigics' complete family of small-cell wireless infrastructure power amplifiers leverages the firm's unique InGaP-Plus technology and innovative design architectures to deliver what is claimed to be industry-leading performance and integration. The AWB7133 and AWB7137 power amplifiers deliver more than 15% efficiency, 28dB gain and –47dBc ACPR @ +24.5dBm of linear output power. The AWB7238 features 13.5% efficiency, 30dB gain, and –47dBc ACPR @ +27dBm linear output power.

The power amplifiers are available in the same compact, low-profile 7mm x 7mm x 1.3mm surface-mount package used across the entire AWB71XX and AWB72XX product lines, allowing the same PCB layout to be used for different bands and power levels. Anadigics' small-cell power amplifiers also offer integrated bias, eliminating the need for complicated external bias circuitry and reducing PCB space requirements.

www.anadigics.com

RF Energy Alliance progress and growth highlighted

At European Microwave Week (EuMW 2015) in Paris, France (6–11 September), the status of the RF Energy Alliance (RFEA) was presented by its executive director Dr Klaus Werner in one of six brief sessions hosted by exhibiting member companies Huber+Suhner, MACOM, NXP Semiconductors and Rogers Corp.

Audiences heard about RFEA's vision, goals and development status of the:

- Q4 2015: RF Amplifier Specification, defining amplifier size, component specifications, cost targets, and paths to efficiencies greater than 65% versus standard high-power amplifier (HPA) modules.
- Q1 2016: System Integration Guidelines, defining the small-signal RF generator and controls, power supply units (PSUs), thermal parameters, module interfaces and system integration guidelines.

Additional topics included power amplifier capabilities and system design overviews, solid-state RF energy's measurable impact on various applications, and the importance of standardization.

Membership growth

The RF Energy Alliance was founded in September 2014 by E.G.O. Elektro-Gerätebau GmbH, Huber+Suhner, ITW, NXP Semiconductors, Rogers Corp and Whirlpool Corp affiliate Whirlpool R&D. It is dedicated to presenting solid-state RF energy's potential as a clean, highly efficient and controllable heat and power source. RFEA has now announced four new members:

- Cardiff University: UK university with research expertise in RF power amplifier design and RF energy applications.
- Comba Telecom: a supplier of infrastructure and wireless enhancement solutions that extend mobile operators' and enterprises' wireless communication networks.
- RJR Polymers: a supplier of air-cavity liquid-crystal polymer (LCP) electronic packaging and pre-applied epoxies solutions, enabling communications infrastructure, RF power and RF energy applications with higher frequencies and better thermal performance at overall lower cost.
- WIN Semiconductors: a provider of pure-play gallium arsenide and gallium nitride wafer foundry services for the wireless, infrastructure and networking markets.

www.rfenergy.org

Anadigics' WiFi infrastructure PA enables Ubiquiti's link distance milestone of 140 miles

Broadband wireless and wireline communications component maker Anadigics Inc of Warren, NJ, USA is shipping production volumes of its AWL5910 power amplifier to Ubiquiti Networks in support of its airFiber 5X carrier backhaul radio. These point-to-point devices leveraged Anadigics' power amplifiers to set a wireless connectivity milestone by linking Los Angeles and Las Vegas, a distance of 140 miles. The real-world applications of this radio address the challenges of wirelessly networking two geographically separated facilities.

"Wireless performance and reliability are advancing at a tremendous pace to sustain the explosive growth in global data demand," says Alex Miller, product marketing manager for WiFi Products at Anadigics. "Anadigics' WiFi infrastructure power amplifiers support this trend by delivering an industry-leading combination of linearity, efficiency, gain and thermal characteristics," he claims.

The firm's family of 802.11ac WiFi power amplifiers for infrastructure applications leverage its patented InGaP-Plus technology and unique design architectures to offer both performance and integration. Operating in the 4900–5900MHz frequency band, the AWL5910 PA provides 31dB of linear power gain and a low 2.0% error vector magnitude (EVM) at 22dBm output power. This ensures stable, reliable high-throughput WiFi connectivity in the toughest modulation formats, says the firm, enabling extremely high transmission data rates. The 802.11ac WiFi power amplifiers integrate a digital PA enable interface that eliminates the need for costly external circuitry. The AWL5910 also features a high-precision integrated power detector that facilitates accurate power control over varying load conditions as well as extending the usable dynamic range.

These levels of performance and integration, coupled with the power efficiency and thermal characteristics, enable support of multiple input multiple output (MIMO) designs that consume less power and are more thermally efficient, says Anadigics. With lower current consumption, the firm's WiFi infrastructure power amplifiers also support the stringent power limitations of Power over Ethernet (PoE) equipment.

The compact 4mm x 4mm x 0.8mm QFN package has RF ports that are internally matched to 50Ω and DC blocked to reduce PCB space requirements. In addition, a CMOS-compatible control interface improves ease of use.

www.ubnt.com

Anadigics shipping WiFi infrastructure front-end ICs to Buffalo

Anadigics is shipping production volumes of its AND0281 and AND0581S WiFi infrastructure front-end integrated circuits (FEICs) to Buffalo for its new high-performance WXR-1750DHP AC1750-class 802.11ac router, which features three antennas with simultaneous dual-band capabilities and four gigabit wired Ethernet ports, as well as HighPower and Beamforming technologies.

"Reliance on WiFi networks continues to grow as the number of connected devices rises," notes Anadigics' president Dave Cresci. "Anadigics' WiFi infrastructure FEICs support this trend by providing an industry-leading combination of integration, efficiency and linearity to minimize time-to-market and maximize throughput at extended ranges," he adds.

Anadigics' family of WiFi infrastructure FEICs leverages the firm's 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 (SP2T Tx/Rx switch for 5GHz models) on a single die. This level of integration greatly simplifies RF design and improves manufacturability and reliability, while reducing PCB space requirements and accelerating time-to-market, says Anadigics.

Operating at frequencies of 2400–2500MHz, the AND0281 is optimized for 2.4GHz applications with 28dB linear power gain and –35dB dynamic error vector magnitude (EVM) at +18dBm output power. Operating at frequencies of 4900–5875MHz, the AND0581S operates in the 5GHz frequency band with 29dB linear power gain and –35dB dynamic EVM at +16dBm output power.

Both FEICs are tuned for optimal performance in 802.11ac applications. In particular, ultra-low EVM in the toughest modulation formats enables extremely high transmission data rates, while high gain and output power levels ensure optimal performance in infrastructure and multimedia applications.

The compact 3mm x 3mm x 0.6mm QFN package also incorporates high-precision, integrated power detector (to ensure accurate power control over varying load conditions and to extend dynamic range) and RF ports (internally matched to 50Ω and DC blocked) to reduce PCB space requirements.

www.buffalo.jp
www.anadigics.com

Infineon's high-frequency radar chip team nominated for Deutscher Zukunftspreis

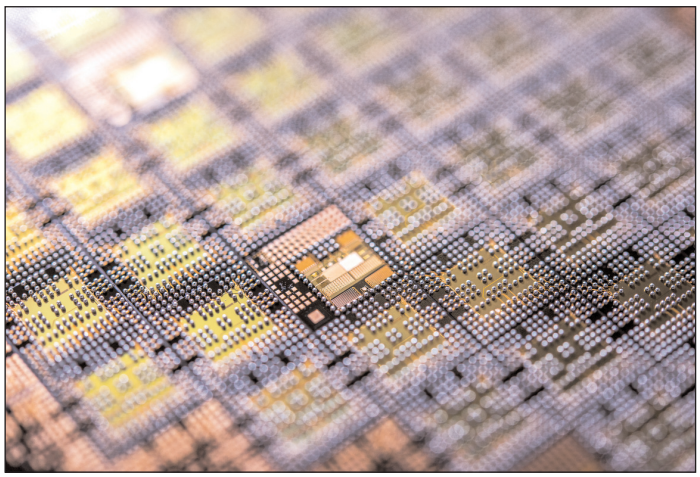
The high-frequency radar chip team at Infineon Technologies AG of Munich, Germany has been nominated for the Deutscher Zukunftspreis 2015 (German Future Award), the German President's Award for Innovation in Science & Technology.

Radar systems in cars measure the distance to other vehicles and their speed in relation to each other in order to give drivers early warning and trigger braking in emergencies. "Radar is a very sophisticated technology. It helps to prevent road accidents and save lives, and also makes driving much more comfortable, for instance in lines of traffic," says Infineon's CEO Dr Reinhard Ploss. "With innovative solutions, the Infineon team has managed to reduce the cost of radar systems considerably. Radar systems that have been confined to drivers of premium cars to date will become affordable for all drivers," he adds. "The nomination acknowledges our employees' outstanding achievements. It is an incentive for further innovations that will not only bring about technical novelties but also prevail on the market and improve people's lives."

Radar technology operates on the basis of high-frequency electromagnetic oscillations sent out as millimeter waves. The standard frequency range for automotive radar applications (such as adaptive cruise control and collision warning) is 77GHz. These high frequencies are necessary to ensure the accuracy of measurements. The radar chips from Infineon send and receive these high-frequency signals and pass them on to the radar electronic control unit.

The jury has nominated Ralf Bornefeld, Dr Walter Hartner and Dr Rudolf Lachner for the Deutscher Zukunftspreis and has hence acknowledged two key innovations that have initiated the breakthrough of radar systems in the automotive market. Infineon claims to be the first company to develop highly integrated circuits for the 77GHz frequency range based on silicon (Si) and silicon germanium (SiGe) instead of gallium arsenide (GaAs) typically used before. Using Si and SiGe material leads to much lower product costs of radar systems. The second innovation is the new packaging technology eWLB (embedded wafer-level ball-grid array), which offers good high-frequency characteristics and simplifies the further processing of radar chips at the automotive system provider. This means another substantial reduction in system costs of the radar system, says Infineon.

Nominated for the Deutscher Zukunftspreis 2015 are Infineon's Ralf Bornefeld (middle), Dr Walter Hartner (right) and Dr Rudolf Lachner (left).



An Infineon radar chip.

In July, Infineon reported that the ten-millionth radar chip for cars had been shipped. The next ten million are already due to be shipped within the next year. Infineon produces its radar chips solely in Germany, with all stages of the process — from chip manufacturing to processing in the package — carried out at its manufacturing plants in Regensburg and Dresden.

This is the fourth time that Infineon has been nominated for the Deutscher Zukunftspreis (in 1998 as Siemens Semiconductor group). The German President has conferred this award for innovation in science and technology since 1997 to reward outstanding achievements in technology, engineering and the natural sciences with great market potential for the German economy. Three teams have been nominated for the Deutscher Zukunftspreis 2015 from a total of 24 proposed technology projects. A jury of independent experts from academia and business selects the nominees and the winner. German President Joachim Gauck will announce the winner and present the award on 2 December in Berlin, Germany.

www.deutscher-zukunftspreis.de
www.infineon.com/deutscher-zukunftspreis

Infineon delivers 10 millionth automotive radar chip

Infineon Technologies AG of Munich, Germany has shipped its 10 millionth high-frequency radar chip. The silicon germanium (SiGe) 77GHz chips are used in radar-based driver assistance systems that recognize objects at ranges of up to 250m. Infineon estimates that in 2014 nearly 50% of 77GHz radar systems in vehicles were equipped with its technology.

In a recent study, market research firm IHS Technology declared Infineon the global market leader in 77GHz chips, which is the standard frequency range for radar applications such as adaptive cruise control (ACC) and collision warning. The first 10 million of these radar chips from Infineon were incorporated primarily in premium and luxury vehicles over the past six years. Infineon anticipates increasing demand and expects that, within the next year, up to 10 million radar chips will also be used in mid-sized and compact cars. So, statistically, one out of every 20 cars will be using a driver assistance system with a 77GHz radar chip from Infineon.

Market research firm Strategy Analytics also confirmed this trend towards safety systems in cars. It expects that in the next five years applications such as distance warning systems and automatic emergency braking will grow by more than 25% annually, due partly to the rating scheme from the independent organization Euro NCAP (European New Car Assessment Programme) that reviews the safety of new vehicles sold in Europe. To achieve the highest rating of five stars, a new car must have a radar-based driver assistance system. Strategy Analytics forecasts that, of the 105 million new vehicles expected to be built in 2020, more than 20 million will use a radar-based distance warning system. So, about 20% of all new vehicles worldwide would be equipped with such a system.

"Our chips make driver assistance systems increasingly accurate and more cost-effective," says Jochen Hanebeck, president of Infineon's Automotive division. "Radar-based driver assistance systems using Infineon chips now are becoming the standard in mid-range and compact cars," he claims. "They are an important growth market for Infineon. Our high system knowledge and close cooperation with leading system suppliers and car manufacturers around the world are key elements to our success."

Broad product portfolio for radar-based driver assistance systems from short to long vicinity range

Even in poor visibility situations, radar chips in the 77GHz range enable vehicles to 'recognize' other road users at a distance of up to 250m, allowing a car to indicate a hazardous traffic situation in time and brake automatically.

In addition to 77GHz radar chips for active safety systems, for distances up to 100m Infineon also offers radar chips in the 24GHz frequency range (mostly for monitoring blind spots). The radar system alerts drivers to vehicles behind them when passing or changing lanes. When parking, the radar detects cross-traffic in the rear and prevents collisions.

www.infineon.com/rasic

Pasternack unveils coaxial packaged bi-directional RF amplifiers

Pasternack Enterprises Inc of Irvine, CA, USA (which makes both passive and active RF, microwave and millimeter-wave products) has introduced a line of bi-directional amplifiers that are used for sending and receiving radio signals in key applications such as unmanned aerial vehicles (UAV), unmanned ground vehicles, L- and S-band radar, military radio, commercial air-traffic control, weather and earth observation, satellites and high-gain driver power amplifiers.

The new bi-directional RF amplifiers consist of two narrow-band models that operate in the L- (1.35–1.39GHz) and S-band (2.4–2.5GHz), using highly linear Class AB LDMOS semiconductor technology. In addition, a general-purpose broadband model covers the 30MHz to 3GHz frequency range, using Class A GaAs technology. Typical gain levels range from 20dB to 23dB with ±0.5dB gain flatness. The key advantage of the designs is fast switching capability (1μs typical) between transmit (Tx) and receive (Rx) states where high output power is generated, while at the same time the sensitive receiver section has a 2.5dB noise figure and sufficient RF gain levels to maintain a high-data-rate link.

The new models are designed for use in both military and commercial applications and are capable of supporting any signal type and modulation format, including but not limited to 3–4G telecom, WLAN, OFDM, DVB and CW/AM/FM. The firm says that its bi-directional amplifiers use the latest technologies and design methods, offering high power density, efficiency and linearity in small lightweight environmentally sealed packages with SMA connectors. The modules also feature a quick-connect circular locking connector for DC and control functions. All designs use a single voltage supply with voltage regulation.

"Pasternack's selection of in-stock bi-directional amplifiers exhibit fast transmit and receive switching capabilities, long transmission range and highly efficient operation, which are critical for use in applications such as unmanned aerial vehicles and cellular networks," says Tim Galla, Active RF Components product manager.

Pasternack's broadband bi-directional amplifiers are in-stock and ready to ship.

www.pasternack.com

TowerJazz Panasonic develops 65nm mmWave 110GHz RF-CMOS platform

Specialty foundry TowerJazz (which has fabrication plants at Tower Semiconductor Ltd in Migdal Haemek, Israel, and at its subsidiaries Jazz Semiconductor Inc in Newport Beach, CA, USA and TowerJazz Japan Ltd) together with analog foundry TowerJazz Panasonic Semiconductor Co Ltd (TPSCo) in Japan have developed what is claimed to be the first 65nm millimetre-wave (mmWave) 110GHz RF-CMOS platform targeted at applications such as wireless communication (60–77GHz), automotive radar (57–86GHz, mostly 77GHz), and imaging and scanning (100GHz), among others.

TPSCo was established by Panasonic Corp, 51% of which was acquired by Tower Semiconductor Ltd and 49% of which is now held by Panasonic Semiconductor Solutions Co Ltd. TPSCo has three manufacturing facilities in Hokuriku, Japan which have been producing large-scale integrated circuits for over 30 years. Areas of process technology focus include: high-dynamic-range image sensors (CIS and CCD) and integrated power devices (BCD, SOI and LDMOS) as well as high-frequency silicon RF-CMOS.

TowerJazz and TPSCo are expanding their mmWave platform capabilities by introducing new process modules and comprehensive validated electronic design automation (EDA) tools and modeling, targeted to support a larger application segment. The platform supports 110GHz with RF modeling for MOSFETs, inductors and transmission lines, a very large set of metal combination and a full set of RF-CMOS elements. RF applications such as WiFi 802.11, Wireless HDMI, and WiGi that require 65nm mmWave technology can now utilize modeling capabilities up to 110GHz. In addition, this platform is automotive qualified at TPSCo's 300mm fab in Uozu City, Japan.

According to a report by MarketsandMarkets, the millimetre-wave technology market was $208.1m in 2014 and will rise at a compound annual growth rate (CAGR) of 43% in the near future. In particular, the North American millimetre-wave market is expected to grow from $96.1m in 2014 to $782.9m by 2020, driven by growing applications in the mobile and telecom sectors. TowerJazz anticipates its growth to surpass overall market growth as customers move from III-V technology to silicon-based technology with either SiGe or RF-CMOS.

"Expanding our 65nm RF-CMOS automotive platform into the mmWave regime is a mandatory part of our global MS/CMOS and RF-CMOS roadmap in order to provide a comprehensive and total solution for our automotive customers in Europe and to our wireless customers in the USA, Europe and across the board," says Ilan Rabinovich, VP & general manager of TowerJazz's MS/CMOS business unit. "This is yet an additional expansion of our offering in this marketplace. Having both advanced SiGe solutions and a 65nm Si-based RF platform enables our customers maximum flexibility in selecting the right technology for their specific application," he adds.

www.towerjazz.com

Guerrilla RF launches broadband, low-noise linear amplifier with integrated bypass

Guerrilla RF Inc of Greensboro, NC, USA — which provides monolithic microwave integrated circuits (MMICs) to wireless infrastructure original equipment manufacturers — has launched a broadband, low-noise linear amplifier with integrated bypass that covers a wide bandwidth with minimal external parts – yielding a compact, low-cost solution. The device integrates low noise figure, high linearity and low-loss bypass functionality into a small application footprint, making it suitable for demanding small-cell, cellular booster and repeater transmit–receive applications in the 700–3800MHz frequency bands.

"The GRF4042 is the initial device in a growing family of high-performance amplifiers offering bypass functionality," says Alan Ake, VP of applications and technical marketing. "All of our devices featuring bypass also incorporate our Guerrilla Armor technology, which provides high off-state isolation even in the presence of high RF input powers," he adds. "This isolation is especially useful in TDD systems in which significant transmitter RF power can leak into the transceiver receive path. When transmitting in a TDD system, the powered-down LNA chain needs to stay off regardless of the level of incident power from the PA. Our GRF4042 addresses this requirement nicely with off-state S (2,1) typically less than –30dB with input powers in excess of +15 dBm."

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

The GRF4042 provides sub-1.0db noise figure, excellent linearity, adjustable current, low-loss bypass and Guerrilla Armor. With integrated DC blocking caps on the RF input/output and internal pre-matching to 50Ω, the device typically requires little or no external matching.

http://guerrilla-rf.com/files/8614/

QEOS and GlobalFoundries to offer first CMOS platform for millimeter-wave markets

GlobalSolutions partnership to enable next-generation wireless technologies for applications in IoT, 5G and automotive

QEOS Inc of Milpitas, CA, USA (a designer of low-power connectivity and sensing CMOS millimeter-wave solutions) and GlobalFoundries of Santa Clara, CA, USA (one of the world's largest semiconductor foundries, with more than 250 customers and operations in Singapore, Germany and the USA) are partnering to co-develop what is claimed to be the first millimeter-wave (mmWave) CMOS platform.

Leveraging GlobalFoundries' 45nm and 40nm low-power process technologies, the mmW platform includes support for the higher data rates required in future mobile broadband access networks, while enabling customers to integrate mixers, low-noise amplifiers (LNAs), power amplifiers (PAs), and inter-frequency (IF) amplifiers, all in a single package. The co-designed platform aims to leverage GlobalFoundries' production-proven expertise in advanced silicon RF technologies and QEOS' next-generation design environment and IP to expand the mmWave wireless technology offerings to enable gigabit interactivity everywhere — from centimeters to hundreds of meters — at a cost of less than $500 per link.

Demonstrations of a 77GHz CMOS design library and an adaptive 60GHz CMOS link for gigabit wireless outdoor connectivity were given at European Microwave Week (EuMW 2015) in Paris, France (6–11 September).

The available mmW IP includes: a low-power Bits In/Out architecture; BIST/BIOS for digital die sort; beam steering; an integrated transceiver; a frequency synthesizer; and co-designed system-in-package with antenna.

"MmW technology is a key pillar for next-generation wireless markets including IoT, 5G and automotive," says Ted Letavic, department leader of strategic applications and product segments at GlobalFoundries.

Leveraging GlobalFoundries' 45nm and 40nm low-power process technologies, the mmW platform includes support for the higher data rates required in future mobile broadband access networks

"Our expanded partnership with QEOS enables our customers to address the challenging requirements for adaptive next-generation gigabit wireless sensing and connectivity, and lays the foundation for accelerating market adoption of mmW products and solutions in high-growth markets," he adds.

"GlobalFoundries' and QEOS' partnership is a key milestone for enabling the next generation of low-power mmWave CMOS," comments Rob Shaddock, chief technology officer of TE Connectivity. "TE Connectivity has been watching the developments in this field closely, and we believe that this is going to have a major impact across the connectivity and sensing markets."

As part of GlobalFoundries' GlobalSolutions ecosystem, QEOS' 45/40nm-based mmWave CMOS IP will be available in two forms. Basic block-level IP will be available from GlobalFoundries, while more complex subsystem IP will be licensable directly from QEOS. QEOS will provide support and design services for all IP.

www.globalfoundries.com
www.qeosystems.com

Analog Devices launches 24–35GHz medium-power distributed driver amplifier

Analog Devices Inc (ADI) of Norwood, MA, USA (which provides ICs for analog and digital signal processing applications) has launched a medium-power distributed driver amplifier that operates at 24–35GHz, suitable for civil and defense communications systems, including point-to-point and point-to-multi-point radios and VSAT and satellite communications (SatCom) applications.

Based on a gallium arsenide (GaAs) pseudomorphic high-electron mobility transistor (pHEMT) design and operating from a DC supply of +5V at 225mA, the HMC1131 provides 22dB of gain, +35dBm output IP3, and +24dBm of output power at 1dB gain compression (P1dB). The amplifier is capable of supplying +25dBm of saturated output power with 16% power-added efficiency (PAE).

Housed in a compact, leadless 4mm x 4mm ceramic surface-mount package, the HMC1131 reduces the number of components required to achieve the desired output power and small-signal gain, lowering development costs and design time by enabling simpler transmit line-ups and higher integration.

Pricing of the HMC1131 is $34.15 each in 1000-unit quantities.

www.analog.com/HMC1131

Singapore University of Technology and Design and Silvaco launch RF IC design collaboration

Program to expand RF design learning to speed innovation

Silvaco Inc of Santa Clara, CA, USA, a provider of technology computer-aided design (TCAD), circuit simulation and IC CAD electronic design automation (EDA) software tools, is collaborating with the Singapore University of Technology and Design (SUTD) to advance and promote integrated circuits (IC) innovation and development in Singapore.

To support the collaboration, Silvaco is providing its full suite of radio frequency integrated circuits (RF IC) design, layout and verification tools to set up SUTD's electrical engineering (EE) lab. The US$5.65m (S$7.91m) joint technology development program is expected to help rapidly expand RF design learning to speed design innovation.

"Silvaco's support will enable SUTD to establish the university's EE lab and create a hotbed for advanced and future research in IC design, and develop cutting-edge technologies required to design IC systems for applications in our daily lives, such as consumer electronics including those for mobile and medical devices," comments professor Yeo Kiat Seng, SUTD's Associate Provost for Graduate Studies and International Relations. "The collaboration will help to transform the semiconductor industry in Singapore from a manufacturing focus to a high-value-added and IC design-driven one, as well as to nurture and groom the next generation of engineering leaders in IC design," he adds.

Professor Yeo Kiat Seng, SUTD's Associate Provost for Graduate Studies and International Relations, and Silvaco's CEO David L. Dutton cement the RF IC design collaboration.

"SUTD is a research-intensive university with innovative research and multi-disciplinary education focused on technology and design that fuels experimentation and breakthroughs," comments Silvaco's CEO David L. Dutton. "This partnership will leverage the strengths of both parties — Silvaco's leading EDA software expertise and SUTD's extensive technology research acumen — to develop new design innovations that will power the next generation of ICs required for leading-edge digital electronics and growing Internet of Things applications."

www.silvaco.com
www.sutd.edu.sg

European Commission approves NXP's acquisition of Freescale, conditional on NXP divesting RF power business

Under the EU Merger Regulation, the European Commission in Brussels, Belgium has approved the proposed acquisition of Freescale Semiconductor Ltd of Austin, TX, USA by NXP Semiconductors N.V. of Eindhoven, The Netherlands (announced in March), conditional upon NXP divesting its radio frequency power business to address the Commission's concerns that the takeover could otherwise have led to higher prices and less competition in this specific market.

The Commission found that the two companies' semiconductor product portfolios were mostly complementary, except for RF power transistors (where NXP and Freescale are the two largest players and close competitors) in particular those used in base stations for mobile telecoms. The Commission was concerned that after the merger, as originally notified, the remaining companies on the market would have been unable to exercise sufficient competitive pressure on the merged entity. This could have led to price rises and a reduced choice for customers.

To address these concerns, NXP offered:

- to sell its RF power business, consisting all key assets and personnel, except assets necessary for front-end manufacturing of these products (i.e. wafers processing);
- a manufacturing agreement with a third-party foundry to perform front-end manufacturing services for the divested business;
- to provide the RF power business with the transitional manufacturing and services agreements required to guarantee business continuity.

The European Commission says that the commitments offered by NXP will allow the purchaser of the divested business to replicate NXP's previous role in the RF power transistors market, maintaining effective competition. The commitments completely remove the overlap between the RF power transistor activities of NXP and Freescale, and adequately address competition concerns identified by the Commission.

www.nxp.com
www.freescale.com

MACOM launches DOCSIS 3.1-compliant 12V CATV push-pull infrastructure amplifier

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 the MAAM-011169 12V CATV push-pull infrastructure amplifier designed to meet DOCSIS 3.1 and C-DOCSIS standards, with production quantities and samples are available now. Targeted at hybrid fiber-coaxial (HFC) network amplifiers and fiber-to-the-premises (FTTP) optical network termination (ONT), the new monolithic microwave integrated circuit (MMIC) amplifier delivers high output power, gain and linearity with low power dissipation.

The MAAM-011169 delivers 46dBmV per channel output power with 25dB gain and is optimized for very low distortion and high linearity in a 75Ω push-pull amplifier circuit. It is reckoned to provide excellent input and output return loss over the 45–1200MHz bandwidth while delivering superior thermal performance in an industry-standard 5mm x 7mm PQFN package.

The MAAM-011169 is the newest addition to MACOM's portfolio of RF components specifically designed to comply with the DOCSIS 3.1 standard for high-bandwidth data transfer over existing HFC infrastructure.

The firm says its CATV technology expertise and global application support network ensure that CATV providers can meet growing bandwidth demands and accelerate their time to market with DOCSIS 3.1 systems and solutions.

High-performance, cost-competitive cable/broadband solutions enable network equipment providers to support end-to-end DOCSIS 3.1-compliant HFC networks

"With the introduction of the MAAM-011169, MACOM delivers a best-in-class next-generation 12V power amplifier for legacy DOCSIS 3.0 and emerging DOCSIS 3.1 HFC networks," says Graham Board, senior director of carrier networks. "MACOM's high-performance, cost-competitive cable/broadband solutions — covering actives, passives and filters — enable network equipment providers to support end-to-end DOCSIS 3.1-compliant HFC networks," he adds.

MACOM's MAAM-011169 amplifier and wired broadband portfolio is on show in booth #2710 at the SCTE Cable-Tec Expo'15 in New Orleans, LA, USA (13–16 October).

www.macom.com/products/product-detail/MAAM-011169
http://expo.scte.org

MACOM adds high-linearity 2W and 4W Ka-band packaged power amplifiers for SatComs

At European Microwave Week (EuMW 2015) in Paris, France (8–10 September), 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) launched the MAAP-011246, a 2-Watt power amplifier, and the MAAP-011139, a 4-Watt power amplifier, in a 5mm x 5mm 32-lead QFN surface-mount technology (SMT) package. The 4-stage, fully matched power amplifiers are suitable for Ka-band SatCom applications, and provide the linearity for either final power amplification stages or driver stages in higher-power applications. "The addition of these 2 watt and 4 watt packaged power amplifiers to MACOM's complete chip-set solution offers customers increased performance and flexibility in next generation Ka-band VSAT systems."

The MAAP-011246 operates at 27.5–31.5GHz, providing 23dB of linear gain, 2W saturated output power and 24% power-added efficiency (PAE). The device offers an IM3 level of –25dBc at 27dBm Pout/tone, making it suitable for high-performance commercial SatCom uplink terminal applications.

The MAAP-011139 operates at 28.5–31.0GHz while providing 22dB of linear gain, 4W of saturated output power and 23% of power-added efficiency. The device delivers greater than 27dBm P_{out}/tone while maintaining IM3 levels of 30dBc, which is twice the linear performance of competing alternatives, it is reckoned.

"The superior linearity performance of the MAAP-011246 and MAAP-011139 are further complemented by their high gain, power-added efficiency and availability in SMT QFN packages," says product manager Paul Beasly. "The addition of these 2W and 4W packaged power amplifiers to MACOM's complete chip-set solution offers customers increased performance and flexibility in next-generation Ka-band VSAT systems."

Production quantities and samples of the MAAP-011246 and MAAP-011139 are available from stock. The MAAP-011139 is available now in both bare die and packaged versions.

www.macom.com/EuMW2015
www.macom.com/products/product-detail/MAAP-011246
www.macom.com/products/product-detail/MAAP-011139-DIE

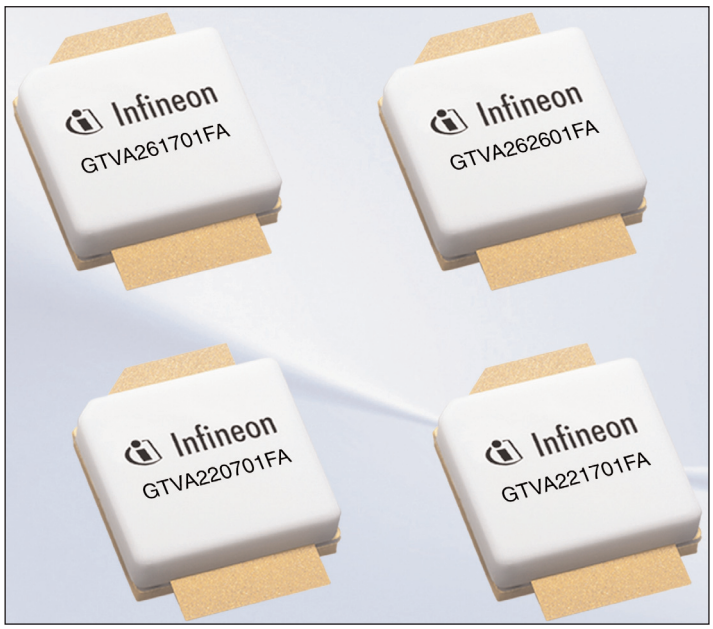
Infineon introduces GaN devices for mobile base-station transmitters; charts path to 5G cellular infrastructure

At European Microwave Week (EuMW 2015) in Paris, France (6–11 September), Infineon Technologies AG of Munich, Germany introduced its first devices in a family of gallium nitride on silicon carbide (GaN-on-SiC) RF power transistors.

Infineon says that, as part of its GaN portfolio, the devices allow mobile base-station manufacturers to build smaller, more powerful and more flexible transmitters. With higher efficiency, improved power density and more bandwidth than existing RF power transistors, the new devices improve the economics of building infrastructure to support current cellular networks, claims the firm. They should also pave the way for the transition to 5G technology with higher data volumes, it adds.

"This new device family combines innovation with knowledge of the application requirements for cellular infrastructure to provide our global customer base with next-generation RF power transistors, says Gerhard Wolf, VP & general manager of Infineon's RF Power product line. "They allow significant improvement in the operating performance and reduction in size of the transmitter side of mobile base stations," he adds. "Additionally, with the transition to wide-bandgap semiconductor technology, we are setting the pace for the continued evolution of the cellular infrastructure."

The new RF power transistors leverage the performance of GaN technology to achieve 10% higher efficiency and five times the power density of the LDMOS transistors commonly used today, it is reckoned. This translates to smaller footprints and power requirements for the power amplifiers (PA) of base-station transmitters currently in use, which operate in either the 1.8–2.2 or 2.3–2.7GHz frequency range. Future GaN-on-SiC devices will also support 5G cellular bands up to the 6GHz frequency range. Infineon reckons that this roadmap allows it to build on its expertise and production technologies for RF transistor technology.



Infineon's new GaN-on-SiC RF power transistor family.

Design flexibility and support for the next-generation of 4G technology are additional benefits of GaN devices for RF power applications. The new devices have twice the RF bandwidth of LDMOS, so that one power amplifier (PA) can support multiple operating frequencies. They also have increased instantaneous bandwidth available for transmitters, which lets a carrier offer higher dates using the data aggregation technique specified for 4.5G cellular networks.

Engineering samples and reference designs are available to customers under specific non-disclosure agreements (NDA).

Earlier this year, Infineon described its broadened patent portfolio related to GaN and announced the expansion of its GaN-on-silicon (GaN/Si) range, GaN/Si epitaxy process and 100–600V technologies resulting from the acquisition of International Rectifier. Infineon also announced a strategic partnership aimed at integrating enhancement-mode GaN-on-silicon transistor structure into its surface-mount device (SMD) packages,
www.infineon.com/rfpower

Custom MMIC appoints Aspen Electronics as UK technical representative

Monolithic microwave integrated circuit (MMIC) developer Custom MMIC of Westford, MA, USA has appointed Aspen Electronics as its new technical representative covering the UK as part of its growing network of technical representatives.

"Their extensive knowledge of the RF and microwave industry in the UK, developed over more than 40 years, gives them an unparalleled understanding of the opportunities for Custom MMIC in this region," reckons president & CEO Paul Blount.

Aspen Electronics was founded in 1974 and has an established team of high-tech professionals offering components and related technologies for the RF/microwave and wireless markets.
www.aspen-electronics.com

Infineon extends lead in power semiconductor market

Infineon Technologies AG of Munich, Germany says that is the market leader in power semiconductors for the twelfth consecutive time. Following the firm's acquisition of International Rectifier at the start of 2015, Infineon has a market share of 19.2%. In comparison, Infineon and International Rectifier had a combined market share in 2013 totalling about 17.5%, according to US market research firm IHS Inc. Infineon's closest competitor has a market share of 7%, adds the firm.

"Through organic growth and the acquisition of International Rectifier we've made our leadership position for power semiconductors even stronger compared to the global competition," says Infineon's CEO Dr Reinhard Ploss. "Our leading technology expertise and our system understanding mean we will profit disproportionately from the forecasted growth."

Helping to efficiently generate, transport and convert power in devices ranging from the kitchen microwave to large-scale wind power turbines, the global market for power semiconductors grew by 6.3% in 2014 to $16.2bn, reckons IHS. The IHS study predicts growing demand for power semiconductors particularly in the automotive and industry sectors through 2019.

In the sub-markets for IGBT modules, discrete IGBTs and MOSFETs, Infineon was the sole player to significantly grow market share in 2014.

In particular, Infineon's MOSFET market share grew from 26.4 to 27.8%, while the second largest competitor reached 10.5%. Infineon grew its stake in the discrete IGBT market from 34.7% to 38.5%, with its nearest competitor achieving 14.1%. Also, as the second-ranked player in the IGBT module segment, Infineon raised its market share from 21.4% to 23.2%, narrowing the gap to the segment leader by slightly more than two to now only about three percentage points.

Infineon also reports that it has once again been listed in the Dow Jones Sustainability Index in 2015. Infineon has been included in both the European and worldwide indexes and is thus listed among the most sustainable companies in the world for the sixth consecutive year.

"We have been listed in the Dow Jones Sustainability Index every year without interruption since 2010. We are very pleased about this recognition and about the positive feedback from those investors, to whom sustainability is of special importance," says Infineon's chief financial officer Dominik Asam, responsible for the topic of sustainability.

www.infineon.com

Lasertec launches system for concurrent surface and PL crystallographic defect inspection of SiC wafers

Metrology and inspection equipment maker Lasertec Corp of Yokohama, Japan has launched SICA88, the latest model of its SiC wafer inspection and review systems. Featuring both surface and photoluminescence (PL) inspection capabilities, SICA88 enables users to concurrently inspect and analyze surface defects as well as crystallographic defects. Lasertec has already received orders from multiple customers including ROHM Co Ltd.

SiC power devices are already being used in applications such as air conditioners, solar cells and railway cars and they are beginning to capture additional markets, with expectations that they will be widely used in electric vehicles, says the firm. However, producing SiC power devices is technically demanding, as various problems remain unsolved, including crystallographic defects that occur in the production process. Quality control and cost reduction therefore pose major challenges. SiC wafer manufacturers find it necessary to enhance and maintain wafer quality while SiC device manufacturers are expected to maintain high yields while reducing production cost.

The SICA inspection tool is designed to help overcome these challenges. Lasertec launched SICA61 in 2009 for R&D use and SICA6X in 2011 for production use. Since then, SICA has become known for its high sensitivity and accurate defect classification capability and has been widely adopted by many users, says the firm.

SICA88 introduces a new platform that combines PL inspection capability with the confocal DIC optics used in the previous-generation SICA models for surface inspection. It now offers simultaneous detection and classification of not only scratches and epitaxial defects on the wafer surface but also crystallographic defects such as basal plane dislocations (BPD) and stacking faults (SF) inside epilayers, assisting the detection and analysis of defects that cause device malfunctions. The SICA88's throughput is 20 wafers per hour (for 6-inch wafers, in high-throughput mode), which is twice that of the SICA6X, and BPD inspection is possible without compromising throughput.

Lasertec says that one of the best ways to utilize the SICA88 is as a process monitor in wafer production, epi processing and device processing to assist root-cause analysis. It also offers a wafer-grading capability that helps to achieve process cost reductions and higher device yields.

www.lasertec.co.jp/en/products/environment/sic/sica88.html

US Energy Department awards $22m to develop wide-bandgap technology for large-scale motors

SiC to be applied in variable-speed, medium-voltage drive systems

As part of the US Administration's effort to increase energy efficiency and double US energy productivity by 2030, the Energy Department is awarding $22m in funding for five projects aimed at merging wide-bandgap (WBG) semiconductor technology with advancements for large-scale motors to increase energy efficiency in high-energy-consuming industries, products and processes, such as the transportation of fossil fuels and industrial-scale compression systems.

Funded through the Next Generation Electric Machines funding opportunity, the projects could cut energy waste by as much as 30%. The projects also aim to reduce the size of megawatt-scale motors and drive systems used in the chemical and petroleum refining industries, natural gas infrastructure, and general industry compressor applications like HVAC (heating, ventilation and air conditioning) systems, refrigeration, and wastewater pumps by up to 50%.

"The industrial sector uses more than 30% of the energy consumed in the USA and is projected to use more, not less, energy over the next 25 years," says David Danielson, Assistant Secretary for Energy Efficiency and Renewable Energy. "Replacing less efficient industrial motor systems with more advanced, variable-speed direct-drive systems and incorporating recent power electronics advances, such as wide-bandgap semiconductors, could reduce industrial electricity consumption by 2–4%, leading to up to $2.7bn in annual energy savings, reducing up to 27 million tons of carbon emissions each year, and creating high-quality manufacturing jobs," he adds.

The projects will leverage the work of the Department's Power America Institute on WBG semiconductors for power electronics by deploying WBG technology to drive large power, industrial and high-speed electric motors and systems. WBG components (for controlling or converting electrical energy into usable power) operate at higher temperatures, voltages, and frequencies than silicon-based technologies.

The projects will leverage the work of the Department's Power America Institute on wide-bandgap semiconductors for power electronics by deploying wide-bandgap technology to drive large power, industrial and high-speed electric motors and systems

They are more durable and reliable, and can eliminate up to 90% of the power losses in electricity conversion compared to current technologies. By focusing on their specific application for large-scale motors, manufacturers can significantly improve the efficiency and productivity of processes ranging from small-scale machining to large-scale refining, pumping and cooling, it is reckoned.

The projects being funded are as follows:

- Calnetix Technologies will design, build and test a high-speed permanent magnet machine and a silicon carbide (SiC)-based variable-speed drive system using a 4160 volt medium-voltage (MV) input. The new medium-voltage motors are expected to achieve up to eight times the power density of similar traditional systems.
- General Electric Company will develop and demonstrate a medium-voltage drive system using SiC semiconductors and a high-speed motor to reduce the system footprint and improve power density and efficiency. To achieve these targets, the program will focus on three technology areas: (i) SiC-based MV high-frequency drive, (ii) a high-speed motor, and (iii) advanced insulation systems.
- Eaton Corp will develop and test an integrated 15kV SiC variable-speed drive and high-speed megawatt motor for gas compression applications. The new drive technology will operate at more than 99% efficiency and achieve 10 times the power density of competing drives, providing an integrated, highly efficient motor and drive system for natural gas applications.
- Clemson University will develop a pre-commercial megawatt-class variable-speed drive based on new motor power converter technologies. The fully integrated prototype system will be made by TECO Westinghouse Motor Company in its Round Rock, TX facility and be demonstrated at Clemson's eGRID Center.
- Ohio State University will design, test and demonstrate a high-performance, high-speed drive capable of integrating into electric grids while avoiding energy losses associated with power transformers. If successful, it is reckoned that the proposed project will significantly advance transformer-less drive technologies for a range of industries and motor applications.

This effort is part of the Energy Department's broader Clean Energy Manufacturing Initiative, which aims to increase American competitiveness in the production of clean energy products and to boost US manufacturing competitiveness by increasing energy productivity.

www.energy.gov/eere/cemi/clean-energy-manufacturing-initiative

ACME's microgravity-processed SiC devices outperform devices made on traditional premium-grade silicon carbide

ACME Advanced Materials Inc (A2M) of Albuquerque, NM, USA has partnered with two silicon carbide (SiC) research groups to independently evaluate and assess the performance enhancement from devices fabricated on its 'S Grade' microgravity-processed SiC substrates. Compared with devices made on traditional prime-grade substrates, initial tests showed that the S Grade devices had improved electronic transport, lower on-resistance, reduced forward voltage, higher current density threshold, and increased reliability, says ACME.

To provide independent verification of these results and develop a deeper understanding of the microgravity process itself, ACME has partnered with Dr Debbie G. Senesky, who runs the EXtreme Environment Microsystems Laboratory (XLab) in the Aeronautics and Astronautics Department at Stanford University, and Dr Michael Dudley, chairman of the Department of Materials Science & Engineering (MSE) at Stony Brook University. Senesky's group has been working with ACME since January to analyze S Grade substrate material properties and build Schottky diode test devices on S Grade substrates. Dudley joined the team in July and his group will bring additional evaluation tools and expertise to the analysis.

"The typical reaction we get from industry when they see our results is, 'No way, this can't be true'," says ACME's president & CEO Rich Glover. "So, we decided to partner with experts that are well known in the power electronics field and let them perform their own independent analysis."

The initial, first-generation device improvements using ACME's S grade SiC material include: superior MOSFET, transistor and diode avalanche energy clamping capability; vastly improved device in-rush current carrying capacity; faster allowable switching dV/dt for converters; and improved short-circuit survivability.

"We've conducted detailed pre-flight and post-flight analysis on these substrates and observe compelling modifications to the material structure," notes Senesky. "The devices we've built on S Grade substrates also show improved electrical performance when compared to devices built on traditional, unprocessed substrates. My team is digging into these results and we plan to start publishing and sharing the results soon," she adds. "These results are quite intriguing and we're looking forward to working with Dr Dudley and applying his unique expertise in SiC microstructure to perform additional analysis."

www.A2-M.com

Cree names Power and RF division Wolfspeed

IPO planned for wide-bandgap SiC power product and GaN RF device business in fiscal 2016

Cree Inc of Durham, NC, USA — which makes silicon carbide (SiC) and gallium nitride (GaN) wide-bandgap semiconductor wafers and devices as well as LEDs — has announced Wolfspeed as the new name for its Power and RF division (which it announced in May would be separate into a standalone company).

In May, Cree submitted a registration statement to the US Securities and Exchange Commission (SEC) for an initial public offering of common stock of its Power and RF subsidiary. In July, it acquired Arkansas Power Electronics International Inc (APEI) of Fayetteville, AR, USA, a provider of SiC power modules and power electronics applications.

Cree says that, founded on the mission to "liberate power and wireless systems from the limitations of silicon", Wolfspeed enters the marketplace as an entrepreneurial growth company with a focused team, a profitable business and more than 28 years of wide-bandgap semiconductor technology and experience.

Cree reckons that the new name will allow the Power and RF division to build brand equity while operating as a separate business although, as a Cree company, Wolfspeed will leverage the parent firm's brand, global footprint, scale and expertise.

"Wolfspeed is providing our customers and our team with a first look at our new company's name, brand identity and purpose in advance of our IPO, which we plan to execute during fiscal year 2016," says Wolfspeed's executive vice president Frank Plastina. "We're building something new on the firm foundation that is Cree," he adds.

Cree reckons that, as the only player in the industry with a fully commercialized, broad portfolio of the most field-tested SiC and GaN power and wireless technologies and products on the market, Wolfspeed's products enable higher power density, higher switching frequencies, and reduced system size and weight. Such advantages lead to smaller systems, lower system costs and improved performance, and can ultimately lead to more powerful applications in the transportation, industrial and electronics, energy, and communications markets.

www.wolfspeed.com
www.cree.com/power
www.apei.net

US Air Force awards Cree's Power and RF Division $4.1m contract extension

SiC power modules to be qualified for F-35 Joint Strike Fighter

The US Air Force has awarded Cree Inc of Durham, NC, USA, which makes silicon carbide (SiC) and gallium nitride (GaN) wafers and devices as well as LEDs, a $4.1m follow-on contract, enabling qualification of a high-performance power electronic module developed for the F-35 Joint Strike Fighter in its facilities Fayetteville, AK.

"Cree is on the forefront of a number of exciting advancements, including the effort to modernize our aircraft for the US Air Force," comments US senator John Boozman. "The company's contributions to an increase in high-tech domestic manufacturing in Northwest Arkansas help drive economic growth in our state and create more well-paying jobs."

Boozman was visiting the Cree campus to discuss the benefits of the project to Arkansas and to tour the firm's Fayetteville facilities. Cree began operating in Arkansas in July with the acquisition of Arkansas Power Electronics International Inc (APEI) of Fayetteville, AR, USA, a provider of power modules and power electronics applications.

"We're excited to get this high-performance module commercially qualified through this program, not only for Department of Defense requirements but also for a wide range of industrial applications," says John Palmour, chief technology officer for Cree's Power and RF Division.

The F-35 Joint Strike Fighter is one of the first major programs implementing the Air Force's new 'More Electric' and 'All Electric' aircraft design philosophy, which mandates the replacement of costly and bulky mechanical hydraulic aircraft flight control systems with lighter weight, high-reliability, low-maintenance electric motors and drives.

The high power densities and high voltages required to operate mechanical flight systems using electric motors are driving a transition to high-density SiC power electronic systems that can operate at higher efficiencies, higher voltages, higher power densities, and higher temperatures in comparison with conventional silicon electronics. The new contract will fund rigorous qualification testing of the developed power modules to broaden integration platforms and commercial viability of the product.

www.cree.com/power

Cree gives presentations on SiC power devices at ECCE

Cree Inc of Durham, NC, USA, which manufactures silicon carbide (SiC)-based power products — including SiC MOSFETs, Schottky diodes, and modules — delivered five technical presentations at the seventh annual IEEE Energy Conversion Congress and Expo (ECCE 2015) in Montreal, Canada (20–24 September).

On 21 September during the plenary session, Dr John Palmour, co-founder & chief technology officer of Cree's Power and RF business unit, presented 'SiC Power Devices: Changing the Dynamics of Power Circuits from 1 to 30kV. He gave an overview of SiC semiconductors across a wide voltage range, discussed the advantages they provide over silicon technologies, and refuted the industry's common cost rebuttal by re-contextualizing the price versus performance data for SiC and silicon in a system-to-system rather than a component-to-component comparison. Palmour will also briefly discuss a few of the high-voltage devices (up to 27kV) that Cree is currently developing.

"The most common knock against silicon carbide is that it's more expensive than silicon, which it is," says Palmour. "However, a component-to-component comparison will never be wholly accurate because silicon carbide is vastly superior to silicon with regard to performance," he adds. "SiC devices make systems less expensive through their ability to operate at much higher frequencies, shrink magnetics, and simplify designs. They can also dramatically cut conduction and thermal management costs in lower-frequency applications. Further, SiC devices can even allow designers to switch from multi-level topologies down to less complex two-level designs. So, as an industry, we've got to switch the focus of this conversation from the cost of the devices to the cost versus performance metrics of the entire system."

The following Cree presentations were also given at ECCE:

- '900V Silicon Carbide MOSFETs for Breakthrough Power Supply Design' by SiC power device application engineer Dr Adam Barkley, in the Poster Session;
- 'Advances in SiC and GaN Based Devices, Packaging, and Systems', by John Palmour and director of business development Dr Ty McNutt;
- '3.3kV SiC MOSFET Update for Medium Voltage Applications', by power business development and program manager Dr Jeffrey Casady, in the session 'Power Electronic Modules for MV/HV Applications';
- '10–25kV Silicon Carbide Power Modules for Medium Voltage Applications', by development electronics packaging engineering manager Dr Brandon Passmore, in the session 'Power Electronic Modules for MV/HV Applications'.

www.2015.ecceconferences.org/

Wolfspeed exhibits GaN HEMTs for radar applications at European Microwave Week

At European Microwave Week (EuMW) 2015 in Paris, France (6–11 September), Wolfspeed of Raleigh, NC, USA, a Cree Company that supplies gallium nitride on silicon carbide (GaN-on-SiC) high-electron-mobility transistors (HEMTs) and monolithic microwave integrated circuits (MMICs), exhibited its newest radar products, including what are claimed to be the highest-power C- and S-band GaN HEMTs on the market (the CGHV59350 and CGHV31500F) in addition to its 50V unmatched general-purpose GaN HEMTs (the CGHV40030, CGHV40100 and CGHV40050).

Specifically designed to solve long-standing issues for radar systems employing traditional traveling-wave tube (TWT) amplifiers, Wolfspeed's GaN RF transistors for radar applications were engineered to deliver the highest power and efficiency available in a small package size, and are not prone to the failure mechanisms associated with high-voltage (kV) TWT power supplies (allowing them to provide longer operational lifetimes).

"Wolfspeed's C- and S-band radar products break power records for GaN power and efficiency performance housed in a small 50Ω package," claims director of sales & marketing Tom Dekker. "This efficient power enables the economical combination of transistors to achieve multi-kilowatt power amplifiers required for defense, weather, and air traffic control radar," he adds. "If we consider the figure of merit for RF power output relative to the area of a 50Ω package, Wolfspeed's 350W C-band device beats the closest commercial GaN competitor by an estimated 3.5 times. Using the same figure of merit, Wolfspeed's 500W S-band device raises the bar by 45% over other commercial S-Band products."

Wolfspeed says that, with high-efficiency, high-gain and wide-bandwidth capabilities in addition to high power density and low parasitics, its general-purpose, unmatched 50V GaN HEMTs significantly improve the efficiency and bandwidth capabilities of multi-octave bandwidth amplifiers, narrow-band UHF applications, and a wide range of L- and S-band products, and are suitable for use in high-power broadband amplifier, CW, and pulsed applications.

www.wolfspeed.com/RF/Products/SBand-XBand-CBand/Packaged-Discrete-Transistors/CGHV59350

MACOM adds 200W GaN-on-Si power transistor

At European Microwave Week (EuMW 2015) in Paris, France (8–10 September), 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) said that it is sampling the NPT2024, a wideband transistor optimized for DC–2.7GHz operation using MACOM's proprietary gallium nitride on silicon (GaN on Si) process. The NPT2024 supports CW, pulsed and linear operation, with output up to 200W. "The technical performance of MACOM's NPT2024 complements our expanding GaN portfolio, which offers the industry with a broad GaN offering boasting high performance, gain, efficiency and affordability," reckons senior product director Gary Lopes.

Delivering performance that is claimed to rival expensive GaN on silicon carbide (GaN on SiC) at a projected volume production cost structure below that of incumbent LDMOS technology, MACOM's 4th generation GaN (Gen4 GaN) technology delivers greater than 70% peak efficiency and 19dB gain for modulated signals at 2.7GHz, which is similar to GaN-on-SiC technologies, and more than 10 percentage points greater efficiency than LDMOS. It also delivers power density that is more than four times that of LDMOS.

www.macom.com/products/product-detail/NPT2024

MACOM samples 4th-gen 100W GaN-on-Si wideband transistor

MACOM says the MAGX-100027-100C0P, a wideband transistor optimized for DC–2.7GHz operation and fabricated using its proprietary fourth-generation GaN on Si process, is now sampling. The GaN-on-Si HEMT D-Mode transistor is suitable for defense communications, land mobile radio, avionics, wireless infrastructure, ISM (industrial, scientific & medical) applications and VHF/UHF/L/S-band radar applications. "This Gen4 GaN transistor provides optimal performance for customers"

The MAGX-100027-100C0P supports CW, pulsed, and linear operation with output power levels up to 100W (50dBm). Featuring 50V operation, the device offers 18.3dB gain at 2.45GHz and 70% drain efficiency for CW operation, and 18.4dB gain at 2.7GHz and 71% drain efficiency for pulsed operation. The 100% RF-tested transistor is available in an industry-standard plastic package with bolt-down flange.

MACOM claims that its 4th-generation GaN (Gen4 GaN) technology delivers performance that rivals expensive GaN on silicon carbide (GaN on SiC) at a projected volume production cost structure below that of incumbent LDMOS technology. Gen4 GaN delivers more than 70% peak efficiency and 19dB gain for modulated signals at 2.7GHz, which is similar to GaN-on-SiC technologies, and more than 10 percentage points greater efficiency than LDMOS. It also delivers power density that is more than four times that of LDMOS.

"The MAGX-100027-100C0P is an ideal candidate for customers looking to support rugged applications," reckons Says product manager Gary Lopes. "Gen4 GaN products extend the innovation and commercialization trajectories of earlier generations of GaN-on-Si, which have demonstrated clear, field-proven reliability in harsh environmental conditions for more than five years."

www.macom.com/products/product-detail/MAGX-100027-100C0P

MACOM ships millionth GaN-on-Si RF power device

MACOM has now shipped more than 1 million GaN-on-Si RF power devices to customers for use in communications, military and other RF applications. The milestone in market adoption of the technology comes as GaN-on-Si is finding new potential markets in applications such as magnetron replacements, automotive ignition systems, high-bay lighting and wireless charging, says the firm.

MACOM claims that its proprietary GaN-on-Si RF process combines the best features of GaAs, GaN-on-SiC and LDMOS in a low-cost and scalable manufacturing flow. The milestone showsfield-proven reliability and ruggedness in demanding applications such as aerospace & defense and civil & commercial communications.

"MACOM's GaN IP portfolio and strategic licensing agreements have set the foundation for a sustainable, cost-efficient technology [that] we believe can enable GaN production at unprecedented economies of scale," says Michael Ziehl, VP of marketing, RF & Microwave. "We expect to see ramping commercial adoption of our GaN technology in other RF applications in the future, including 4G/LTE base stations and RF energy applications."

Qorvo expands plastic-packaged GaN RF transistors to X-band for marine and avionics radar

Qorvo has launched three new unmatched gallium nitride (GaN) RF transistors in low-cost QFN plastic packages — designed to operate in the 8–12GHz frequency band — to enable smaller size and greater reliability in civilian marine, airborne and infrastructure radar systems.

Qorvo's GaN technology, paired up with the small packaging, enables high linear gain and power efficiency. The TGF2977-SM (in a 3mm x 3mm QFN package) has output power (P3dB) of 37dBm, drain efficiency of 50%, and linear gain of 12.5dB. The TGF2978-SM (in a 3mm x 3mm QFN package) has output power of 43dBm, drain efficiency of 45%, and linear gain of 11dB. The TGF2979-SM (in a 3mm x 4mm QFN package) has output power of 44dBm, drain efficiency of 45%, and linear gain of 11dB.

"Qorvo is expanding GaN in low-cost QFN plastic packaging to include X-band transistors for marine and avionics radar," says Roger Hall, general manager of Aerospace and Defense Products. "Radar manufacturers that are converting Magnetrons to solid-state power amplifiers (SSPAs) and radar arrays can produce smaller, more efficient radar units as a result of GaN's size, weight and power efficiencies," he adds. "They are also assured that Qorvo's best-in-class GaN solutions have met stringent heat and moisture stress testing so that the products will operate in harsh environments."

The new X-band power transistors will be available in fourth-quarter 2015. Qorvo showcased its portfolio of plastic-packaged GaN solutions at European Microwave Week (EuMW 2015) in Paris, France (8–10 September).

Qorvo launches 3W GaN-on-SiC Ka-band power amplifier for commercial VSAT satellite ground terminals

Qorvo has launched a cost-effective, high-performance Ka-band 3-watt GaN power amplifier (PA) for commercial VSAT satellite ground terminals transmitting high-speed internet data.

The TGA2636-SM GaN PA is fabricated using Qorvo's 0.15μm gallium nitride on silicon carbide (GaN-on-SiC) process, and operates across a 28–31GHz frequency range while delivering 3W of saturated output power and 25dB linear gain at 30% power-added efficiency (PAE) in a compact 5mm x 5mm surface mount package.

"Qorvo's 0.15μm high-frequency GaN process delivers three times the power density of past-generation GaAs pHEMT solutions," reckons Gorden Cook, general manager of Qorvo's transport business unit. "With unmatched, power, device gain and reliability, the technology is ideal for both saturated and linear high power amplifier for Ka-band satellite ground terminal transmit applications," he adds. "Supporting both saturated and linear applications, the TGA2636-SM delivers 3W of peak output power for traditional saturated-power VSAT ground terminal applications and, when operated in a 'linear power back-off mode' required for higher-order modulation systems, enables more effective use of the Ka-band spectrum, resulting in higher data rates delivered to the user."

The new GaN VSAT power amplifier began sampling in third-quarter 2015. Production quantities will be available in first-quarter 2016.

Qorvo showcased its GaN power amplifiers at European Microwave Week (EuMW 2015) in Paris, France (8-10 September).

www.qorvo.com

Diamond Microwave launches 1kW ultra-compact pulsed GaN X-band solid-state power amplifiers

At European Microwave Week (EuMW) in Paris, France (6–11 September), Diamond Microwave Devices Ltd of Leeds, UK announced a ten-fold rise in its power output capability with the addition of a 1kW X-band model to its range of GaN-based pulsed solid-state power amplifiers (SSPA).

The DMX1K001 operates over a 1200MHz bandwidth centred at 9.5GHz. The compact design is only 244mm x 134mm x 50mm excluding heatsink and connectors, making it suitable as an alternative to a travelling-wave tube amplifier (TWTA) in radar applications.

"These amplifiers are extremely compact, employing a chip-and-wire microwave design," says business development manager Ian Davis. "Performance is combined with a power-to-volume ratio we believe to be among the highest in the industry for such products," he adds. "Similar designs can be tailored to suit other frequency ranges in the 1–18GHz range."

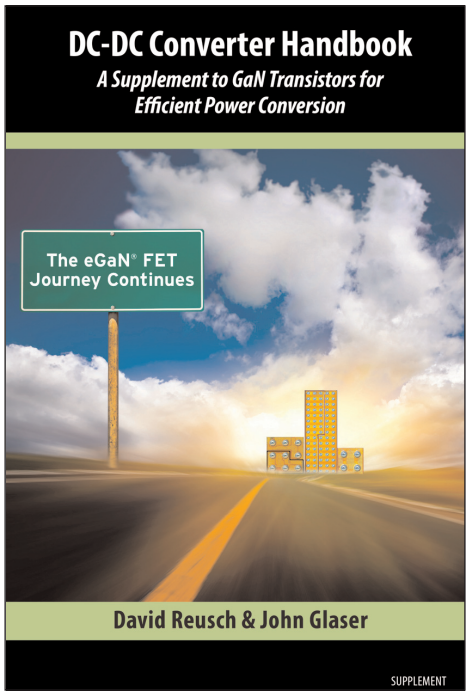
Suitable for demanding defence, aerospace and communications use, amplifier range features designs that are flexible in layout and architecture, and are fully customizable to individual specifications for electrical, mechanical and environmental parameters.

www.diamondmw.com

EPC publishes DC–DC Conversion handbook

Efficient Power Conversion Corp (EPC) of El Segundo, CA, USA, which makes enhancement-mode gallium nitride on silicon (eGaN) power field-effect transistors (FETs) for power management applications, has published a handbook, 'DC–DC Conversion: A Supplement to GaN Transistors for Efficient Power Conversion' (by Dr David Reusch and Dr John Glaser), as a practical engineering guide showing how to achieve increased efficiency and power density in datacom equipment and other power conversion applications using GaN power transistors.

The book addresses how power conversion systems will continue to improve in order to keep pace with the rapid improvements in computing power and the need for efficient data centers. With a focus on the use



of high-performance GaN technology, the DC–DC handbook goes through step-by-step analysis of how to create power conversion solutions using GaN devices. The analysis makes direct performance comparisons with state-of-the-art silicon power transistors traditionally used in power conversion systems.

Also, combining the discussion of power conversion systems architectures and the superior performance of GaN technology, the book introduces a new power delivery architecture that takes advantage of the superior performance attributes of GaN – showing the increased power density that can be achieved with high-frequency switching.

'DC–DC Conversion: A Supplement to GaN Transistors for Efficient Power Conversion' is available for $39.95 and can be purchased from Digi-Key, or from Amazon.com.

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

Guerrilla RF's new high-linearity gain blocks act as broadband pre-drivers for GaN power amplifiers

Guerrilla RF Inc of Greensboro, NC, USA — which provides monolithic microwave integrated circuits (MMICs) to wireless infrastructure original equipment manufacturers in market segments including enterprise/carrier-class WiFi access points, small cells, wireless backhaul and cellular repeaters — has added to its family of high-linearity gain blocks (which features a combination of simple-application schematic, flat gain and high compressed output power operating from near DC up to 4GHz).

The GRF2012 and GRF2013 are suitable as cost-effective pre-drivers for existing broadband gallium nitride high-power amplifiers as well as a multitude of general-purpose, high-performance gain block applications. Their flat gain and flexible biasing allow for high levels of re-use both within a single design and across platforms, says the firm.

The gain blocks address a critical industry need for cost-effective, broadband pre-drivers for GaN power amplifiers (PAs), reckons the firm. "With flexible biasing and V_{dd} capability up to 8V, these amplifiers provide consistent, broadband, compressed output power that GaN designers have been searching for," says Alan Ake, VP of applications and technical marketing. "These versatile devices provide high levels of performance covering a wide frequency range, all with internal matching. This results in a low part count which ultimately yields compact, low-cost solutions for design engineers."

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

A typical GaN pre-driver application of the GRF2012 and the GRF2013 (announced in May) deliver a compressed output power greater than +25dBm using a V_{dd} of 8V over a wide frequency range of 200–2600MHz. This bandwidth matches up well with the broadband performance capability of some of today's newer GaN PAs, reckons Guerrilla RF. Their flexible biasing capability allows V_{dd} over a range of 2.7–8.0V and the device I_{ddq} can be set independently from the Vdd, allowing for optimal power consumption and efficiency, adds the firm.

Guerrilla RF also offers SOT-89 variants of GRF2012 and GRF2013 as the GRF3012 and GRF3013, respectively. These SOT-89 variants offer similar broadband compressed output power capability compared with the GRF2012/2013 devices and can also be used as drop-in replacements for industry-standard SOT-89 gain blocks while offering superior performance, it is claimed.

All four devices in the family are sampling now. Pricing is $1.48 for the GRF2012 and GRF2013 and $1.10 for the GRF3012 and GRF3013 each, in 10,000-unit quantities.

http://guerrilla-rf.com

Fuji Electric
Innovating Energy Technology

Fuji Electric Lambda Series
New, Compact, Powerful

The New Generation of Low Voltage Earth Leakage Circuit Breakers

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

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

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

or contact us: fuji-dc@fecoa.fujieletric.com

Advantech Wireless' second-gen GaN-based 300W/400W X-band SapphireBlu SSPA/SSPB for military applications

Advantech Wireless Inc of Montreal, Canada (which manufactures satellite, RF equipment and microwave systems) has released a 300W/400W X-band SapphireBlu SSPA/SSPB (solid-state power amplifier/solid-state power block) — based on the firm's second-generation gallium nitride (GaN) technology — for military applications.

The firm says that the new systems provide very high linearity and high power density in a compact size. With a weatherproof construction, the units are suitable for communications applications in the harshest of environments.

"The second-generation X-band GaN SSPAs are designed to meet the stringent requirements of military standards for mobile satcom terminals," says VP business development Cristi Damian. The new SSPAs provide a 60% increase in linearity over the previous-generation solid-state technology while reducing the size and energy consumption by more than 50%. Designed to be mounted on ruggedized military trailers, they are a direct replacement for 750W TWTs (travelling-wave tubes), fully compliant with the latest versions of Mil-Std-810G. They are also compliant with the latest revision of Mil-Std-188-164A.

Their built-in design features of the second-generation X-band GaN-based SapphireBlu SSPAs/SSPBs result in a product with exceptional linearity and operating efficiency, it is claimed. The design is based on Advantech's industry-proven solid-state high-power amplifiers.

www.advantechwireless.com

Pasternack expands portfolio of GaN power amplifiers

Pasternack Enterprises Inc of Irvine, CA, USA (which makes both passive and active RF, microwave and millimeter-wave products) has expanded its range of gallium nitride coaxial power amplifiers (PAs).

The high power density of GaN technology dissipates heat more effectively, which results in amplifier designs that have significantly higher output power levels over broadband and narrowband frequencies, says the firm. The rugged connectorized designs have the advantage of high output load impedance, offering easier impedance matching over wider bandwidths using lower-loss components. Applications include commercial and military radar, jamming systems, medical imaging, communications and electronic warfare.

Pasternack's range of RF amplifiers includes GaN-based models that feature very high gain levels from 43dB to 60dB across mostly broad frequency bands ranging from 30MHz to 7.5GHz. Saturated output power levels range from 10W to 100W, with 20–35% power-added efficiency (PAE). The thermal efficiency of GaN technology enables these assemblies to be integrated into smaller more compact coaxial packages with the same level of high reliability.

Pasternack's GaN power amplifiers.

All of the firm's high-power GaN amplifiers have single voltage supplies that are internally regulated. The 50Ω input/output matched designs are adaptable to a range of power and modulation requirements. The PAs also have harmonic response of –15dBc to –20dBc under worst-case conditions. The GaN amplifiers are designed to withstand environmental conditions such as humidity, altitude, shock and vibration. Some models are also equipped with integrated heat-sinks and cooling fans. Most designs are EAR99.

"These highly efficient PAs cover broad and narrowband frequencies with high levels of gain and power in small coaxial packages," says Tim Galla, Active RF Components product manager.

Pasternack's GaN power amplifiers are in-stock and ready to ship now.

www.pasternack.com

GaN Systems showcases high-current 650V, 100A gallium nitride power transistors for first time at Energy Conversion Congress & Expo

At the 17th Conference on Power Electronics and Applications (EPE'15 - ECCE Europe) hosted by CERN in Geneva, Switzerland (8–10 September), GaN Systems Inc of Ottawa, Ontario, Canada, a fabless developer of gallium nitride-based power switching semiconductors for power conversion and control applications, displayed its GS66540C 650V 100A high-current GaN power transistors for the first time.

Part of the firm's family of 650V GaN power transistors based on its proprietary Island Technology, the high-density devices are said to achieve extremely efficient power conversion with fast switching speeds of >100V/nS and ultra-low thermal losses. The GS66540C is supplied in an evolved form of GaN*PX* packaging specially developed for higher operating currents, providing the lower inductance and greater surface-mount mechanical robustness required by power modules for the industrial and automotive markets. The near-chip-scale parts have no wirebonds and offer what is described as step-change improvements in switching and conduction performance over traditional silicon MOSFETs and IGBTs.

Parts are now sampling with major customers (including OEMs and tier-1 manufacturers) and are being designed into solar, industrial and automotive applications.

The GS66540C is supplied in an evolved form of GaN*PX* packaging specially developed for higher operating currents

Also at EPE'15, GaN Systems displayed multiple customer platforms, including a 2kW commercial vehicle inverter from global transportation technology company Ricardo.

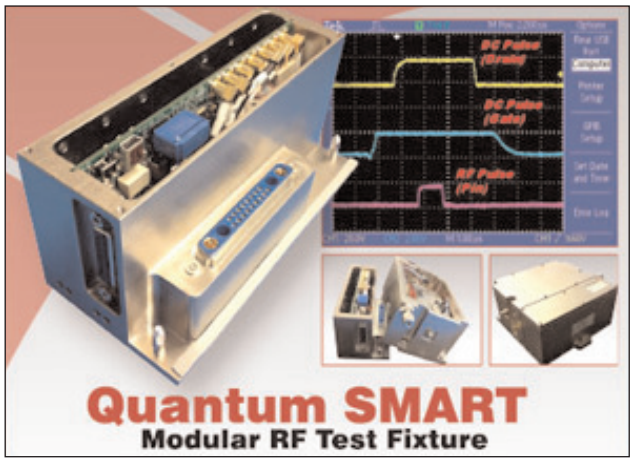
GaN Systems claims to be the first company to have developed and productized a comprehensive portfolio of GaN E-HEMT power devices with current ratings from 7A to 250A, in both 650V and 100V ranges. Its Island Technology die design, combined with its extremely low inductance and thermally efficient GaNPX packaging and Drive Assist technology, provides a 45-fold improvement in switching and conduction performance over traditional silicon MOSFETs and IGBTs.

www.gansystems.com

Accel-RF launches Quantum SMART fixture for bench-top testing to speed GaN and SiC device development

Accel-RF Instruments Corp of San Diego, CA, USA (which produces turn-key reliability and performance characterization test systems for compound semiconductors) says that it has 'unplugged' the RF SMART Fixture from its automated test platform and made it available for bench-top testing. The new Quantum SMART fixture enables concurrent testing for reliability validation, performance characterization, and product qualification through RF-biased burn-in and product functional testing.

"Unplugging the SMART Fixture from our accelerated life-test platform for use on a benchtop allows for a quantum reduction in the traditional semiconductor technology development roadmap," says president & CEO Roland Shaw. "Implementing Accel-RF's Quantum SMART solution provides both accelerated and enhanced return on investment (ROI) by launching products into the market at a much faster pace," he adds. "The streamlined productivity of this test solution is crucial for rapid insertion of the new generation of gallium nitride (GaN) and silicon carbide (SiC) compound semiconductor technologies envisioned in key commercial and military market sectors."



The Quantum SMART fixture is a programmable self-contained DC bias and RF stimulus control module capable of synchronizing independent pulsed-bias and pulsed-RF signals to a device-under-test (DUT) or remote subsystem. The signals are controlled from a user-interface compatible with Accel-RF's LIFETEST software. The fixture is capable of 'active' temperature control and monitoring of a remote DUT through embedded firmware in the microprocessor.

www.accelrf.com

IQE's non-wireless business rises year-on-year from 21% to 24% of revenue

Photonics sales grow by 28% from £5.8m to £7.4m; infrared revenue grows from $4.3m to £4.6m

For first-half 2015, epiwafer foundry and substrate maker IQE plc of Cardiff, Wales, UK has reported unaudited results in line with expectations and its July trading update.

Revenue was £53.2m, down 11% on £60m in second-half 2014 but up 2% on first-half 2014's £52m. Driven by revenue growth and high operational gearing, adjusted operating profit rose by 5% from first-half 2014's £6.4m to £6.7m, leading to a 5% rise in adjusted fully diluted earnings per share (EPS) from 0.86p to 0.90p. Cash generated from operations has risen by 13% from £4m in first-half 2014 to £4.5m in first-half 2015. Net debt has hence been cut further, from £35.5m a year ago and £31.3m at the end of 2014 to £31.1m at the end of June 2015.

"This was a solid start to the year, in which we delivered continued improvement in our financial results and further reduced our borrowings," notes IQE's chief executive Dr Drew Nelson.

IQE's revenues continue to diversify, with non-wireless revenue rising from 21% of sales in first-half 2014 to 24% of sales.

In particular, photonics sales grew rapidly (up 28% year-on-year from £5.8m to £7.4m). "Growth in the photonics business follows on from strong engagement by IQE in its customers' product development programs over the past few years," says Nelson. "The increasing number and quality of customer product development programs is a positive lead indicator which is providing a high level of confidence over the growth outlook for photonics," he adds.

"Other non-wireless businesses continue to make good progress," Nelson continues. Infrared revenue grew from $4.3m in first-half 2014 to £4.6m. Regarding advanced solar wafers (CPV), during first-half 2015 IQE began pilot production with its triple-junction technology and achieved initial sales into field deployments.

Regarding GaN technologies, continued progress in new product development should lead to initial sales into the RF and power markets in the next 12–18 months.

Wireless revenue business was stable, although revenue of £40.5m is down on first-half 2014's £41.3m, impacted in part by some temporary production disruption at one customer site (unrelated to epiwafers) which pushed second-quarter demand into Q3.

"Whilst we remain vigilant to the macro-economic risks, our customer forecasts continue to reflect a normal second-half weighting of demand," says Nelson. "IQE's board remains confident in achieving its full-year expectations," he concludes.

Growth in the photonics business follows on from strong engagement by IQE in its customers' product development programs over the past few years. The increasing number and quality of customer product development programs is a positive lead indicator which is providing a high level of confidence over the growth outlook for photonics

On 9 July IQE entered into a new joint venture with Cardiff University to create the Compound Semiconductor Centre Ltd (CSC), which aims to accelerate the development and commercialization of compound semiconductor technologies in Europe, and to provide an anchor for the development of a compound semiconductor cluster. To establish the CSC, IQE contributed equipment worth £12m (matched by a £12m cash contribution from Cardiff University). IQE will also license certain intellectual property (IP) to the CSC. The CSC has been established from 1 August, which will create a non-cash exceptional gain of about £4.7m in IQE's full-year financial statements due to the difference between the book value and market value of the equipment contributed by IQE. The firm also receives and recognizes revenue of £2m relating to the IP license.

Also on 15 September, IQE said it has signed an agreement with Translucent Inc, a subsidiary of Australia's Silex Systems Ltd, for the exclusive licence of its Rare Earth Oxide (cREO) semiconductor technology, and taken an option to subsequently acquire the technology. IQE will pay Silex Systems $1.5m within six months in consideration of the licence and option agreement, which will include transferring manufacturing and characterization equipment from Translucent to IQE as well as the exclusive services of two key engineers for 12 months in order to transfer the cREO technology to IQE. The agreement also includes an exclusive option to acquire the cREO technology and IP portfolio for $5m within 6 months of exercise of the option, plus a long-term royalty agreement of 3% of epi products sold using the cREO technology transferred, or 6% of cREO templates sold using the cREO technology transferred.

www.iqep.com

IQE signs exclusive licence and option agreement to acquire Translucent's cREO technology

Epiwafer foundry and substrate maker IQE plc of Cardiff, Wales, UK has signed an agreement with Translucent Inc, a subsidiary of Australia's Silex Systems Ltd, for the exclusive licence of Rare Earth Oxide (cREO) semiconductor technology, and taken an option to subsequently acquire the technology.

IQE says that Translucent's cREO technology offers a unique approach to the manufacture of a wide range of compound semiconductor on silicon products, including gallium nitride (GaN) on silicon (Si) for power switching and RF technologies markets. It is protected by a wide-ranging IP portfolio consisting of 74 granted patents and 13 additional patent applications, adds the firm.

"We are at the forefront of a new era in the semiconductor industry which is bringing to market unique high-performance compound semiconductor materials required for the modern 'Internet of Things' world," says IQE's CEO Dr Drew Nelson. "At the same time we are leveraging the low-cost and large-wafer-size benefits of the silicon industry that has been at the core of the information technology revolution over the last 40 years," he adds. "We are very excited to be able to take Translucent's unique cREO technology to market, and thereby create a significant new platform to drive our business into several new large-volume areas".

Key terms of the agreement are as follows:

- The agreement provides IQE with an exclusive 30-month licence for the commercialization of the Translucent cREO technology and an exclusive option (exercisable solely at IQE's discretion) on the subsequent acquisition of the cREO technology.
- IQE will pay Silex up to a maximum consideration of $1.5m ($0.085m of which is conditional upon certain delivery obligations being met), payable within six months of the date of the agreement in either cash or IQE shares, for the licence and option agreement.
- The agreement includes the transfer of a range of manufacturing and characterization equipment from Translucent to IQE, and also includes the exclusive services of two key engineers for 12 months in order to transfer the cREO technology to IQE. Translucent will then cease all operations in Palo Alto, CA, their sole development site.
- Within the 30-month licence period, IQE has an exclusive option to acquire the cREO technology and IP portfolio for a consideration of $5m, payable within 6 months following exercise of the option in either cash or IQE shares. In addition, a long-term royalty will be payable in cash to Translucent on the sale of IQE products which utilize the cREO technology transferred as follows: 3% on epi products, or 6% on cREO templates.
- All new IP generated relating to the technology will belong exclusively to IQE, as of today's date.
- Should the licence expire after 30 months without IQE taking up the assignment option, or should the agreement otherwise be terminated, all rights to the cREO technology that was transferred to IQE and the related equipment will revert to Translucent.

"This is a great outcome for Translucent, representing an excellent path to market for the cREO technology after an extensive research and development program over the past decade by our team in Palo Alto," says Silex's CEO Dr Michael Goldsworthy. "IQE is the world's leading epiwafer supplier, and epitaxy is the key technology for the introduction of new high performance materials required for the continued evolution of the global semiconductor industry. IQE is very well positioned to capitalize on the introduction of new semiconductor materials, and is the best commercial partner to take Translucent's unique technology to market."

www.translucentinc.com
www.iqep.com

IQE wins Business of the Year awards

IQE of Cardiff, Wales, UK has won the titles of Business of the Year and International Business of the Year at the Cardiff Business Awards, in a ceremony at Cardiff City Hall on 18 September.

The awards ceremony was organized by local company Grapevine Event Management and the International Business award was sponsored by Brighter Communications.

"We are delighted that the judges recognised IQE's leadership and vision in such a vibrant city," says IQE Group president & CEO Dr Drew Nelson. "These awards also recognise the dedication and the commitment of our employees to establish IQE as a key player in Cardiff and as the world's leading supplier of semiconductor wafers," he adds.

"We set up the Cardiff Business Awards to really shine a light on these businesses and celebrate Cardiff as a great place to do business," comments Cardiff Business Awards founder Liz Brookes of Grapevine Event Management. "It was fantastic to be able to recognise and publicly reward the very deserving winners, and we look forward to seeing their businesses grow and develop."

http://cardiffbusinessawards.com

SPTS achieves $1bn export sales from Wales headquarters

SPTS Technologies Ltd (an Orbotech company that manufactures etch, PVD and CVD wafer processing solutions for the MEMS, advanced packaging, LED, high-speed RF on GaAs, and power management device markets) has surpassed $1bn in cumulative export sales of semiconductor processing equipment from its manufacturing headquarters in Newport, South Wales, UK. This milestone was achieved over the past six years since the founding of SPTS in 2009.

With support from Welsh Government Research, Development and Innovation (RD&I) funding, SPTS continues to develop its process solutions for advanced packaging applications, including fan-out wafer-level packaging and plasma dicing of wafers for higher-yield device singulation.

"SPTS has a long history of innovation in the new wafer processing technologies for the global semiconductor and micro-electronics manufacturing industries, with advanced packaging remaining a strategic and high-growth segment of our business," says Kevin Crofton, president of SPTS Technologies and corporate VP at Orbotech. "Our proven ability to develop and commercialize new products and solutions has been key to achieving our first billion dollar export sales milestone. In 2014, SPTS was awarded significant R&D funding from the Welsh Government in support of a three-year project, which will assist us in ensuring that the advanced packaging solutions developed in Newport by our R&D team will continue to provide customers around the world with the most technically advanced and low-cost-of-ownership solutions available," he claims.

"SPTS Technologies has a track record of identifying niches and successfully exploiting them, and [in 2014] was awarded Anchor Company status by the Welsh Government in recognition of its strategic importance to the Welsh economy in terms of exports, job creation, R&D investment and supply chain support," comments Edwina Hart, Welsh Minister for Economy, Science and Transport. Presented with the Queens Award for Enterprise in International Trade 2013, SPTS exports over 95% of its products.

"The company spends over £50m a year on materials and the impact of its 'buy local' policy means that three of their top ten supplier are Welsh firms and 80% of its annual spend goes to firms in an 80-mile radius of SPTS," Hart adds. "Each £1m it spends supports 10 jobs in the local economy, which represents a considerable indirect economic benefit for Wales. By providing support to anchor companies such as SPTS, we are enhancing the economic and industrial development in the region."

www.spts.com

SUSS MicroTec launches XB8 semi-automated high-force wafer bonder

SÜSS MicroTec AG of Garching, near Munich, Germany, a supplier of equipment and process solutions for microstructuring in semiconductor and related markets, has launched the XB8 bonding platform. "In addition to the high precision and the repeatability of the bonding process from wafer to wafer, a uniform process result across the wafer is essential for achieving a high yield."

Designed for a wide range of bonding processes, the XB8 supports substrates with a wafer size of up to 200mm. Key process parameters can be adjusted in a wide range, making the system suitable for advanced process development. In a production environment, the high level of automation and reliability ensure a high level of process stability, the firm says.

Typical applications include advanced packaging, MEMS, 3D integration and LED manufacturing. The XB8 wafer bonder offers a broad parameter window and is therefore suitable for carrying out all bonding processes. Bond force up to 100kN is available with a temperature range of up to 550°C. Different substrate shapes and wafer sizes are processed in specifically adapted fixtures. A multi-bond fixture, for example, enables the maximum possible throughput increase by bonding up to eight wafers at once.

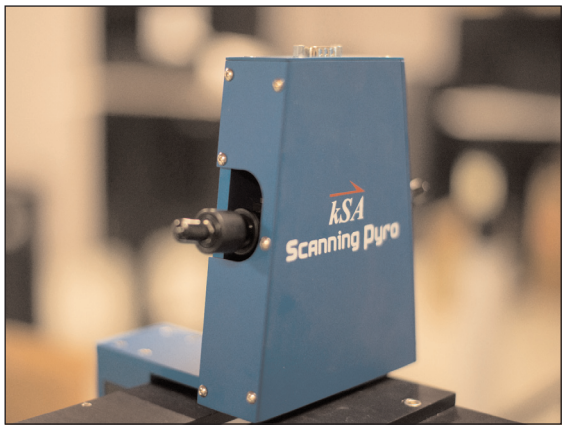
"In addition to the high precision and the repeatability of the bonding process from wafer to wafer, a uniform process result across the wafer is essential for achieving a high yield," says Stefan Lutter, general manager of the bonder product lines. "The independent new heaters guarantee an even temperature distribution and also ensure an optimal bonding force homogeneity within the entire temperature range," he adds. "The innovative mechanical and thermal structure of the XB8 wafer bonder enables optimal bonding force and temperature distribution across the wafer, resulting in a high product quality and yield."

www.suss.com/XB8

k-Space launches kSA Scanning Pyro temperature profile tool for MOCVD epiwafer production

k-Space Associates Inc of Dexter, MI, USA (which supplies thin-film metrology tools for the semiconductor, compound semiconductor and solar markets) has introduced the kSA Scanning Pyro, an in-situ tool designed to measure temperature variations across Veeco K465i wafer carriers.

MOCVD fabs generally perform spot temperature measurements on wafer carriers to help tune the heater zones in an attempt to achieve uniform temperature profiles, says the firm. Making use of the K465i's slit viewport, the kSA Scanning Pyro utilizes a custom dual pyrometer to acquire a complete, high-resolution carrier temperature map in a single scan. The tool can be adapted to other MOCVD tools, including the Aixtron G4 and G5, and the Veeco EPIK700.



kSA Scanning Pyro.

"This tool is designed to quickly, easily, and accurately generate full carrier temperature maps on Veeco K465i and EPIK700 production MOCVD reactors," says CEO Darryl Barlett. "The kSA Scanning Pyro generates high-resolution, full-carrier-temperature maps to facilitate near real-time temperature adjustments and to identify hot/cold spots on carriers and wafers," he adds. "MOCVD fabs with this tool can expect to have a competitive advantage in terms of yield, wafer uniformity and device performance."

The new tool uses technology that combines simultaneous temperature measurements from two scanning sensor heads to map the entire carrier, from center thru the outer edge, says the firm. Users can acquire either a full wafer carrier scan or a select sub-set of the full scan, and can then perform analysis with proprietary kSA software to identify problem areas. With this information, engineers can make process and/or hardware adjustments to improve their product.

www.k-space.com/products/

Plessey's chip-scale optics for GaN-on-Si LEDs cuts cost and increases design flexibility

On-chip MEMS-type features enable light emission angles down to 10° direct from the LED

UK-based Plessey has developed a patented technology for chip-scale optics (CSO) based on its gallium nitride on silicon MaGIC (Manufactured on GaN-on-Si I/C) LEDs.

Chip-scale optics permits the design of light emission angles down to 10° direct from the LED. Having the primary optics on-chip eliminates the cost of primary optics typically found in packaged LEDs and chip-on-board modules. Furthermore, it significantly lowers the cost and provides for far greater design freedom for secondary optics within a luminaire, says the firm. The first applications include retail spot lighting, hospitality lighting, high and low bays, street lighting and stadium lighting. It is estimated that Plessey's chip-scale optics can halve the cost of these lighting applications.

"The CSO technology was originally designed as an on-chip phosphor dam," says Plessey's chief technology officer Dr Keith Strickland. "We realised that the original growth silicon, normally sacrificed during LED production, could be shaped and used to form mechanically robust, MEMS-type features on the emitting surface of a vertical LED. The degree of collimation is controlled in part by the mechanical dimensions of these on-chip structures, and we have demonstrated emission angles as low as 10°. The IC industry has used silicon for over 60 years and can be readily fashioned into many shapes and patterns. We have created silicon MEMS features in a variety of other applications and can manage to incorporate a complex primary optical design on the chip," he adds.

Plessey's chip-scale optics applied to a MaGIC GaN-on-Si LED.

"High-end lighting designers do not count lumens per Watt as the primary figure of merit for LEDs," notes Plessey's principal optical designer Dr Samir Mezouari. "A lighting designer aims to illuminate a particular surface area. Chip-scale optics can significantly simplify luminaire designs by forming symmetrically collimated beams with narrow angles or asymmetric beams to form elongated far-field light profiles," he adds. "Schemes to collimate monochromatic light at the LED level have been developed before, but no-one has previously collimated white light at the LED level."

Plessey is exhibiting an LED demonstrator of the chip-scale optics at LuxLive (the UK largest lighting show) at London's ExCeL arena (18–19 November). Samples will be available in first-quarter 2016.

www.plesseysemiconductors.com/led-plessey-semiconductors.php

Plessey to showcase latest GaN-on-Si LED solutions at LuxLive

UK-based Plessey is to exhibit its latest GaN on silicon LED solutions at LuxLive (Europe's biggest annual lighting event) at London's ExCeL arena (18–19 November). Co-located this year with Strategies in Light, the combined event program covers key market sectors that are moving towards solid-state lighting solutions, including retail, hospitality, healthcare, education, commercial, street and industrial lighting.

"We have the technology and supply chain to provide mass customization of lighting solutions for manufacturers in all segments in the lighting market," says Plessey's LED sales director Giuliano Cassataro. "This allows the significant environmental, reliability and quality of light benefits from a state-of-the-art LED light engine to be realised in any application. Whilst there is overcapacity in the low- and mid-power market, there is insufficient supply in the fastest-growing markets of high-power and super-high-power LEDs," he adds. "Plessey's recent capacity expansion of its Plymouth facility, combined with its differentiated technology where integration of intelligence and optics is possible, is the direction that LED lighting is headed and we will be showcasing this integration of solid-state lighting solutions at LuxLive."

At stand E26, Plessey is holding product demonstrations presented by technical and design experts, providing an opportunity to gain a deeper understanding of its latest products and solutions for the commercial, industrial, consumer and wearable lighting segments. The show is free to attend with tickets available at:

http://luxlive.co.uk/
www.plesseysemiconductors.com

Plessey wins £6.7m grant from UK Regional Growth Fund for LED production expansion

Annual manufacturing capacity to grow from over 100 million square millimetres to 3 billion square millimetres of GaN

UK-based Plessey says that the Regional Growth Fund (RGF) has officially granted £6.7m towards the expansion of its facility in Plymouth for manufacturing its MaGIC (Manufactured on GaN-on-Si I/C) gallium nitride on silicon LEDs.

Plessey says that it will increase its manufacturing capacity from over 100 million square millimetres of gallium nitride material per year to more than 3 billion square millimetres. Facility modifications will take place during 2015, with additional manufacturing tools and supporting equipment coming on stream from 2015 through to 2017.

According to the report 'Lighting the Clean Revolution: The rise of LED street lighting and what it means for cities', lighting is responsible for 19% of global electricity use and about 6% of global greenhouse-gas emissions. Doubling lighting efficiency globally through LEDs would have a climate impact equivalent to eliminating half the emissions of all electricity and heat production in the EU. Also, like many other energy-efficient technologies, efficient lighting is expected to boost global prosperity. In the UK alone, cutting the energy used by lighting by 40% would save £6.5bn in annual energy costs, and reduce energy demand equivalent to 33 mid-size power stations.

Driven by high-brightness LEDs delivering higher energy efficiency in all lighting applications, the solid-state lighting market is projected to rise at a compounded annual growth rate (CAGR) of 7.31% to $22.2bn in 2020, according to a new market research report ('Solid State Lighting & Fluorescent Lighting Market by Technology — Forecast to 2020' from MarketsandMarkets).

"The expansion will bring additional well paid technical jobs to the site, and strengthen our long-term future by providing the base for new lighting technologies and products to be manufactured in the UK," says Plessey's finance director Chris Bailey. "The project also aligns very well with national strategies, such as the Growth Review, and it aims to increase and support manufacturing in the UK to make the UK Europe's leading exporter of high-value goods and services."

www.plesseysemiconductors.com/led-plessey-semiconductors.php

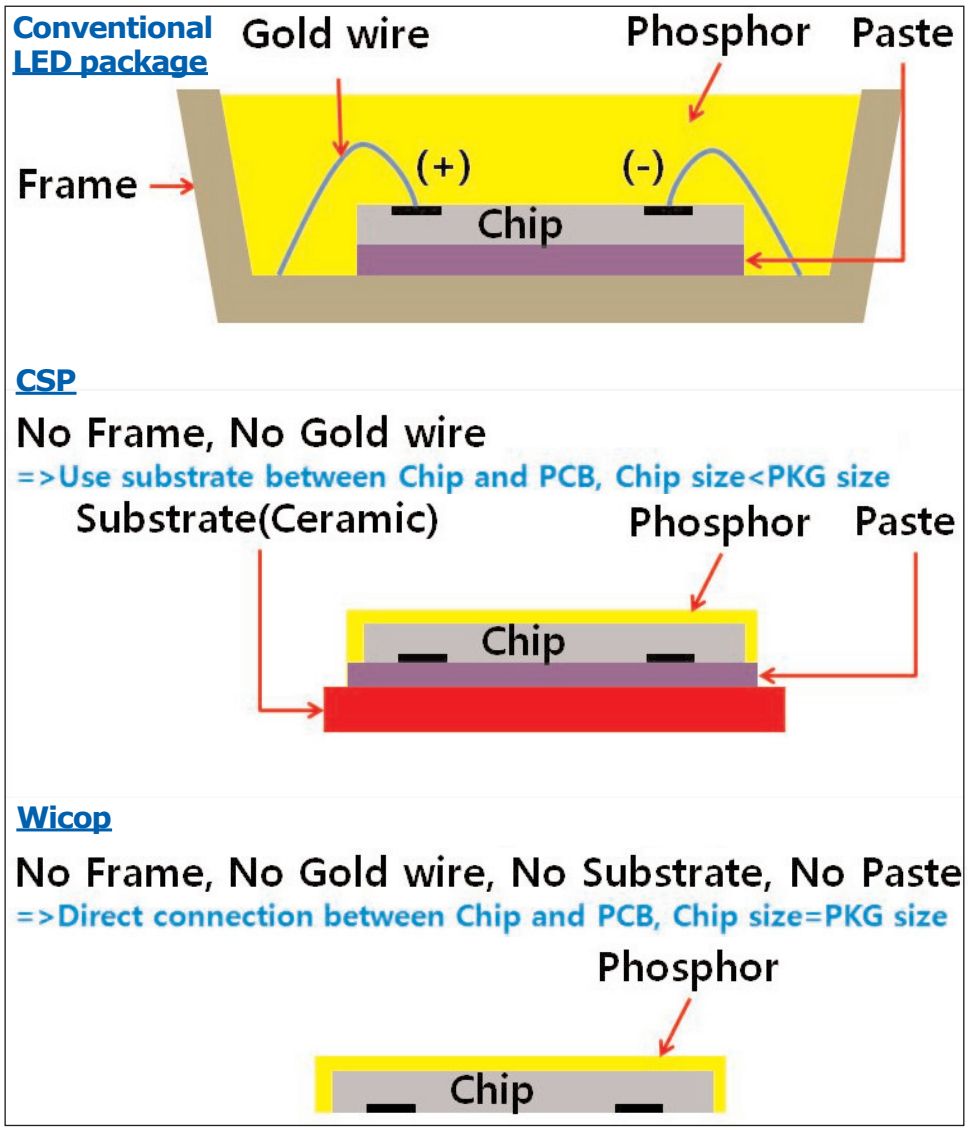
Seoul Semiconductor to mass produce Wicop LEDs

South Korean LED maker Seoul Semiconductor is to mass produce its Wicop (Wafer Level Integrated Chip on PCB) LEDs for use in lamps. Designed to directly connect the chip to the PCB, Wicop does not require the packaging processes, such as die bonding or wire bonding, which are necessary for conventional LED package production. Further, Wicop does not require the main LED package component parts, such as lead frame, gold wire, etc. Wicop overcomes the limits of existing chip-scale packaging (CSP), adds the firm.

Conventional LEDs that require packaging processes, such as die bonding and wire bonding, have a package size larger than the chip (the size of the chip cannot be made smaller), but with Wicop the sizes of the chip and package are the same.

Derived from silicon semiconductor manufacturing, CSP technology miniaturizes the size of semiconductor parts (the package) to the size of a chip. Generally, when the size of the package does not exceed more than 1.2 times the chip, it is classified as CSP. Some firms introduced this technology into LED products in 2012. However, because those products required bonding equipment, intermediate substrate or ceramic or silicon material to attach the chip to the PCB, it is difficult to see the technology as a complete CSP, concludes Seoul Semiconductor.

Seoul Semiconductor has released the first complete concept of Wicop products in which the size of the package is the same as that of the chip. Since 2013, Seoul Semiconductor has supplied Wicop to customers for use in LCD backlighting, camera flash and vehicle head lamps. Now, with the release of its LED package Wicop2 for use in lamps, the firm is making the technology applicable to all fields of LED industry. Seoul Semiconductor plans to target the LED lighting-source market in lights, vehicle, and IT parts, which is currently estimated to be about 20trillion WON ($20bn).



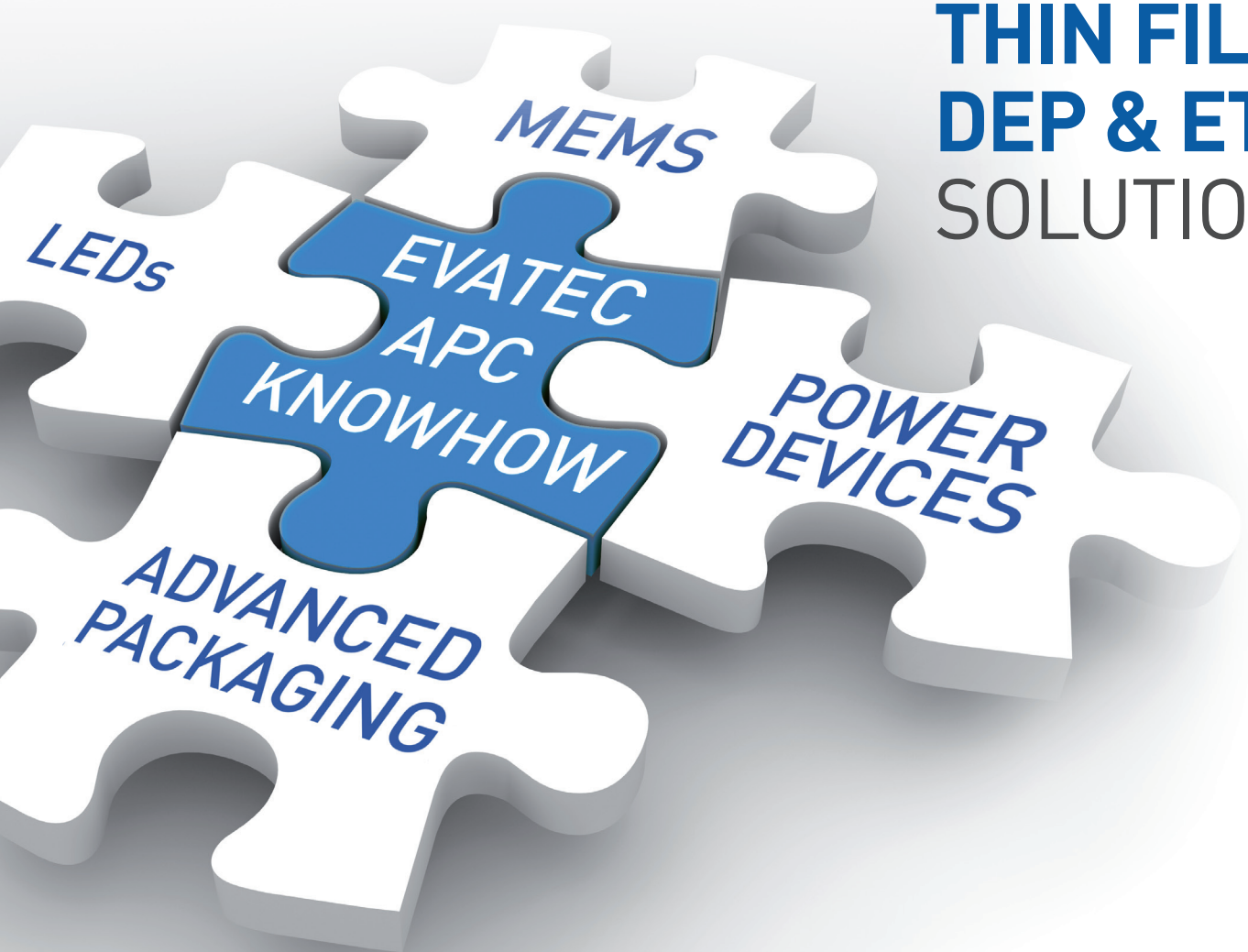
"Through the development of Wicop, which is an innovative small sized, highly efficient LED technology, the effective value of packaging equipment —which was once essential in semiconductor assembly process — will noticeably decrease," says Kibum Nam, head of Seoul Semiconductor's Central Research Center. "As all of the parts which had been used for more than 20 years will not be necessary any more, there will be a huge change in the future LED industry".

Wicop is a new concept LED product. Seoul Semiconductor developed and produced it for the first time in 2012. Since it is designed to directly connect the chip to PCB, there is no need for a packaging process such as die bonding or wire bonding. Also, as there is no intermediate substrate, the size of the chip and package are the same. It is characterized by the small size and high efficiency. It is also good for the high luminance and thermal conductivity.

In the case of the existing widely used TOP LED, a lot of materials are required for the product such as die bonding equipment to attach the chip to the lead frame, wire bonding equipment to connect electrodes to the gold wire, and lead frame, gold wire and adhesives in each process. As conventional LEDs require such packaging processes (die bonding and wire bonding) and have a package size larger than the chip, the size of the chip could not be made smaller. and does not use other main materials by directly attaching the chip to the PCB.

www.SeoulSemicon.com

COMPLETE **THIN FILM DEP & ETCH** SOLUTIONS



evatec process systems

Let Evatec engineers help you solve your manufacturing puzzles. From raising throughput in Under Bump Metallisation (UBM) processes on 12 inch, to delivering plasma damage free sputter processing on GaN for LEDs and Power Devices, Evatec platforms with Advanced Process Control (APC) raise yields and lower Cost of Ownership. For more information about Evatec visit our website at **www.evatecnet.com** or contact **your local sales agent**.

RADIANCE SPUTTER CLUSTER


BAK EVAPORATOR


LLS EVO II LOAD-LOCK SPUTTER


CLUSTERLINE® 300 II SPUTTER

MORE INFO

LEDs • ADVANCED PACKAGING • POWER DEVICES • MEMS • TELECOMS • PHOTOVOLTAICS • EVATEC - THE THIN FILM POWERHOUSE

www.evatecnet.com

Seoul Viosys and SETi to jointly commercialize Violeds UV LED sterilization technology

UV LED solution provider Seoul Viosys Co Ltd and Sensor Electronic Technology Inc (SETi) of Columbia, SC, USA (in which Seoul Viosys acquired a majority stake in August) are to jointly commercialize and expand sales of Violeds technology. The technology, which utilizes a UVC wavelength and is ideal for sterilizing purposes, has been used by NASA aboard the International Space Station (ISS), where it has facilitated various experiments that require a sterile environment to ensure their validity.

"Violeds technology applied to the use in the space station for disinfection is a very good example of "Creative Economy" a novel technology will contribute to increased employment and to the growth of the national economy as well," says Seoul Viosys' CEO Jaejo Kim.

Seoul Viosys was established in 2002 as Seoul Optodevice (a subsidiary of South Korean LED maker Seoul Semiconductor Co Ltd) based on a technical cooperation with Japan's Nitride Semiconductor Co Ltd (the first firm to develop long-wavelength UV LEDs, emitting at 360–400nm, in 2001). It is said to be the first firm specializing in UV LEDs (spanning epitaxy, chip, package and module manufacturing) and the first to develop short-wavelength UV LEDs. Seoul Optodevice was renamed Seoul Viosys in 2013 to denote its expansion from a visible LED and UV LED chip maker to a UV LED system provider.

NASA astronaut Rick Mastracchio using the micro-biological test chamber, which includes the Violeds apparatus of SETi. (Photo Credit: NASA, Microgravity Science Glove box.)

In 2005 the firm made an equity investment in SETi, and subsequently produced its first 254–340nm UV-C and UV-B (deep UV) LEDs. Seoul Viosys has since maintained close technical cooperation with SETi for over 10 years to commercialize UV LED chips with wavelengths below 350nm. According to the firm, it is now capable of producing LEDs spanning the entire UV wavelength range (from 230nm to 405nm), and holds over 10,000 patents related to the field. Applications include the bio, hardening, forgery detection, medical appliances and sterilization markets.

Seoul Viosys says that it will expand SETi's capacity for mass production by up to three times, and will expand into new product markets for Violeds.

www.s-et.com
www.seoulviosys.com

Toshiba adds 140lm 4A5B-type LEDs to TL1L4 range of high-power white LEDs

Tokyo-based Toshiba Corp's Semiconductor & Storage Products Company is now shipping four new products in its TL1L4 series of gallium nitride-on-silicon (GaN-on-Si) high-power white LEDs for lighting applications such as street lights, flood lights, LED light bulbs and down-lights.

Available in a 3.5mm x 3.5mm lens-top package, the new 4A5B-type TL1L4 series LEDs achieve a high luminous flux of 140lm (minimum, for a forward current (I_F) of 350mA and a junction temperature (T_j) of 85°C, i.e. 'hot binning'), compared to the 130lm (minimum) of conventional general products in the TL1L4 series. The forward voltage (V_F) is 2.8V (at I_F=350mA, T_j=85°C). At an ambient temperature of 25°C, luminous flux is 165lm.

The four new products are available in color temperatures (CCTs) of 6500K (TL1L4-DW0,L4A5B), 5700K (TL1L4-NT0,L4A5B), 5000K (TL1L4-NW0,L4A5B) and 4000K (TL1L4-WH0,L4A5B), with a color rendering index (CRI) of Ra70.

Toshiba says that the new LEDs make it possible to achieve the market requirements for lighting fixture efficacy of more than 110lm/W (under conditions of 90% driver efficiency and 90% optical efficiency, at a junction temperature of 85°C), and that they can contribute to improving the luminous efficacy and lowering the power consumption of LED lighting.

http://toshiba.semicon-storage.com/ap-en/product/opto/white-led.html

Pick your size.

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

Temescal
UEFC–4900

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

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

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

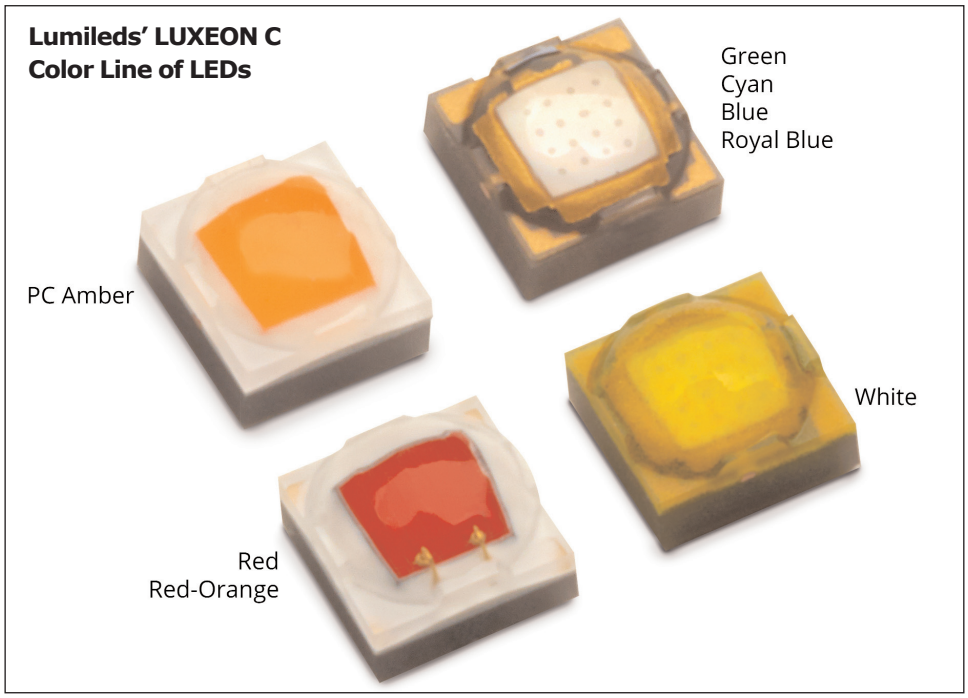
FerroTec

Lumileds achieves smooth color mixing with LUXEON C Color Line of LEDs

LED maker Lumileds of San Jose, CA, USA has announced a new approach to achieving color mixing with its high-power LUXEON C Color Line of LEDs. "We've solved the problems of beam halos and mismatched, unmixed color by designing our platform to offer multiple colors with a single focal length," says David Cosenza, product manager for the LUXEON C Colors Line. When secondary optics are applied, the consistent focal length maximizes optical efficiency and provides matching emission patterns, enabling sleek color mixing, says the firm.

Smooth color mixing is particularly significant in studio, stage and television lighting applications that may combine seven colors or more. "Initial feedback from studio lighting professionals confirms that Lumileds LUXEON C Color LEDs' precise color mixing and optical performance will enable a new generation of lighting designs," says Cosenza.

High center-beam candle power (CBCP) or 'punch' is often essential in architectural lighting, notes Lumileds. Applications such as tall, narrow wall washers take advantage of LUXEON C Colors' low dome design, which keeps the source size small, leading to higher punch, more compact optics and greater optical control, it is claimed. Narrow beams are also used in emergency vehicle lighting, where superior punch is essential.



In addition, LUXEON C Color is claimed to be the industry's first hot-tested color line. By specifying LED performance at 85°C, users get guaranteed performance at application conditions. "Predicting changes in chromaticity and light output across temperature for different colors is now a problem of the past," reckons Cosenza. Also, by using what is reckoned to be the industry's lowest-thermal-resistance substrates (as low as 2.8°C/W), users can drive the LEDs harder.

The LUXEON C Color Line features a broad portfolio of colors in a compact 2mm x 2mm package. Colors include PC Amber, Red-Orange, Red, Cyan, Green, Blue and Royal Blue. Phosphor-converted whites are initially available at correlated color temperatures (CCTs) of 4000K and 5700K with 70 CRI (color rendering index). Additional models will become available in the coming months.

www.lumileds.com/LUXEONCColors

BluGlass receives $300,000 foundry development order

BluGlass Ltd of Silverwater, Australia says that one of its key specialized epitaxy customers has committed to an order for about $300,000 of foundry development, to be delivered over the next six months.

The customer is developing a specialty LED application for which BluGlass will be supplying the green and blue LED epiwafers for their unique product.

"This order from one single customer for epitaxial development is the largest foundry order that the company has received to date," notes BluGlass' managing director Giles Bourne. "It forms part of our strategy of growing the custom epitaxy and revenue-generating service part of our business over the coming months," he adds. "We see this large repeat order as a testament to our team's ability to deliver custom epitaxy at an industry-competitive standard."

Spun off from the III-nitride department of Macquarie University of Sydney, Australia in 2005, BluGlass developed a low-temperature process using remote-plasma chemical vapor deposition (RPCVD) to grow materials including gallium nitride (GaN) and indium gallium nitride (InGaN) on glass substrates, potentially offering cost, throughput and efficiency advantages for the production of LEDs and concentrated solar cells.

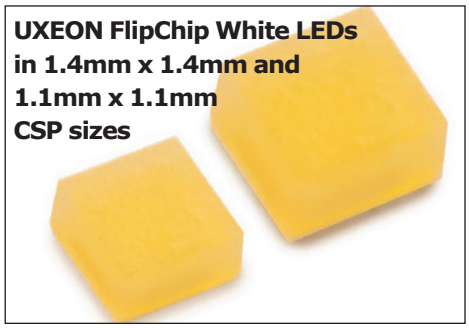
www.bluglass.com.au

Lumileds extends CSP range with FlipChip White

LED maker Lumileds of San Jose, CA, USA has launched the LUXEON FlipChip White LED, which uses CSP (chip-scale packaging) technology.

After spearheading the adoption of CSP in LEDs, Lumileds has shipped more than 500 million LED emitters to date across several applications. The firm first introduced the LUXEON FlipChip Royal Blue in February 2013, giving luminaire makers design flexibility by starting with the LED die. In early 2015, Lumileds released the LUXEON FlipChip UV, and it has now introduced the LUXEON FlipChip White for the general illumination market.

CSP technology eliminates the traditional submount to minimize package size, which enables manufacturers to attach the LED die directly to the PCB, allowing overall system cost reductions. Lumileds says that its CSP technology is optimized to deliver high efficacy at high current density, achieving what is claimed to be industry-leading lumen density and lm/$ to illumination applications.



UXEON FlipChip White LEDs in 1.4mm x 1.4mm and 1.1mm x 1.1mm CSP sizes

Lumileds says that high-lumen applications such as outdoor and industrial lighting benefit from the high-drive-current capabilities and robust high-power architecture of LUXEON FlipChip White LEDs. In addition, the small source size and high lumen density of LUXEON FlipChip White enables high packing density and superior beam control for directional lamps and luminaires, the firm adds. LUXEON FlipChip White is offered in two package sizes (1.4mm x 1.4mm; 1.1mm x 1.1mm) and a range of CCTs (correlated color temperatures) across a CRI (color rendering index) of 70 or 80.

Lumileds says that it aims to further accelerates industry's adoption of CSP technology by offering LUXEON FlipChip White on its Matrix Platform. These LED boards, linear flex and modules can come configured with LUXEON FlipChip White along with connectors, optics, wiring and/or electronics, improving time-to-market and simplifying the supply chain, the firm claims.

www.lumileds.com/LUXEONFlipChipWhite

Cree launches high-intensity versions of XLamp XQ-E color LEDs, doubling candela performance

LED chip, lamp and lighting maker Cree Inc of Durham, NC, USA has introduced the XLamp XQ-E High Intensity LED, which is claimed to be the first family of color LEDs optimized for optical performance.

The drop-in upgrade for proven XQ-E High Density designs enables lighting manufacturers to double the candela performance with minimal re-design. The new High Intensity LEDs leverage XQ-E's proven optical symmetry and consistency across all colors to improve color mixing and to simplify the production process for lighting manufacturers. Built on Cree's SC5 Technology Platform, the XQ-E High Intensity LED is reckoned to be the smallest building block available for color LED designs, allowing lighting manufacturers to quickly boost performance and reduce size for directional applications such as track and architectural lighting.

"At Lumenpulse, candela is the name of the game, and we want to put as much light as possible on the surface we are illuminating, as efficiently as possible," says Greg Campbell, senior VP & chief technology officer at LED lighting manufacturer Lumenpulse of Montreal, Canada. "The XQ-E High Intensity is a perfect tool in our toolkit to maximize candela output for our innovative products."

Available in white, red, red-orange, PC amber, green, blue and royal blue, the XQ-E High Intensity LED features Cree's new primary optic design that reduces optical source size by more than 50% to deliver optical control.

"The combination of high lumen output, innovative primary optic and the tiny footprint of the XQ-E High Intensity LEDs enables us to create compact luminaires that deliver a lot of punch," comments Antonio Di Gangi, CEO of Italy-based LED lighting firm DGA.

The XQ-E High Intensity White is available in correlated color temperatures (CCTs) ranging from 2700K to 6200K and color rendering index (CRI) options of 70, 80 and 90. Product samples are available now and production quantities are available with standard lead times.

www.cree.com/xlamp/xqehi

Cree expands portfolio of LED downlights with KR8 and LR6

Cree has launched new KR8 and LR6 LED downlights, designed to deliver better lighting performance and better value for new and existing commercial spaces.

The new KR8 downlight expands the KR Series by adding the firm's first 8-inch downlight, and features Cree WaveMax Technology and TrueWhite Technology. This combination brings optical efficiency, precise beam control and long product life to higher ceiling applications, such as theaters, airports and auditoriums. The newest generation of Cree's LR6 downlight provides better light quality at a lower price.

With the new KR8 downlight, Cree's architectural downlight portfolio now addresses ceiling heights from 8 feet up to 40 feet. Also, the KR8 downlight covers most commercial and retail applications with 6000 and 8000lm outputs, achieving what other high-lumen output LED downlights have not been able to deliver, it is claimed, with more light, a range of beam spreads and unrivaled optical control. The

specification-grade downlight integrates Cree's WaveMax Technology and uses a unique dual optic design that enables high precision with beam angles as tight as 15°, providing light uniformity and better color performance with a 90-plus CRI (color rendering index).

The new KR8 downlight provides double the lifetime of its nearest competitors, and delivers dimming capabilities down to 1% for lower energy bills and payback of less than two years. Designed with contractors and electricians in mind, the KR8 downlight features easy two-step installation, and is offered in warm, neutral and cool color temperatures. It is sold through Cree lighting sales channels throughout the USA and Canada, and is backed by a 10-year limited warranty.

The new Cree LR6 downlight delivers up to 1800lm of light at a minimum CRI of 90. With luminous efficacy of up to 100lm/W, it uses up to 89% less energy than the incandescent downlight it replaces and up to 58% less than a CFL (compact fluorescent lamp). This performance is achieved by combining Cree's TrueWhite Technology with an integrated driver and thermal management design.

LR6 downlights features Cree's patented Flip-Clip technology, securing easily into all 6-inch IC and non-IC housings without the need for professional installers. The LR Series can also be used in new construction for recessed or pendant lighting applications, and is available in warm or neutral color temperatures, with three lumen packages and a variety of trim options. Like the previous-generation product, the new LR6 downlight is covered by a 10-year limited warranty (typically double the warranty of the nearest competitor solutions, it is reckoned).

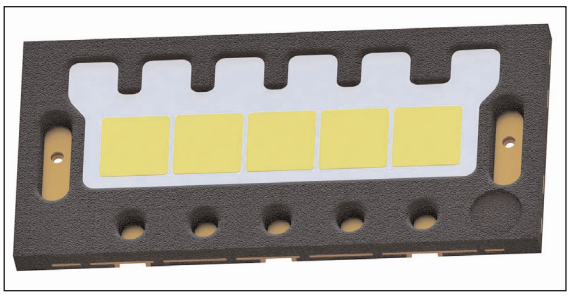
www.cree.com/lighting/LRseries
www.cree.com/lighting/KRseries

Osram Opto unveils Oslon Black Flat S LED prototype, providing up to 2000lm for automotive applications

At the International Symposium on Automotive Lighting (ISAL 2015) in Darmstadt, Germany (29–30 September), Osram Opto Semiconductors GmbH of Regensburg, Germany unveiled the Oslon Black Flat S, a surface-mount technology (SMT) LED prototype with a brightness of up to 2000lm.

This high brightness output was achieved by combining five high-current chips (from the firm's latest UX:3 generation of chips) with an improved SMT package. The prototype LED is operated at a current of 2A and a voltage of 15.5V. The optical output is 6.5W.

In terms of increasing output, the new SMT prototype Oslon Black Flat S is a logical development of existing versions of the firm's automotive product family and shows that high luminous flux values of up to 2000lm are possible from a single



LED, sufficient to act as the light source for combined low-beam and high-beam systems. At the same time, the SMT component has a footprint of 3.75mm x 7.9mm, which is only slightly larger than the previous 5-chip version.

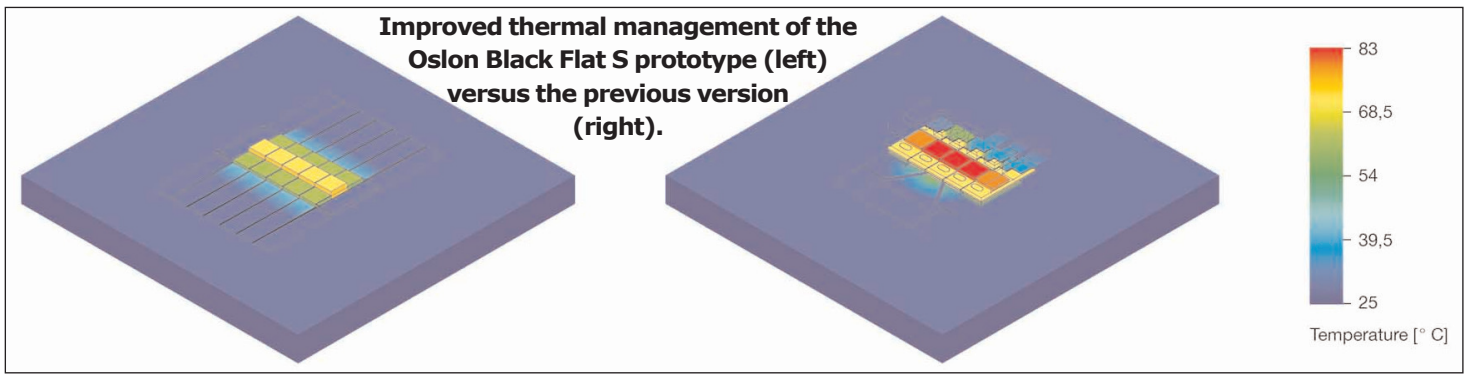
At a current of 1A, a power loss of 12W and an ambient temperature of 25°C, the temperature at the chip is only 69°C, so the temperature difference compared with the previous version is reduced from 58°C to 44°C.

The basis for the high brightness is improved heat distribution — essential in view of the high currents involved. The thermal connection with the package is greatly improved by larger contact pads, allowing passive cooling. This, in turn, reduces system costs considerably. The Oslon Black Flat S LED is consequently a viable alternative for vehicles that are currently equipped with to high intensity discharge (HID) headlamps.

"The five chips in the Oslon Black Flat S can also be driven individually," notes Joe Jablonski, automotive applications engineer at Osram Opto Semiconductors. "The future LED version will be an ideal solution for adaptive front lighting systems."

The Oslon Black Flat S LED is due to be added to Osram's automotive portfolio at the end of 2016.

www.osram-os.com



Improved thermal management of the Oslon Black Flat S prototype (left) versus the previous version (right).

Cree introduces new LED bulbs

LED chip, lamp and lighting maker Cree Inc of Durham, NC, USA has introduced a new range of LED bulbs, which deliver 460 lumens (40-watt replacement) and 815lm (60-watt replacement) in soft white (2700K) and daylight (5000K) color temperatures inside a durable, shatterproof housing. Both new bulbs have achieved ENERGY STAR certification by meeting all the high-performance requirements, says the firm.

In keeping with Cree's belief that customers should not compromise, the new Cree LED bulb is built to deliver true LED performance in color quality, light output and dimming. It has an improved longer lifetime of over 27 years (30,000 hours), lasting as much as six times longer than some LED bulbs. Its 4Flow Filament Design ensures that it looks and lights like a traditional incandescent. The new bulb also provides consumers with a higher color rendering index of 83 to better display colors, true ENERGY STAR compliant omnidirectional distribution for all-around light, and is fully dimmable with most standard dimmers and suitable for enclosed fixtures. The new range is backed by a 100% satisfaction guarantee.

Available as 40-watt and 60-watt replacements, consumers can purchase the new Cree LED Bulb at www.homedepot.com/cree and in The Home Depot stores for as little as $7.97.

www.creebulb.com

MACOM announces CDR+VCSEL driver interoperability with II-VI's VCSELs

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) says that its new MALD-37045 four-channel 25.78G/28.05G VCSEL driver — which features an integrated clock data recovery (CDR) and an equalizer — has been proven to be interoperable with vertical-cavity surface-emitting lasers (VCSELs) of II-VI Inc of Saxonburg, PA, USA.

Together with the MATA-37044, a companion transimpedance and limiting amplifier with CDR, MACOM's latest chipset solution has been implemented by customers in 100G QSFP modules and active optical cables (AOCs) as a complete electronics solution with proven results, says the firm. The devices consume ultra-low power, making them suitable for small form-factor applications.

The MALD-37045 and MATA-37044 both feature CDR functionality for use as a complete transmit and receive solution for optical modules and on-board optical engines. The reference-free CDRs in the MALD-37045 and MATA-37044 are programmable, re-timing at 25.78, 27.95 and 28.05Gbps. The companion devices have their respective outputs and inputs spaced on 250µm centers to maintain compatibility with standard optical interfaces, and each device can be individually controlled through the 2-wire serial interface.

The MALD-37045 provides programmable bias and modulation current, enabling interoperability with a variety of VCSELs, including II-VI's lasers. The MATA-37044 includes a high-sensitivity transimpedance amplifier (TIA) with selectable bandwidth to support interoperability with short-wave and long-wave photodetectors.

"Our new chipset expands MACOM's existing family of CDRs, laser drives and TIA products and, by combining our expertise in low-power and high-performance semiconductors with II-VI's established 25.8Gbps VSCELs, we are working to ensure that our customers get a fully interoperable, best-in-class solution," says MACOM's director of marketing Marek Tlalka.

"As a result of this synergy, we are able to provide customers with a reliable, low-power and proven solution," comments Michele Agresti, II-VI's product line manager for datacom VCSELs.

MACOM says that the MALD-37045 and MATA-37044 are optimal one-stop solutions for optical modules, active optical cables and on-board optical engines. They can be used in 100G Ethernet, EDR InfiniBand and 32G Fibre Channel applications, providing a low-power interoperable solution required by small form-factor optical subassemblies.

The MALD-37045 and MATA-37044 were shown operating with II-VI's VCSELs in demonstrations at the 17th China International Optoelectronic Expo (CIOE 2015) in Shenzhen, China in early September.

www.ii-vi.com/business_units/II-VI-Laser-Enterprise.html
www.macomtech.com

Sweden's KTH selects Mellanox end-to-end EDR 100Gb/s InfiniBand solutions

Mellanox Technologies Ltd of Sunnyvale, CA, USA and Yokneam, Israel, a supplier of end-to-end InfiniBand and Ethernet interconnect solutions and services for data-center servers and storage systems, says its EDR 100Gb/s InfiniBand solutions have been chosen by Sweden's KTH Royal Institute of Technology for use in its PDC Center for High Performance Computing.

The PDC Center provides HPC services to Swedish academia as part of the Swedish National Infrastructure for Computing (SNIC), as well as internationally via the Partnership for Advanced Computing in Europe (PRACE) infrastructure. Services include supercomputing and storage resources plus assistance from a range of application experts.

Mellanox says that its robust and flexible EDR InfiniBand solution offers higher interconnect speed, lower latency and smart accelerations to maximize efficiency and will enable the PDC Center to achieve what is claimed to be world-leading data-center performance across a variety of applications, including advanced modeling for climate changes, brain functions and protein-drug interactions. The PDC Center is the latest deployment of Mellanox EDR InfiniBand technology to validate its expanding global adoption. The increasing use of InfiniBand technology was first illustrated in the TOP500 Supercomputers List in June 2015, with more than 50% of those included utilizing InfiniBand.

"Mellanox understands the critical role high-performance computing plays in today's academic research communities"

"Incorporating Mellanox's latest technology ensures that PDC will continue to provide top-level and consistent performance for our researchers throughout the system's lifetime," comments PDC Center's technical director Daniel Ahlin.

www.pdc.kth.se
www.mellanox.com/related-docs/prod_silicon/pb_switchib_edr_switch_silicon.pdf

Alfalight receives Wisconsin Innovation Award

Alfalight Inc of Madison, WI, USA, which designs and manufactures infrared and visible laser and electro-optical systems for defense and security applications, has won the 2015 Wisconsin Innovation Awards honor for manufacturing, citing the firm's novel Non-Lethal Ocular Disruptor with Enhanced Safety (NLOD-ES). Winners in ten categories were selected from 170 entrants and 33 finalists, judged by a panel of 18 industry experts.

Alfalight developed the NLOD-ES to meet the needs of the US military. Serving a wide variety of applications, the NLOD-ES laser projects an intense, precisely metered, green light over a kilometer, temporarily impairing vision. The optical disruptor acts as a safe, stand-off warning applicable to drivers of vehicles approaching checkpoints as well as for crowd control.

The NLOD-ES uses novel laser technology to protect troops and civilians in conflict and war zones. The device provides for effective medium-range engagement with individuals whose intent is unknown, while Alfalight's unique laser power modulation algorithm with full range-finder integration controls the power on target to avoid the risk of injury while delivering its dazzling light beam. The intense green beam can be used for hailing, warning, suppression (due to temporary vision impairment) and illumination. The NLOD-ES is battery operated, compact and highly ruggedized; weighing less than 12 ounces, it is usable both in hand-held and rifle-mounted configurations.

"The rugged and portable nature of the NLOD-ES puts innovative technology in the field where it can support the mission by saving lives every day," says director of product marketing Rob Williamson PhD. "This product is a testament to our research and development, product engineering, and manufacturing groups," he adds.

www.wisconsininnovationawards.com
www.alfalight.com

Alfalight's Non-Lethal Ocular Disruptor-Enhanced Safety (NLOD-ES) laser system dazzles vision to act as a safe, stand-off warning at checkpoints and for crowd control.

GigOptix establishes Global Customer Operations unit

GigOptix Inc of San Jose, CA, USA (a fabless supplier of analog semiconductor and optical communications components for fiber-optic and wireless networks) has announced the inception of the Global Customer Operations Organization (GCO), led by executive VP of global sales & marketing Dr Raluca Dinu. The change in organization structure aims to establish complete alignment of the firm's operations with the customers' requirements, by integrating into one organization the driving of a strategic roadmap, tactical and product marketing, engineering applications, and global sales.

"While GigOptix has always been driven by technology and leading-edge innovation, the continuous growth of the company requires a focused marketing-driven direction," says Dinu. "The Global Customer Operations Organization leads the business directions and provides the product and technology roadmap targeting profitable markets and strategic customers," he adds. The Marketing Department will be driven by four marketing directors, each with full leadership of a roadmap and profit and loss (P&L) in their areas. "With an extremely knowledgeable, technical marketing and sales team, GigOptix is poised to strengthen its business in its existing markets, develop its presence in new markets aligned with its strategic directions, and fundamentally deliver performance in line with market expectations," Dinu says.

GigOptix has correspondingly added two new marketing directors: Dr Koichi Murata as director of the GigOptix Telecom Marketing, and Anthony Jackson as director of Wireless and RF Product Marketing.

As a veteran of the optical communications industry, Murata previously worked for Nippon Telegraph and Telephone Corp (NTT) Laboratories for 26 years. His activity revolved around the development of high-speed mixed-signal ICs using III-V semiconductor technologies for long-haul large-capacity optical transmission systems. As senior manager of the High-Speed Devices and Technology Laboratory and the Metro-Access Network Division, Murata managed the development and commercialization of the optical components and modules for 100/400Gbps digital coherent systems, InP-based Mach–Zehnder modulators, InGaAs/InP avalanche photodiodes (APDs), next-generation network control LSIs for the convergence of mobile and access network, and optical sab-assemblies for 100GbE and 400GbE. He has 96 individual patents, and has published more than 160 papers in professional journals and international conference publications.

Jackson joined GigOptix from TriQuint/Qorvo, where he led the marketing RF product line, with emphasis on low-noise amplifiers (LNAs) and surface acoustic wave (SAW) filters used in mobile handsets, tablets, and other wireless devices. Prior to Qorvo, Jackson led the development and delivery of 2.5Gbps through 3Gbps wireless and RF contracts at AC Wireless.

In addition, marketing directors for the other product lines are:

- Tom Kapucija leads Datacom Marketing. In his previous experience, at Micrel he managed product line marketing for LR/ER applications to 11.3Gbps as well as the FTTx product portfolio for GEPON, GPON, and next-generation XGPON. At Mindspeed, his primary responsibility was the development and launch of the Broadcast video portfolio for HDTV applications at 1.5 and 3.0Gbps as well as the asynchronous crosspoint switch portfolio to 3.2Gbps. At Gennum, Kapucija was responsible for the serial broadcast video family transition from SDTV to HDTV with definition and launch of the first complete single-rate chipset and roadmap definition for a multi-rate family to support SDTV and HDTV requirements.
- Dan Takise leads ASIC Global Sales and Marketing activities. Previously, he was VP of marketing at ESS, where his responsibility included product marketing, technical product marketing, application team, and marcom of about 60 people, for products that included DVD, DVD recorder, PC and mobile audio, chipsets with annual revenue of more than $300m. Before ESS, Takise was general manager of NEC's Consumer Division, responsible for VR MIPS-based embedded processors, TV, set-top box and 1394 chipsets.

www.gigoptix.com

GigOptix closes public offering of common stock

GigOptix says the underwriters in its public offering, (announced on 21 August) have — pursuant to the terms of an underwriting agreement — exercised in full their option to purchase 1,425,000 newly issued shares of common stock at $1.70 per share to cover over-allotments. Net proceeds to the firm from the offering were about $2.28m (after underwriting discounts and commissions).

GigOptix expects to use the net proceeds from the stock offering for potential acquisitions for strategic growth, including acquiring critical technologies and scalable businesses. The firm says the focus will be on multiple attractive global targets, including entities that it has been tracking for the last couple of years.

Cowen and Company LLC and Roth Capital Partners acted as joint book-running managers for the offering. Craig-Hallum Capital Group LLC acted as co-manager.

GigOptix acquires CMOS SerDes supplier Terasquare

GigOptix has acquired Terasquare Co Ltd of Seoul, South Korea, a fabless supplier of low-power-consumption CMOS SerDes high-speed communication interface semiconductors for 100Gbps Ethernet, Fiber Channel and EDR Infiniband applications.

GigOptix is paying about $4m to Terasquare's investors and an extra $1.15m of Terasquare's debt and other liabilities. Based on Korean Government subsidies provided to Terasquare, the acquisition is neutral to accretive immediately on closing.

"We have a proven track record of acquiring and integrating companies in the most financially prudent manner. Each acquisition has served as a building block to generate continuous growth in our business," says chairman & CEO Dr Avi Katz. "The acquisition of Terasquare is the next piece in our long-term plan of creating the industry's premier supplier of datacom high-speed chipset solutions. It also represents another point along our initial 2007 roadmap and Strategic Plan to expand GigOptix through inorganic and organic growth. We look forward to furthering our leadership position in the growing 100Gbps datacom market, which is being driven by the unprecedented install-base growth of the Cloud, data-center, Social and Web2.0, Internet of Things (IoT) and Big Data demand and, together with the optimization of our front-end customer support and technical teams, we will enhance GigOptix's position as a dominant player in the markets we serve," he adds.

"We are pleased to welcome the Terasquare team to the GigOptix family and to extend GigOptix's global operations, with Terasquare becoming the company's headquarters in Korea under the name GigOptix-Terasquare Korea (GTK) Co Ltd," continues Katz. "The acquisition puts us in an excellent position to enhance our dominating position at the current data-center 40Gbps active optical cables (AOCs) and transceivers generation, and with the introduction of the complete 100Gbps chip-set solutions, as the datacom market transitions from 40Gbps to 100Gbps, and to next generations in later years of PAM4 optical interconnects." GTK Co Ltd will also serve as GigOptix's hub for the proliferation of its other high-speed connectivity and consumer electronics products.

"Terasquare completes GigOptix's 100Gbps datacom chip-set product portfolio, bringing to the market the best solution to support the insatiable need for unlimited bandwidth and speed of the interconnect pipes while maintaining the cost-centric structure of the products that address this market," reckons Dr Raluca Dinu, executive VP global customer operations. "The 40Gbps AOC and transceivers market will dominate the next few years, where GigOptix's ICs have undoubted leadership and, with the 100Gbps Ethernet market starting to become relevant in 2017 — with deployments for at least the following 5 years — GigOptix's enhanced solid team of very experienced analog and digital designers is poised to timely address the next wave of Ethernet deployments of PAM4 modulation format chipsets," he adds. "To support the strong demand and stringent performance requirements in the 100Gbps datacom market, we decided to combine the advantages of the silicon germanium (SiGe) technology for maximum IC performance and CMOS technology for lowest-power-consumption CDR at 100Gbps or beyond, for NRZ or later for PAM4 applications."

Analog and digital expertize

Terasquare's CEO Dr Jinho Park is now GigOptix's VP of CMOS products engineering and general manager of GTK. Terasquare's chairman professor Hyeon-min Ba is chairman of GigOptix's Technical Advisory Board and a member of GTK's board. "The knowledge that accompany Jinho and Hyeon-min, and the Terasquare team as a whole, will be applied to extend GigOptix's datacom product portfolio," says Katz.

Complete datacom product line

Terasquare's all-CMOS, low-power architecture platform allows integrated testability features. As well as the quad-channel CDR technology and products for 100GbE datacoms, additional products using forward error correction (FEC) and electrical dispersion compensation (EDC) for other, complementary applications will be available as the two portfolios merge. The Quad CDR solution is applicable to 100Gbps Ethernet (QSFP28, CFP2, CFP4), OTU-4, 32G Fiber Channel, and EDR Infiniband.

"The patented, low-power digital architecture further expands and complements our leading datacom TIA and laser driver portfolio to include unique CDR products that can be user-optimized for use in either the transmit or receive direction," notes datacom marketing director Tom Kapucija. "Internal evaluation and 100GbE link testing, with the HXC42400, shows that the partitioning of the CDR function and its power dissipation away from the temperature-sensitive, high-performance VCSEL and photo-detector circuit elements enables operation with our TIA and VCSEL drivers to 300m using OM4 multi-mode fiber."

GigOptix will integrate Terasquare products into its datacom portfolio, re-branding the quad-channel CDR to the HXC42400. Its architecture enables low power dissipation and what is said to be the first solution with programmable receiver and transmitter bandwidth in a single device to optimize input jitter tolerance (IJT) and output jitter transfer for superior link performance.

Bundling the 100G HXC42400 CDR with the already commercialized HXT8204 VCSEL driver and HXR8204 TIA are suitable for optical module, active optical cable, and optical engine applications with their partitioning of the CDR power dissipation from the temperature-sensitive VCSEL, VCSEL driver, photo-detector and TIA circuit elements for 100m and extended-reach use to 300m.

www.terasquare.co.kr

Oclaro samples 100G QSFP28 client-side transceiver compatible with both CLR4 and CWDM4 specs

Oclaro Inc of San Jose, CA, USA is sampling a 100G QSFP28 client-side transceiver that meets both the CWDM4 MSA and CLR4 Alliance optical interface specifications, as well as the IEEE 802.3bm CAUI-4 electrical interface specification.

Featuring low power consumption of 3.5W and high transmission performance quality through the use of Oclaro's internal uncooled 1310nm 28Gbps directly modulated laser (DML) technology, the new QSFP28 client-side transceiver is suitable for 100G interconnections between data-center switches in addition to interfaces in high-end routers and packet-optical transport systems.

"The key to our success in the 100G pluggable transceiver market has been our proprietary indium phosphide laser technology," says Yves LeMaitre, president of Oclaro's Optical Connectivity Business. "With our new QSFP28 100G transceiver, mega-scale data-center operators will be able to transition from 40G to 100G on their existing single-mode fiber infrastructure without significantly expanding footprint, cost or power consumption."

Data-center architectures have evolved from shorter-reach multi-mode fiber links to longer-reach single-mode fiber interconnections between switches typically running at 10G or 40G. Until recently, the only 100G standard specified by the IEEE for single-mode fiber links has been the 100GBASE-LR4 standard for 10km reach based on WDM wavelengths that require temperature-stabilized lasers even though many links only need reaches up to 2km. To address the issues, the CWDM4 MSA developed a new interface standard based on CWDM wavelengths, removing the requirement for a thermoelectric cooler (TEC) and allowing a low-cost design at low power consumption. At the same time, a group of firms also formed a new CLR4 Alliance to generate an open, multi-vendor specification, establishing and releasing a spec similar to the CWDM4 standard. Because this new standard did not require forward error correction (FEC), which can sometimes cause latency issues, it was more desirable for applications such as high-performance computing, computer clustering and high-speed trading that cannot tolerate latency. Oclaro is a founding member of both the CWDM4 and CLR4 MSA, and, with its 100G QSFP28 transceiver, it can now support both these standards with a single design that offers low power consumption, low cost and high-quality transmission.

Features of the transceiver include:

- Oclaro's proprietary uncooled 1310nm 28Gbps DML, enabling both CWDM4 and CLR4 specifications for low power consumption without compromising transmission performance;
- Based on cost-effective design leveraging Oclaro's manufacturing experience, gained as the market leading supplier of single-mode 100G client-side transceivers;
- Ability to operate without FEC protocol on host card to deliver lower end-to-end latency.

www.oclaro.com

Oclaro samples high-bandwidth lithium niobate modulator

Oclaro has announced early sampling of a 400Gb/s high electro-optic bandwidth lithium niobate ($LiNbO_3$) external modulator for designing and testing 400G and higher networks on a single wavelength. Designed to enable 400G and beyond speeds on a single wavelength or carrier, the high electro-optic bandwidth polarization multiplexed quad parallel PM-QMZ device that integrates into a hermetic package an input beam splitter, four parallel Mach–Zehnder modulators configured for I–Q modulation, a polarization combiner and monitor photodiodes for power and bias control.

Key features include:

- 3dB electro-optic bandwidth exceeding 35GHz;
- smooth optical response up to 50GHz, enabling a symbol rate of up to 64Gbaud;
- an extinction ratio above 25dB to enable complex modulation formats; and
- insertion loss below 13dB for high efficiency.

By eliminating the need to use two wavelengths with the 16-QAM modulation format, the new 400G external modulator is designed to enable networking companies to more quickly design and test next-generation, high-speed networks that deliver the highest level of performance and reliability.

"To scale to 400G speeds and higher in the future, optical networking companies are improving spectral efficiency and lowering the cost per bit in fiber transmission systems, something that is not economical with two wavelengths," says chief commercial officer Adam Carter.

As optical network capacities continue to increase to meet the rising demands for bandwidth, optical designers have turned to coherent modulation techniques to obtain the highest transmission speeds and lowest bit error rates (BERs) in their networks, Oclaro says. The most advanced systems have port capacities of up to 400G. While in the past they were limited to using two wavelengths to achieve this, they can now achieve 400G capacity on a single wavelength, making it easier to deliver the increased bandwidth telecom operators are demanding, the firm adds.

TeraXion's InP modulators enable single-wavelength 400Gb/s system performance

TeraXion Inc of Quebec City, Canada (which designs and manufactures optoelectronic components and modules for high-speed fiber-optic transmission networks as well as fiber lasers and optical sensing applications) says that access to cost-effective 400Gb/s systems is now possible with its indium phosphide (InP)-based modulators.

Next-generation single-wavelength transmission systems beyond 100Gb/s bring complex challenges that require high modulation performance, power efficiency and small dimensions, says the firm. Modulators with low drive voltages are consequently necessary to minimize the power dissipation of high-port-density systems. In addition, a high modulation bandwidth increases spectral efficiency by enabling higher symbol rate applications necessary for 200Gb/s, 400Gb/s and beyond. Small-footprint characteristics are equally imperative to enable compact transceiver modules.

"Our commercially available indium phosphide modulators are ready to meet system requirements for 100Gb/s and upcoming advanced modulation formats," says Ian Woods, VP of high-speed photonic components. "This accessibility comes directly from our modulators' capability of reaching higher bandwidths up to 40GHz while being small and Vpi efficient," he declares. "Our modulators indeed offer unique low Vpi drive voltage down to 1.5V," Woods adds. "TeraXion has been sampling 400Gb/s-ready IQ modulators since the beginning of this year and customers are actively advising us that their general performance is superior to lithium niobate modulators, particularly at higher symbol rates."

TeraXion says that the high bandwidth response of its InP-based modulators can enable increased spectral efficiency and reach. In collaboration with academic and industry partners, single-wavelength 400Gb/s system performance has been demonstrated, so far only possible using a TeraXion InP DP-IQM package that exhibits a bandwidth greater than 35GHz.

"Our work with these partners demonstrates the clear benefits of using high-bandwidth modulators for single-carrier 400Gb/s applications and supports TeraXion's leading role in making these future enabling technologies accessible," says Woods. TeraXion's chip-on-carriers are also available for co-packaging with laser, drivers or receivers.

www.teraxion.com/en/iqm

Avago unveils ultra-low-power Fast Ethernet SFP transceiver for industrial automation, controls and networking

Avago Technologies Ltd (which designs and supplies III-V-based analog interface components for communications, storage, consumer and industrial applications) has launched the AFBR-57E6APZ ultra-low-power Fast Ethernet small-form-factor pluggable (SFP) fiber-optic transceiver module device, designed for industrial automation, controls and networking applications.

"Fast Ethernet is widely used in industrial automation, controls and networking. As more fiber-optic nodes are added to the network, cumulative heat dissipation becomes an industrial concern, prompting the need for low-power fiber-optic transceiver solutions," notes Martin Weigert, VP & general manager of Avago's Industrial Fiber Product Division (IFPD).

Compatible with SFF-8074i and SFF-8472 MSA specifications as well as the 100BASE-FX version of IEEE 802.3u, the device features a re-designed chip-set for LED control, diagnostic monitoring interface (DMI, providing real-time information on temperature, LED bias current, LED average output power and receiver average input power) and signal processing, significantly reducing the module power dissipation (255mW typical and 405mW maximum). Compared with the previous-generation device, the AFBR-57E6APZ consumes 42% less power while delivering what is claimed to be superior electrical and optical performance. Link distances are up to 2km using 50/125μm or 62.5/125μm multimode fiber.

"Our new ultra-low power 100BASE-FX SFP module is an ideal solution that addresses the power issue that affects many of our industrial customers, enabling them to simplify the network rack design and avoid having to use expensive cooling fans and ventilation in their systems," says Weigert. The industrial operating temperature range is –40°C to +85°C. Robust, long-life LED technology prevents catastrophic failure of the laser like sudden death or mirror degradation.

Samples and production quantities are available now through Avago's direct sales channel and worldwide distribution partners.

www.avagotech.com/products/industrial-fiber-optics/industrial-fiber-optic-transceivers/sfp/afbr-57E6apz

Finisar's profits fall after higher-than-expected costs from new-product qualifications

OpEx to be cut from 21.8% to targeted 20% of revenue

For its fiscal first-quarter 2016 (ended 2 August), fiber-optic communications component and subsystem maker Finisar Corp of Sunnyvale, CA, USA has reported revenue of $314m, down 1.9% on $320m last quarter and 4% on $327.6m a year ago.

However, last quarter had an extra (14th) week (rather than fiscal Q1's 13). "Taking that into consideration, the first fiscal quarter had a higher average weekly revenue relative to the prior quarter," notes executive chairman Jerry Rawls.

Due mainly to the impact of one fewer week than the prior quarter, datacom product sales fell by $8.7m (3.6%) on last quarter (with legacy 100G CFP down after an extremely strong fiscal Q4, and wireless not as strong as expected). "Strength in revenue was primarily driven by 40 Gigabit transceivers for datacom applications," says Rawls. Telecom product sales rose by $2.7m (3.4%) on last quarter.

We have started taking actions to reduce our operating expense levels. Our target is to ultimately have operating expenses at approximately 20% of revenue

Finisar had two 10%-or-greater customers. The top 10 customers represented 60.7% of total revenue, up from 58.8% last quarter.

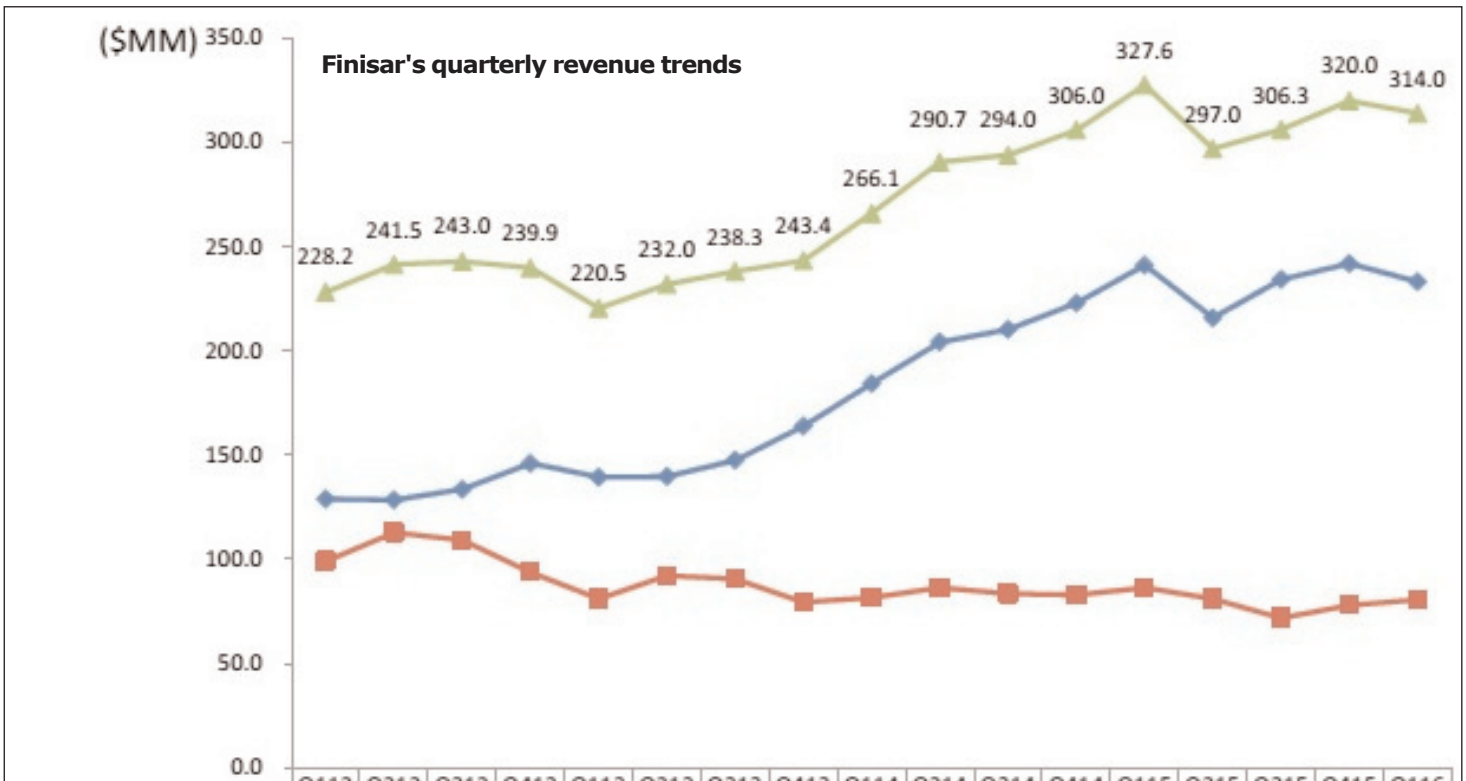
On a non-GAAP basis, gross margin has fallen further, from 32% a year ago and 30.3% last quarter to 30.2%.

Operating expenses rose slightly from $68.2m last quarter to $68.4m (more than the expected $67–68m), due mainly to higher-than-expected costs associated with the qualification of new products.

Operating income fell from $35.4m (10.8% of revenue) a year ago and $28.8m (9% of revenue) last quarter to $26.5m (8.4% of revenue). Likewise, net income fell from $33.3m ($0.32 per diluted share) a year ago and $26.9m ($0.25 per diluted share) last quarter to $24.5m ($0.23 per diluted share).

Capital expenditure was $34.7m, up on just $30.1m last quarter, as the timing of some of the expenditures associated with the building construction in Wuxi, China were pushed into fiscal first-quarter 2016.

During the quarter, cash, cash equivalents and short-term invest-



	Q112	Q212	Q312	Q412	Q113	Q213	Q313	Q413	Q114	Q214	Q314	Q414	Q115	Q215	Q315	Q415	Q116
Datacom	129.1	128.5	133.7	146.1	139.5	139.8	147.6	163.9	184.4	204.3	210.4	223.0	241.2	215.9	234.4	242.0	233.3
Telecom	99.2	113.0	109.3	93.8	81.1	92.2	90.7	79.5	81.6	86.4	83.6	83.0	86.4	81.1	71.9	78.1	80.7
Total Optics Revenue	228.2	241.5	243.0	239.9	220.5	232.0	238.3	243.4	266.1	290.7	294.0	306.0	327.6	297.0	306.3	320.0	314.0

ments rose by $5.5m from $490.2m to $495.7m.

For fiscal second-quarter 2016, Finisar expects revenue of $304–324m (with telecom sales relatively flat and, in datacoms, 40G down after an extremely strong fiscal Q1 and 100G for data centers bouncing back). Gross margin should be about 30%, "as we continue to see a high level of competition," says Finisar.

"We have started taking actions to reduce our operating expense levels," says Rawls. Operating expenses are expected to be cut from 21.8% to 21.4% of revenue. "Our target is to ultimately have operating expenses at approximately 20% of revenue… during the first half of fiscal 2017," notes Rawls.

Operating margin is expected to be 8–9%. Earnings per diluted share should be $0.20–0.26.

CapEx is expected to be about $35m. Build-out of the remaining floors of the second building in Wuxi, China will be completed by the end of fiscal 2016, after which CapEx should drop back down to a more normalized level of $30m.

"While we expect the remainder of fiscal 2016 to be challenging, we are optimistic about fiscal 2017," says Rawls. "We expect to benefit from the ramp of many new products and associated revenue growth driven by both data-center construction and upgrades and the increased deployments of ROADMs and 100G coherent transceivers in the telecom metro market," he adds.

While we expect the remainder of fiscal 2016 to be challenging, we are optimistic about fiscal 2017. We expect to benefit from the ramp of many new products and associated revenue growth driven by both data-center construction and upgrades and the increased deployments of ROADMs and 100G coherent transceivers in the telecom metro market

"We continue to believe that the long-term growth prospects of our company and the optical communications industry are positive," says Rawls. "From our position as the industry leader, we will continue to develop the technology and the next generation of products for both the datacom and the telecom markets. Finisar's revenue is driven primarily by growth in the global demand for bandwidth due to the increasing distribution and use of video, images and digital information. In addition, Finisar continues to benefit from the growth in cloud services, which drives networking hardware upgrades of existing data centers and the buildout of new hyperscale data centers."

Finisar's CEO Eitan Gertel resigns

Finisar says that its board of directors had accepted the resignation of CEO & director Eitan Gertel. Executive chairman Jerry Rawls will continue to serve as principal executive and will also assume the title of CEO.

"On behalf of the entire board, we thank Eitan Gertel for his contributions to Finisar," says Robert Stephens, lead director of the board of directors.

"Since joining the company in 2008 in connection with the Optium merger, Eitan has played an important role in Finisar's success as the world's largest supplier of optical transceivers and subsystems," says Rawls. "We appreciate Eitan's leadership and the important strategic initiatives he has driven for the company," he adds.

"Jerry, who has a proven track record with our employees, partners and customers and has been our co-principal executive officer, will now provide additional leadership as our chief executive officer," comments Stephens.

www.finisar.com

Finisar receives Excellence in Delivery and Flexibility Award from Cisco

During Cisco's 24th Annual Supplier Appreciation Event at the Santa Clara Convention Center in California on 9 September, fiber-optic communications component and subsystem maker Finisar Corp of Sunnyvale, CA, USA received the 2015 Excellence in Delivery and Flexibility Award for "executing under tremendous delivery and flexibility pressures, while quickly adapting to Cisco's Lean hubbing requirements and adopting the company's cloud-based SCP material management platform".

"Our Supplier Appreciation Awards highlight exceptional performances by the very best of our extended supply chain," says John Kern, senior VP, Supply Chain Operations, at Cisco. "Our theme this year, 'Embrace the Pace: Transforming Tomorrow Together', emphasizes the criticality of flexibility, collaboration and accelerated innovation," he adds.

Cisco presented awards to suppliers in recognition of their contributions to its success in fiscal 2015. At the event, Cisco recognized the dedication and successes of its strategic suppliers and manufacturing partners, testifying to its commitment to close partnership with its supply network.

www.huawei.com

First Solar and skytron open EMEA operations center

First Solar Inc of Tempe, AZ, USA, which makes thin-film photovoltaic modules based on cadmium telluride (CdTe) as well as providing engineering, procurement & construction (EPC) services, has announced the opening of a new Operations Center in Berlin, Germany, to be managed and operated by its Berlin-based subsidiary skytron energy GmbH (acquired in mid-2014). It is First Solar's third facility of its kind in the world, joining its existing Operations Centers in Tempe, Arizona in the USA and Sydney in Australia.

Founded in 1977, skytron energy provides utility-scale PV monitoring, control and supervision systems to solar power plants. It supports more than 6000MW of utility-scale assets globally, through its advanced monitoring and Supervisory Control and Data Acquisition (SCADA) solutions. skytron also supplies O&M services for First Solar in Europe.

The new Operations Center will provide remote monitoring, real-time supervision and plant control capabilities for photovoltaic (PV) energy assets located across the Europe, Middle East & Africa (EMEA) region. It is manned by a specially trained team that will supervise the ongoing operation of power plants under management; tracking performance, detecting and diagnosing issues, and scheduling and advising on-site activities. The facility is also capable of energy forecasting and ensuring that power plants under management conform to grid requirements.

"Photovoltaic solar's emergence as a mainstream power generation resource, particularly in competitive markets, has made professional and focused operations and maintenance (O&M) more relevant than ever before," says Troy Lauterbach, First Solar's VP for global O&M. "PV plants are now recognized as high-value assets; their owners are focused on ensuring that they are optimized to reliably deliver the energy necessary to ensure profitable returns to investors," he adds. "First Solar, with its industry-leading fleet availability and track record of being able to enhance power plants to consistently deliver more energy than expected, is well placed to help plant owners meet, and exceed, their energy yield goals," he reckons.

The new Operations Center in Berlin for remote monitoring, real-time supervision and plant control capabilities of photovoltaic energy assets across Europe, the Middle East and Africa (EMEA).

First Solar is said to be the world's largest utility-scale solar O&M provider, managing a portfolio of over 4000MW of PV plants, each ranging from $2MW_{AC}$ to $550MW_{AC}$ in capacity. First Solar O&M has recorded an average fleet availability of greater than 99% in each of the last five years, compared with an industry average of 98%.

"The Berlin Operations Center is an important component of our service offering in one of the world's fastest-growing geographies. This investment reflects the significant demand we see for professional O&M services," says Stefan Degener, First Solar's senior director for O&M in the EMEA region. "We are now well equipped to support the needs of the established energy markets in Western Europe through skytron energy, with capabilities that span managing existing assets and new projects," he adds. "We are also looking to support the fast-growing emerging markets in the Middle East and in Africa, with technology driven solutions that will boost PV's competitiveness."

"Customers whose power plants are managed by this Operations Center will benefit from several gigawatts of combined First Solar and skytron energy experience, that spans all commercially viable PV technologies," says skytron energy's managing director Jörgen Klammer. "Equipped with the latest technology, this facility is capable of identifying and mitigating potential issues, real-time monitoring of plant performance and providing remote support when and where it is needed," he adds. "In an increasingly competitive energy marketplace, this Operations Center will be a critical part of our customers' efforts to optimize their PV power plants for performance and profitability."

www.skytron-energy.com
www.firstsolar.com

Southern Power acquires controlling stake in 300MW Desert Stateline Facility from First Solar

Marking a major milestone in the strategic expansion of its renewable generation portfolios, Atlanta-based Southern Company subsidiary Southern Power has acquired a controlling interest in its largest solar asset — the 300MW Desert Stateline Facility in California — from 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. First Solar will retain the remaining stake. The project represents the fourth shared acquisition between Southern Power and First Solar.

"By continuing to leverage Southern Company's and First Solar's complementary strengths, we are accelerating the development of solar as an important component of a diverse fuel mix now and in the future," comments Southern Company's chairman, president & CEO Thomas A. Fanning.

Southern Power's seventh solar acquisition in California, the Desert Stateline Facility will be located on 1685 acres of federally managed public land in San Bernardino County and is expected to consist of about 3.2 million of First Solar's solar modules mounted on fixed-tilt tables. Once operational, the facility is expected to be capable of generating enough electricity to help meet the energy needs of nearly 100,000 average homes.

"Our strategic relationship capitalizes on each company's core competencies," says First Solar's CEO Jim Hughes. "We are actively discussing ways to continue and broaden this relationship," he adds. "This facility and other similar facilities allow leading energy companies to place First Solar's advanced thin film PV technology at the heart of utility-scale generation facilities, enabling power providers to include competitive, reliable renewable energy in their portfolios."

First Solar is building and will operate and maintain the Desert Stateline Facility. Construction began in October 2014 and is expected to be completed in phases. The plant is slated to be fully operational in third-quarter 2016.

The electricity and associated renewable energy credits (RECs) generated by the facility will be sold under a 20-year power purchase agreement (PPA) with Southern California Edison Company.

Southern Power assembled its renewable portfolio (which now totals more than 1450MW of generating capacity ownership either already in operation or under development) through the strategic development of 20 solar, wind and biomass projects across the USA. Southern Company has added or announced more than 3300MW of renewable projects since 2012.

Southern Power says that the Desert Stateline Facility fits its business strategy of growing its wholesale business through the acquisition and construction of generating assets that are substantially covered by long-term contracts.

www.firstsolar.com
www.southerncompany.com

Solar Frontier's CIS PV modules chosen for 26MW project in North Carolina

Tokyo-based Solar Frontier — the largest manufacturer of CIS (copper indium selenium) thin-film photovoltaic (PV) solar modules — is supplying its CIS solar module technology for a 26MW project located near Raleigh, North Carolina, USA.

Solar Frontier signed the module supply agreement with a California-based solar equipment supplier and initiated the first of a series of shipments in late August. The project will be constructed by Vaughn Industries LLC, a team of full-service electrical contractor specialists (including power transmission and distribution, substation and renewable energy projects).

"Solar Frontier is pleased to add this project to our growing footprint in the Americas and, as we expand our presence in the market, to add Vaughn Industries to our expanding network of trusted national construction leaders," says Solar Frontier Americas' chief operating officer Charles Pimentel.

"Solar Frontier is a company whose product we recognize and value for its quality production and high-performance in the field," comments Vaughn Industries' CEO Tim Vaughn.

Solar Frontier says that its CIS technology generates higher energy yield (kilowatt-hours per kilowatt peak) in real-world environments than conventional crystalline silicon technologies, and that its projects have gained increasing attention from investors and project developers across the Americas.

With more than 400 staff, specialty contractor Vaughn Industries services the industrial/commercial sectors, including electrical, renewable energy, mechanical (HVAC and pipefitting), plumbing, and high-voltage substation, high-voltage transmission and distribution construction.

www.vaughnindustries.com
www.solar-frontier.com

Arkansas-led team receives $750,000 NASA grant to develop SiGeSn solar devices for space missions

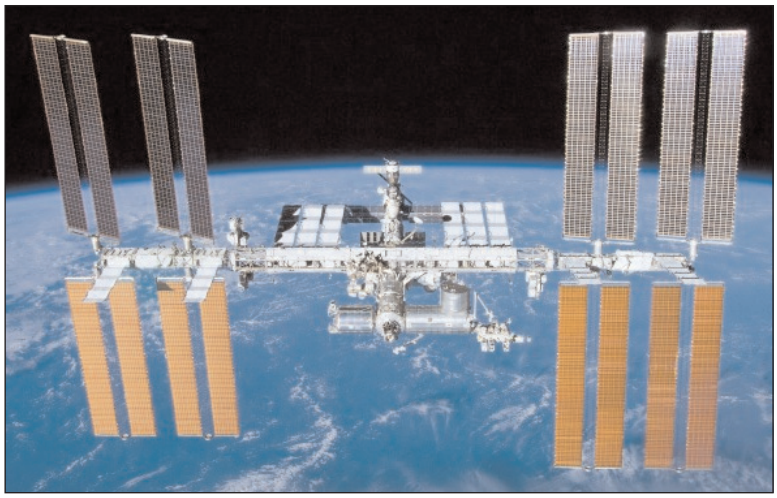
University of Arkansas researchers are working on a promising new material to create more efficient photovoltaic solar cells to be used in space missions.

Shui-Qing 'Fisher' Yu, associate professor of electrical engineering, will serve as principal scientific investigator on the multi-institutional project. The team will develop photovoltaic devices made of silicon-germanium-tin (SiGeSn), which has been proven to increase efficiency in electronic devices that source, detect and control light.

The project is made possible by a $750,000 NASA/EPSCoR grant to the Arkansas Space Grant Consortium Office at the University of Arkansas at Little Rock. EPSCoR (Experimental Program to Stimulate Competitive Research) is a funding program to increase state participation in competitive aerospace-related research activities.

"Now we have the opportunity to move forward developing a high-performance solar cell for space applications," says Yu.

Yu will collaborate with Hameed Naseem, professor of electrical engineering; Mansour Mortazavi, physics professor at the University of Arkansas at Pine Bluff; and Allan Thomas, physics professor at the University of Arkansas at Little Rock.



The University of Arkansas is developing SiGeSn photovoltaic devices for space missions such as the International Space Station.

Yu, Naseem and Mortazavi previously received a $725,000 grant from the US Air Force Office of Scientific Research to work on similar technology.

The researchers grow and characterize silicon-germanium-tin materials on silicon substrates using ultra-high-vacuum chemical vapor deposition. For the NASA project, the researchers will capitalize on their work with silicon-germanium-tin to develop photovoltaic devices that can be integrated into existing solar cells to achieve a more efficient, optimal energy yield. Existing triple-junction PV technology used by NASA has reached its efficiency limit, it is reckoned. The new material is intended to boost performance, helping NASA achieve its 15-year, 45% efficiency goal for solar devices. The new material should also lower the cost of manufacturing and make the devices more radiation tolerant.

The research plan includes device design and simulation, material growth and characterization, optical characterization of silicon-germanium-tin materials, and development of silicon-germanium-tin photoconductors.

Related to this research, Yu has also received a $96,455 grant from the US Army Research Office to upgrade equipment used to characterize silicon-germanium-tin-based devices.

http://asgc.ualr.edu

EnerPlex Generatr 100 wins Best of Show Award at CTIA Super Mobility Conference

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 — says that, at the CTIA Super Mobility Conference, its EnerPlex Generatr 100 won a Best of Show Award for the Most Versatile Charging Accessory from iPhone Life Magazine.

The EnerPlex Generatr 100 is a lightweight and portable power solution for a wide array of consumer electronics. The 100 has USB outputs for phones and tablets, a 12V port for lights, and a standard 110V outlet for powering laptops and other large electronics. The Generatr 100 can be charged via wall outlet, or sun using EnerPlex's patented solar panels.

"It is an honor that once again our leading-edge design and engineering has been recognized by this product award. The Generatr 100 embodies the concept of Mobility Power, providing power across a wide range of devices in a compact, lightweight and high-performance product," says Justin R. Jacobs, manager of brand development for EnerPlex.

www.AscentSolar.com

umicore
Precious Metals
Chemistry

Of course we are happy about every goal. And every sharp LCD screen.

Football without fans? Impossible. Just like the production of liquid crystals without our **Palladium catalysts** would also be impossible. So, you cheer on the game and we'll take care of the crisp, clear picture.

Employee: Eliciane Silva/General Management Assistant

www.chemistry.umicore.com

Innovation made. Easy.

Transparent conductive oxides and wafer bonding of III-Vs and silicon

A low-temperature process at 200ºC results in electrical resistance of less than 0.5Ω-cm^2.

The National Renewable Energy Laboratory (NREL) and University of California Santa Barbara in the USA have developed a wafer bonding technology for III-V materials and silicon (Si) using transparent conductive oxide (TCO) interlayers of indium zinc oxide (IZO) [Adele C. Tamboli et al, Appl. Phys. Lett., vol06, p263904, 2015]. The plasma-activated bonding is carried out at low temperature (200°C), avoiding thermal expansion mismatch problems. TCO interlayers protect the semiconductor from oxidation during the plasma activation.

The researchers see the process being used to create tandem solar cells with GaInP top cells and (amorphous/crystalline) heterojunction with intrinsic thin layer (HIT) silicon bottom cells. HIT-type cells already incorporate transparent conductive oxide as the top surface. "Such a device is promising for >30% efficiency 1-sun or low concentration solar cells at reasonable costs," the researchers write.

Apart from photovoltaic applications, the technique could also find use in integrating III-V optoelectronics with Si CMOS electronics. The researchers believe the process could also be used with other TCO materials such as indium tin oxide (ITO).

Two test samples of wafer-bonded materials were produced (Figure 1): III-V-to-sapphire and III-V-to-Si. The first sample was for optical characterization and the second for electrical testing. The sapphire was 430µm-thick double-side-polished c-plane crystal. The heavily n-type silicon substrate was 500µm thick with 0.001–0.005Ω-cm resistivity.

The III-V material consisted of heavily n-type (100) gallium arsenide (GaAs) substrate, 500nm n-type gallium indium phosphide ($Ga_{0.5}In_{0.5}P$) etch stop, and 25nm heavily n-type gallium indium nitride arsenide (GaInNAs) contact. The GaInNAs was doped with selenium.

The 8nm amorphous indium zinc oxide (IZO) wafer-bonding surfaces were created with RF sputtering. The IZO layer thickness was kept thin to avoid parasitic reflectance — the estimated reflection from the layer for GaInP/IZO/Si was 3.2% at 700nm wavelength, just below the GaInP band edge, and 1.0% at 1200nm, near the silicon band edge.

The III-V material was separated into 1cmx1.2cm pieces. Before bonding, the samples were cleaned in acetone, isopropanol and tergitol. The 30-second 100W oxygen plasma activation was carried out in an EVG 810 tool. After activation, the samples were stacked face-to-face and bonded in 225mbar vacuum, using a Süss SB6 system.

For the optical testing, the GaAs substrate was etched away in a 1:1 mix of hydrogen peroxide and ammonium hydroxide. A wax coating was used to avoid parasitic etching of the IZO and GaInNAs layers. An anti-reflection coat was added to the exposed

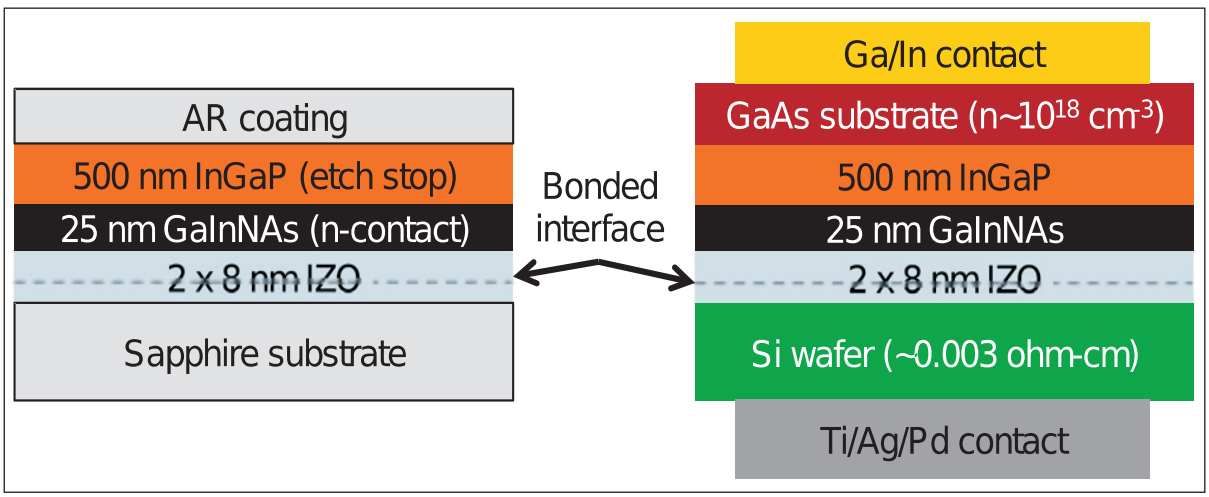


Figure 1. Schematics of test structures used to demonstrate TCO-based wafer bonding: structure on left used to measure optical properties; (b) structure on right used for testing electrical properties.

GaInP consisting of 75nm magnesium fluoride and 40nm zinc sulfide. The III-V/Si sample was prepared for electrical testing by adding contacts.

For bonding, the IZO surfaces need to be flat and atomic force microscopy (AFM) measurements gave roughness estimates of less than 0.1nm root mean square.

A range of bonding temperatures up to 400°C were tested. High-temperature bonding resulted in cracking due to thermal expansion mismatches. At the medium temperature of 200°C, the III-V/Si sample bonded over large areas with an adhesion strength of 0.3MPa.

The researchers comment: "This bond strength is lower than optimized Si–Si plasma-activated bonds (11MPa), since the high temperatures necessary to convert hydrophilic to covalent bonds must be avoided due to thermal expansion mismatch."

Reducing the bonding temperature to 100°C decreased the bond strength, "presumably due to large unbonded areas, which were visible as interference fringes at the III-V/sapphire samples," the researchers add.

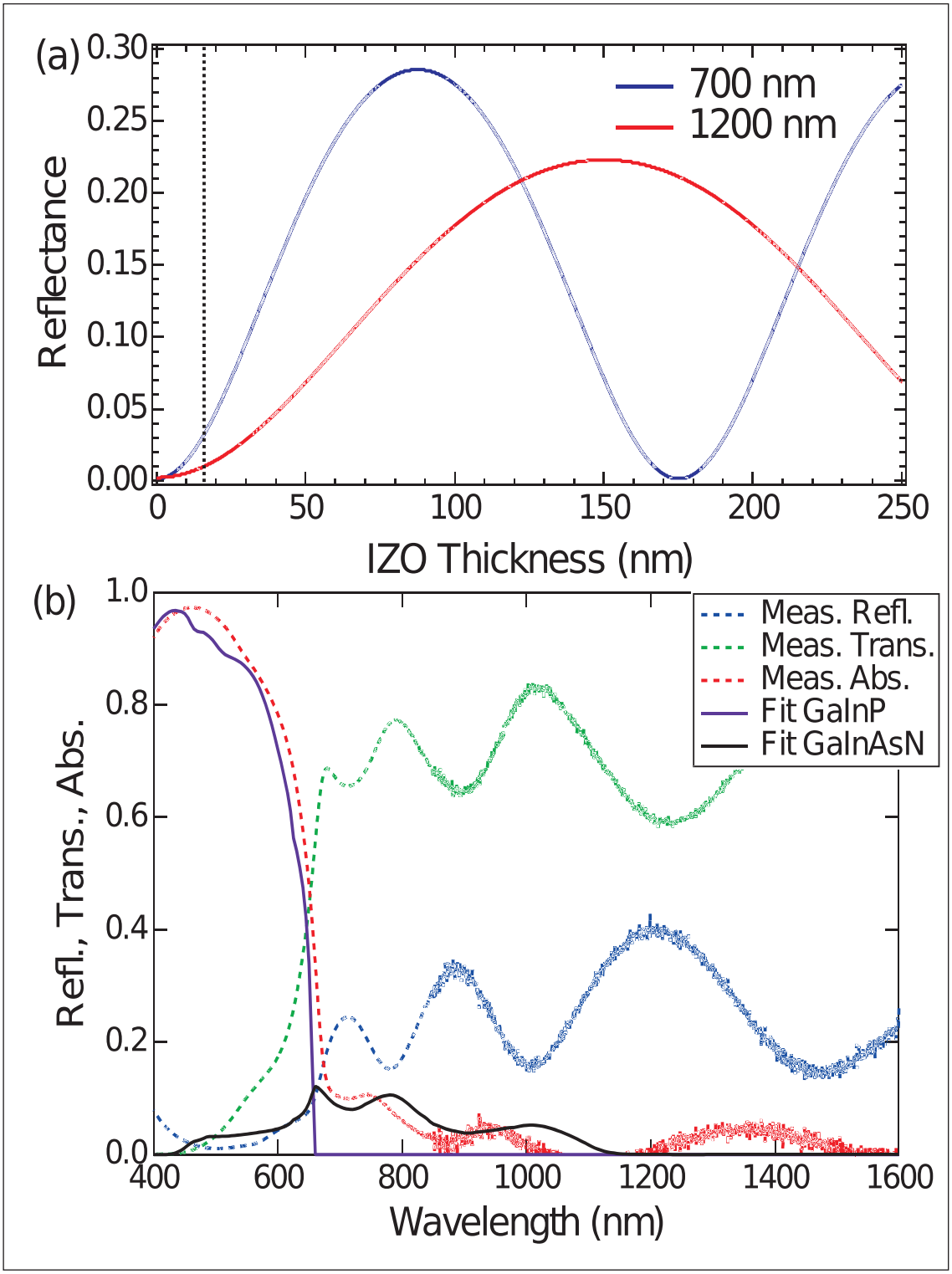


Figure 2. (a) Calculated reflectance of IZO layers of varying thickness sandwiched between GaInP and silicon. (b) Measured optical properties of III-V/IZO/sapphire bonded samples.

In the light absorption tests (Figure 2), the majority of the less than 10% of parasitic loss occurred in the n-GaInNAs contact layer with 1eV bandgap. This layer is needed for ohmic contact between the IZO and GaInP. The GaInNAs could be thinned or replaced with a more optimized material, the researchers believe.

The optimal electrical resistance of less than 0.5Ω-cm^2 was achieved with 200°C bonding. At higher temperatures, cracking inhibited current spreading; at low temperatures, the current flow was restricted by the reduced bonding area. The researchers comment: "These results would contribute a voltage loss of <10mV in a tandem cell operating at 1 sun (20mA/cm^2), sufficient for a high-efficiency tandem cell." ■

http://dx.doi.org/10.1063/1.4923444

Author: Mike Cooke

Mid-infrared interband cascade lasers on indium arsenide substrate

Intermediate cladding enables lower current threshold and higher-temperature operation.

University of Oklahoma in the USA has developed interband cascade (IC) lasers on indium arsenide (InAs) substrates with low threshold and high-current operation [Lu Li et al, Appl. Phys. Lett., vol106, p251102, 2015]. The researchers claim the threshold current of 247A/cm^2 at 300K for a 4.6μm wavelength device as "the lowest ever reported among semiconductor mid-infrared lasers at similar wavelengths".

Interband cascade lasers on gallium antimonide (GaSb) substrates have achieved good results in the 3–4μm wavelength range. Devices developed on InAs substrates have longer wavelength up to 11μm. These devices use a heavily doped outer cladding layers to create a plasmon waveguide. However, such laser have only demonstrated pulsed operation up to now. The new Oklahoma work has also produced continuous-wave operation for the first time, according to the researchers.

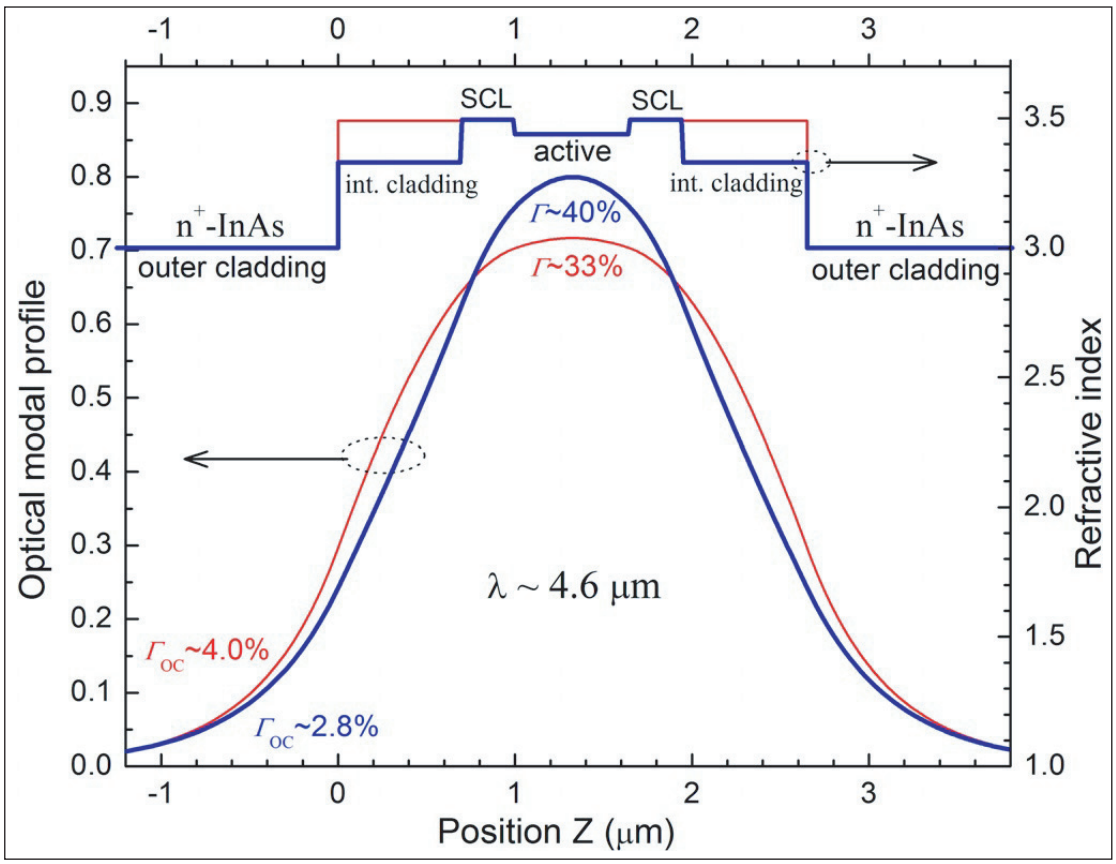


Figure 1. Calculated optical modal profiles of interband cascade lasers without (thin lines) and with intermediate superlattice cladding layers (thick lines).

The problem with plasmon waveguides with n$^+$-InAs cladding is high optical absorption loss. Some groups have tried to overcome this by inserting thick (>1μm) undoped InAs separate confinement layers at the cost of optical confinement, reduced optical gain, and increased current threshold.

To try to gain the best of both approaches, Oklahoma has inserted an intermediate cladding layer between the plasmon outer cladding and the separate confinement layers. The intermediate cladding pushes the optical field into the central part of the device and reduces the field in the outer plasmon cladding, avoiding absorption loss there (Figure 1).

The laser diode heterostructures were grown on n-type InAs substrate using molecular beam epitaxy (MBE). The separate confinement and intermediate cladding layers were symmetrical about the active region based on multiple cascades (Figure 2).

The intermediate cladding consisted of a 25Å/23Å InAs/AlSb superlattice of which 3Å of the AlSb layer was an AlAs interface for strain balancing. Carrier transport was smoothed between the intermediate cladding and other parts of the device by transition/connection bridges consisting of digitally graded ~58nm InAs/AlSb(As) quantum wells.

Various broad-area mesa stripe and narrow-ridge laser diodes were produced with uncoated facets. The 1.5–2.0mm laser bars were mounted epi-side up on copper heat-sinks.

Broad-area (BA) devices with intermediate cladding in pulsed operation showed lower 300K threshold current density and higher-temperature operation, compared with a laser diode produced without intermediate cladding.

The researchers report that "a BA device from a 15-stage wafer [labeled] R140 had a threshold current density J_{th} of 247A/cm^2 near 4.6μm at 300K, the lowest ever reported among mid-IR semiconductor lasers at similar wavelengths." They add: "Another BA device from a 10-stage wafer R144 lased at temperatures up to 377K near 5.1μm, . . . the highest operating temperature reported for electrically pumped interband lasers at this wavelength."

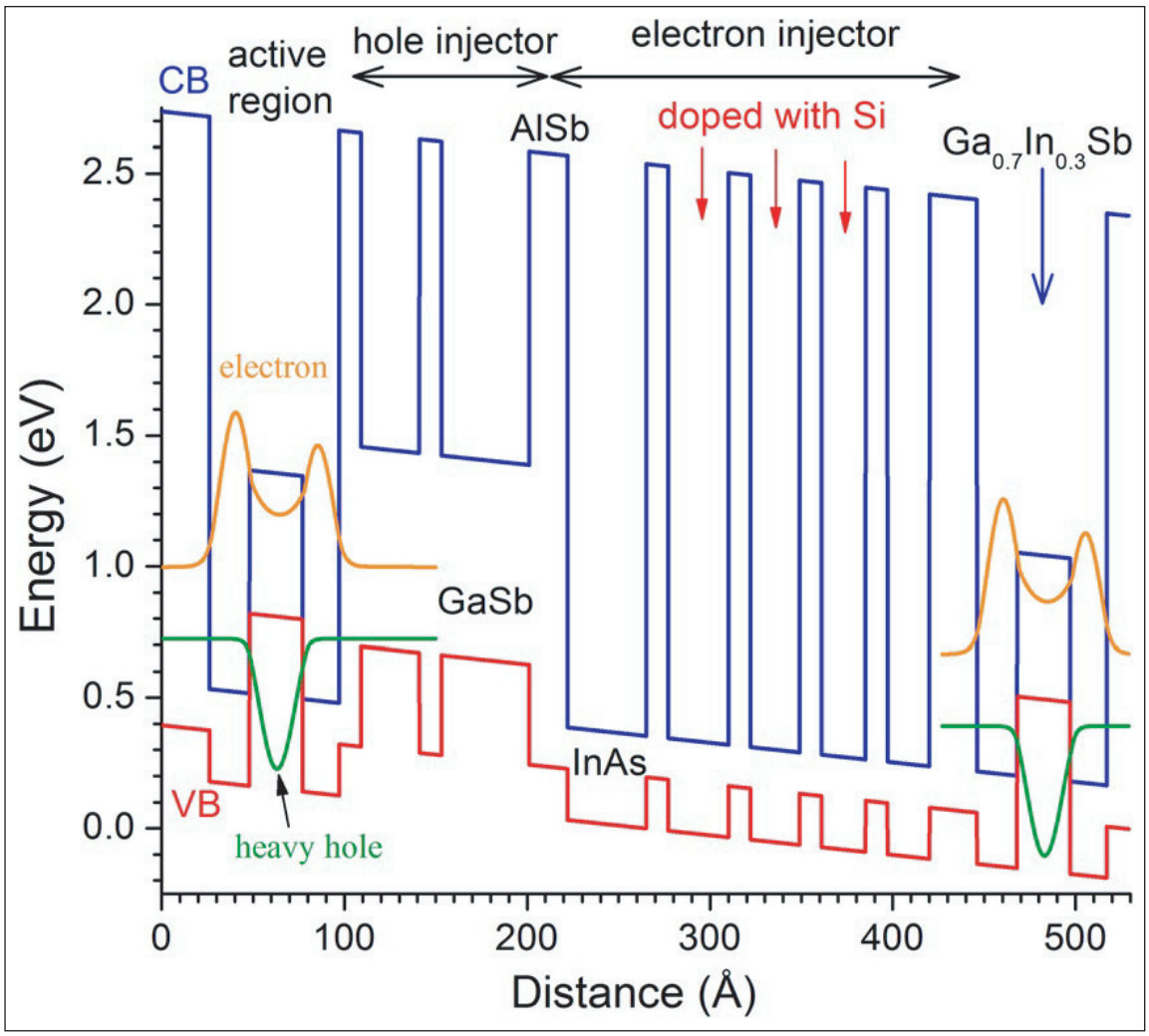


Figure 2. Calculated band-edge diagram of one cascade stage and layer sequence.

The characteristic temperature T_0, representing the threshold shift, was in the range 46-57K for 10- and 12-stage BA laser diodes, which is comparable to state-of-the-art GaSb-based interband cascade lasers in the 3–4μm wavelength region, according to the team.

Continuous-wave performance was tested on narrow-ridge devices with a 4μm electro-plated gold top contact. The output wavelengths were in the range 4.6–4.9μm for 10- and 12-stage devices.

The 10-stage laser achieved higher-temperature performance since the operating voltage was lower. One 10-stage device managed 1.6mW/facet output power at 300K. The input power at threshold was less than 0.52W. Lower input power has been achieved in GaSb interband cascade lasers for shorter wavelengths of 3–4μm. The researchers say they are encouraged by the results from their initial attempt at implementing intermediate cladding in InAs substrate IC lasers.

The thermal resistance of the 10μm-wide ridge devices in continuous-wave operation was in the range 6.5–11K-cm^2/kW. This is higher than for a reported device with thicker superlattice cladding (i.e. without intermediate cladding). "This suggests that there is still room for improving thermal dissipation of these InAs-based interband cascade lasers even without employing epilayer-down mounting," the team writes.

The narrow-ridge devices had similar high-temperature limits as the broad-area laser diodes in pulsed mode — up to around 376K. However, at temperatures below 320K, the current threshold was 45–71% higher. Shorter-wavelength 3–4μm interband cascade narrow-ridge laser thresholds are around 21% higher than for broad-area devices.

"This suggests a somewhat significant current leakage from the sidewalls due to imperfect passivation, which implies further room to achieve better performance by reducing this surface leakage," the team writes.

Substantial mode hopping was seen for the narrow-ridge devices at 310K, suggesting to the researchers that material non-uniformity was an issue. ■

http://dx.doi.org/10.1063/1.4922995

Author: Mike Cooke

Lowering threshold currents for m-plane III-nitride VCSELs

An ion implant aperture and planar indium tin oxide design has reduced the threshold current by a factor of five.

University of California Santa Barbara (UCSB) in the USA has reduced the threshold current density of its non-polar m-plane III-nitride vertical-cavity surface-emitting lasers (VCSELs) by a factor of five [J. T. Leonard et al, Appl. Phys. Lett., vol107, p011102, 2015].

The reduction is attributed to the use of a planar indium tin oxide (ITO) design, and the replacement of the plasma-enhanced chemical vapor deposition (PECVD) silicon nitride aperture by an aluminium (Al) ion implant process. The ion implant aperture also reduced the forward voltage by about 1V for given current density.

Longer-wavelength VCSELs using other III-V compound semiconductor materials benefit from structures with small active-region volume, short cavity length, circular beam profile, low beam divergence, and perpendicular emission from the substrate.

The UCSB team sees potential from similar properties for III-nitride devices for applications such as plastic optical fiber (POF) and free-space data communication. Single-mode operation could be useful in atomic clocks.

VCSELs can be formed into 2D arrays, which could lead to high-power-density ultraviolet III-nitride devices for pico-projectors, micro-displays, backlighting for small electronics, laser-based lighting, and bio-sensing.

The use of the m-plane oriented III-nitride structures avoids performance degradation from the quantum-confined Stark effect and also benefits from lower transparency carrier and current densities, higher material gain, and anisotropic gain characteristics, compared with conventional c-plane structures.

The epitaxial structure (Figure 1) was grown on Mitsubishi Chemical m-plane gallium nitride (GaN) using atmospheric-pressure metal-organic chemical vapor deposition (AP-MOCVD). After p-GaN activation, the VCSEL fabrication (Figure 2) began with etching of a 300nm mesa. The laser aperture was created using aluminium ion implantation (outsourced to Leonard Kroko Inc) with a titanium/gold hard mask. Next, a patterned 47nm ITO intra-cavity contact was deposited and silicon nitride was applied to the mesa sidewalls.

A 16-period distributed Bragg reflector (DBR) was deposited on a chromium/nickel/gold stack on the p-side ITO. The DBR consisted of tantalum pentoxide and silicon dioxide layers with a ⅛-wavelength tantalum pentoxide spacer next to the ITO.

The silicon nitride on the mesa sidewalls was etched away from the region of the sacrificial indium gallium nitride (InGaN) multiple quantum well (MQW) to prepare for photo-electro-chemical (PEC) etching.

Contact	p^{++}-GaN	14nm
Contact	p-GaN	56nm
Electron blocking layer (EBL)	p-$Al_{0.2}Ga_{0.8}N$	5nm
Active MQW	10 QW 405nm emission	3nm in 1nm barrier
Contact	n-GaN	770nm
Contact	n^{++}-GaN	50nm
Sacrificial MQW	3 QW 415nm emission	7nm in 5nm barrier
Template	GaN	1.2µm
Substrate	m-GaN	1° offcut to [000-1]

Figure 1. Epitaxial layer structure.

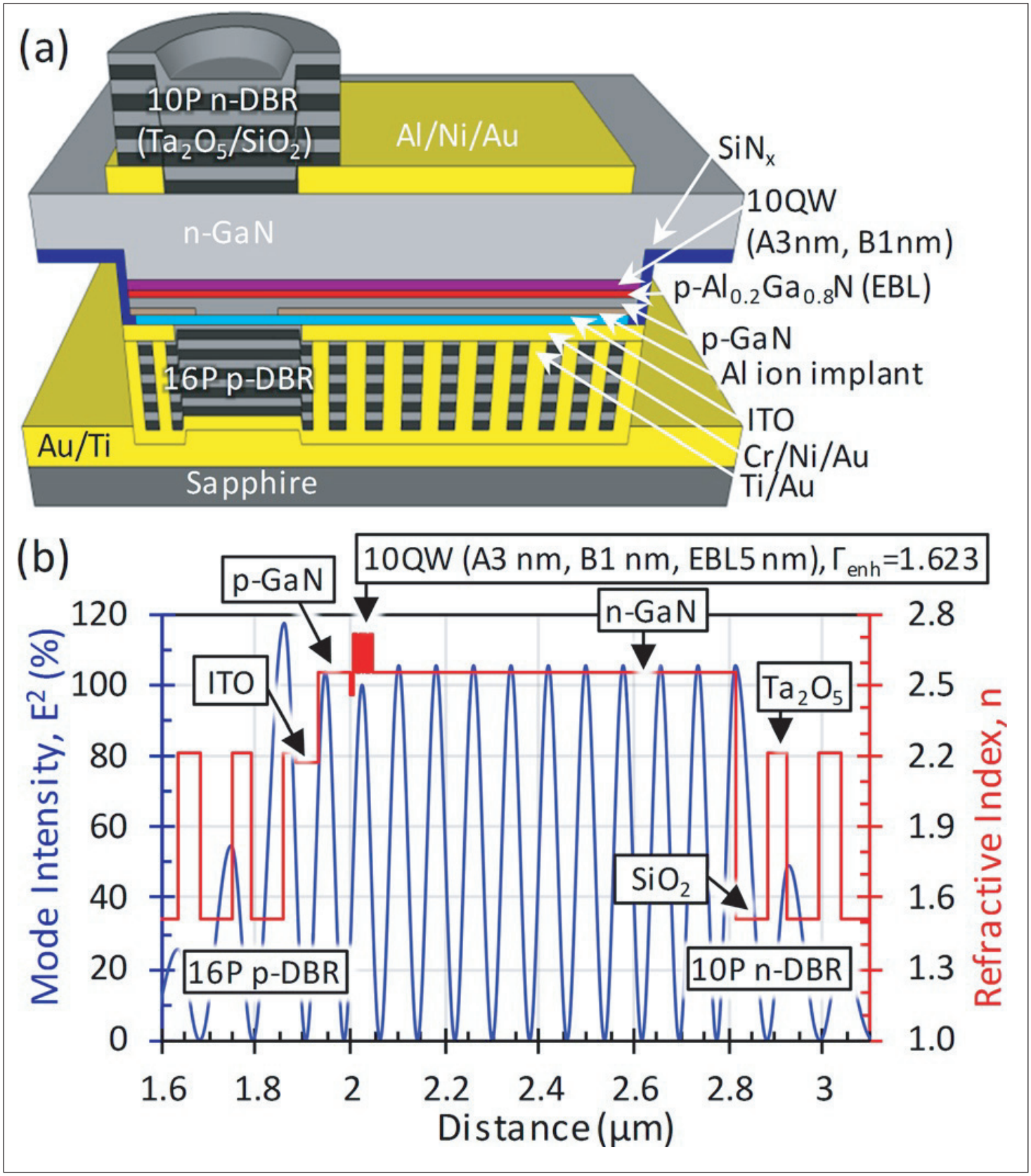


Figure 2. (a) Schematic of flip-chip non-polar VCSEL. (b) Cavity-mode intensity E2 (normalized to the peak in the active region) and refractive index profile of 10-period MQW.

Also, titanium/gold was applied as a conformal coating around the DBR to form the PEC cathode and p-contact pad for the VCSEL.

The structure was then flip-chip bonded at 200°C for 2 hours to a sapphire substrate with titanium/gold coating using a graphite compression fixture. The PEC was carried out to remove the substrate and sacrificial MQW, exposing the n-GaN contact layer. The PEC used potassium hydroxide solution and 405nm excitation from a laser diode.

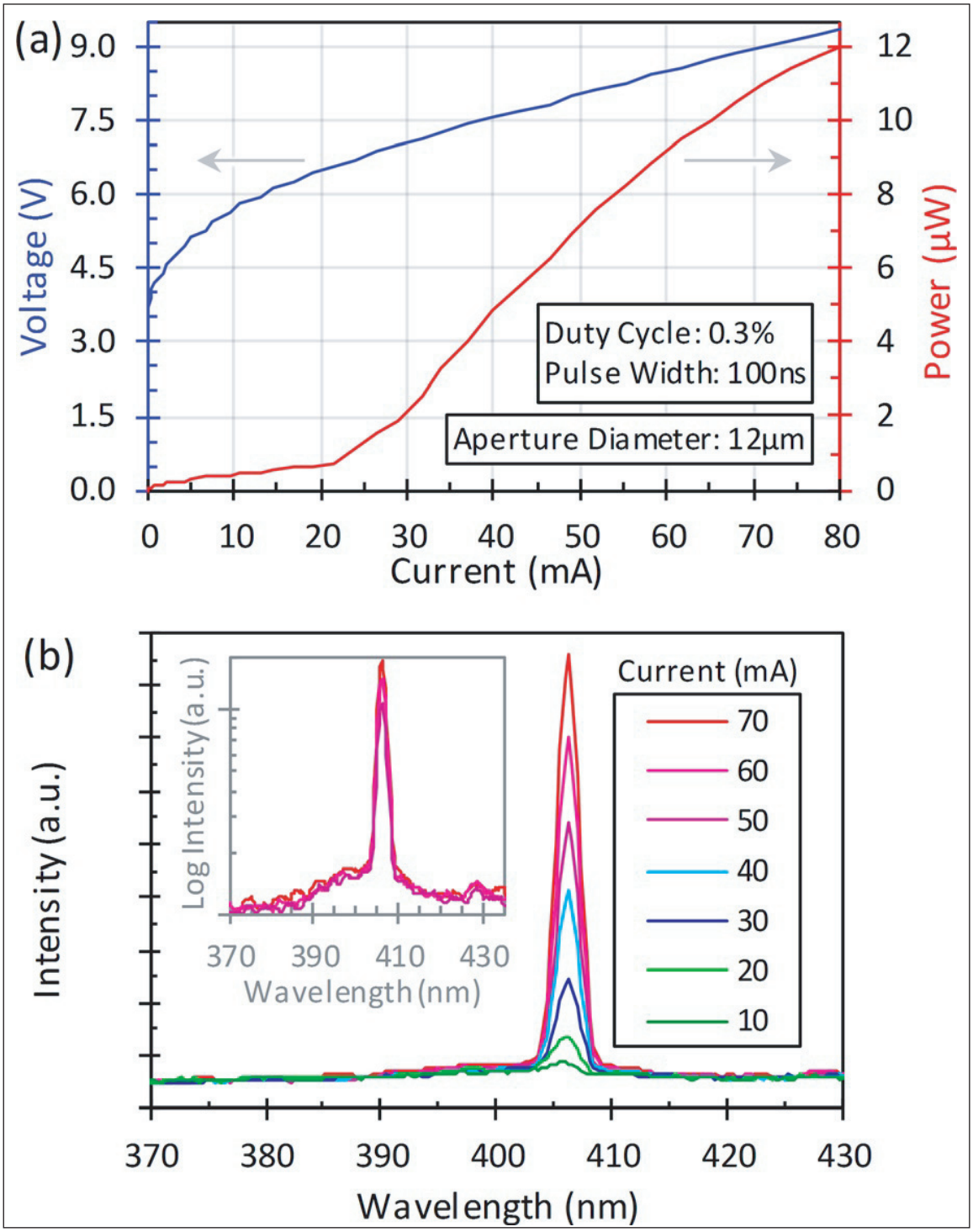


Figure 3. (a) Pulsed light output power, current, voltage (LIV) characteristics measured on 12μm-aperture-diameter VCSEL. (b) Emission spectrum versus current.

The VCSEL was completed with deposition of an aluminium/nickel/gold n-contact and 10-period DBR.

The researchers increased the number of active QWs to 10, over 5 in previous work, in the hope of reducing the threshold current density from 89kA/cm^2. The higher number of wells compensated for anomalous losses in the ITO contact layer. If the ITO losses could be reduced, lower numbers of wells would be more favorable, according to the researchers.

In 0.3%-duty-cycle 100ns pulse operation, the threshold current and voltage were 18mA (16kA/cm^2) and 6.4V, respectively, for a 12μm-diameter aperture VCSEL. The output power was 12μW at 80mA. The emission was single-mode longitudinal at 406nm. At 70mA, the full-width half maximum (FWHM) was ~2nm. The polarization of the light was 100%.

The researchers comment: "The overall yield of these devices is markedly higher than we observed previously, though we still see a large variation in the Jth across a single chip. A number of other improvements, [. . .] include optimization of the p-DBR deposition conditions to reduce ion damage, optimization of the flip-chip bonding conditions to mitigate catastrophic increases in the operating voltage, and optimization of the Mg doping in the EBL [electron-blocking layer] to reduce Mg diffusion into the MQW."

Optical microscope inspection of the emission showed non-uniform lasing across the aperture. The non-uniformity is likely due to filamentation for which a variety of explanations have been put forward: material inhomogeneity, surface morphology, local cavity length, current spreading, lateral index fluctuations, the polycrystalline ITO contact, or poor thermal conductivity of the p-DBR. However, the researchers comment: "We believe that the filamentation (i.e. spatially non-uniform lasing) is predominately a result of non-uniform current spreading, contact resistance, absorption loss, and/or lateral index fluctuations." ■

http://dx.doi.org/10.1063/1.4926365

Author: Mike Cooke

semiconductorTODAY

COMPOUNDS & ADVANCED SILICON

Choose *Semiconductor Today* for . . .

MAGAZINE

Accurate and timely coverage of the compound semiconductor and advanced silicon industries

Targeted 41,000+ international circulation

Published 10 times a year and delivered by e-mail and RSS feeds

WEB SITE

Average of over 19,700 unique visitors to the site each month

Daily news updates and regular feature articles

Google-listed news source

E-BRIEF

Weekly round-up of key business and technical news

E-mail delivery to entire circulation

Banner and text marketing opportunities available

www.semiconductor-today.com

Join our LinkedIn group: Semiconductor Today

Follow us on Twitter: Semiconductor_T

Aluminium indium gallium nitride nanowire LEDs on silicon

A spontaneous core-shell structure presents a barrier against efficiency-sapping surface recombination. Devices emit wavelengths between 430nm and 630nm.

McGill University in Canada has developed light-emitting diodes based on aluminium indium gallium nitride (AlInGaN) nanowires on silicon with spontaneous core-shell structures that inhibit non-radiative surface recombination, improving efficiency, across a wide range of visible wavelengths from blue-green to red [Renjie Wang et al, Appl. Phys. Lett., vol106, p261104, 2015].

The vertical nanowire structures (Figure 1) were created on silicon (111) substrates using radio-frequency plasma-assisted molecular beam epitaxy (PAMBE) in a nitrogen-rich environment. The 70nm AlInGaN core–shell active region was sandwiched between 200nm of silicon-doped n-GaN and 150nm magnesium-doped p-GaN.

The n- and p-GaN contact regions were grown at 770°C. The temperature of the active-region growth was between 610°C and 700°C. The Ga beam equivalent pressure during the active-region growth was 4.5×10^{-8}Torr. The In and Al pressures were varied — between 1.2×10^{-7} and 2.6×10^{-7} Torr and between 1.7×10^{-9} and 1.3×10^{-8} Torr, respectively.

The varying growth conditions enabled photoluminescence peaks between 410nm and 630nm — a fair proportion (~70%) of the visible spectrum of 390–700nm. Three samples with wavelengths in the blue-green range 495–515nm were chosen for closer study (Table 1). The core–shell structure was found to increase carrier lifetimes, compared with InGaN nanowires (0.2ns). The short lifetime in InGaN nanowires without any Al is related to surface recombination.

Elemental studies using various probes showed the AlInGaN region of sample C to consist spontaneously of an indium-rich core and an 18.5nm-thick predominantly AlGaN shell. Similar results were found for the other samples. The AlGaN shell provides a barrier against carrier migration to surface recombination states.

The researchers explain the spontaneous formation of the core-shell structure as being due to different diffusion and desorption properties of indium, gallium and aluminium. Indium in particular desorbs more easily than the other species of atom. "The desorbed In atoms cannot be immediately compensated by impingent atoms, due to the shadowing effect of neighboring nanowires," the researchers write. The balance of these properties are also dependent on temperature.

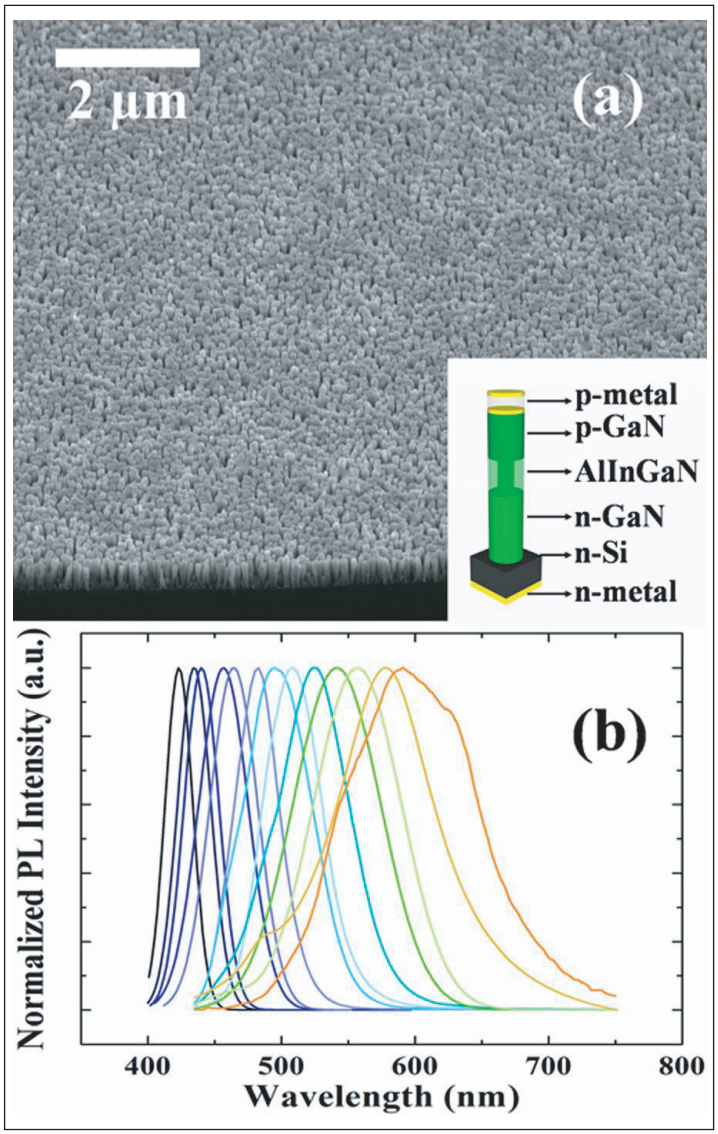


Figure 1. (a) Scanning electron micrograph of AlInGaN core-shell nanowire arrays grown on Si substrate. Inset: schematic of nanowire LED. (b) Normalized photo-luminescence spectra of AlInGaN core-shell nanowires under different growth conditions.

The thickness of the AlGaN shell correlated with lifetime. Sample A with a low Al flux had a thin shell and correspon-

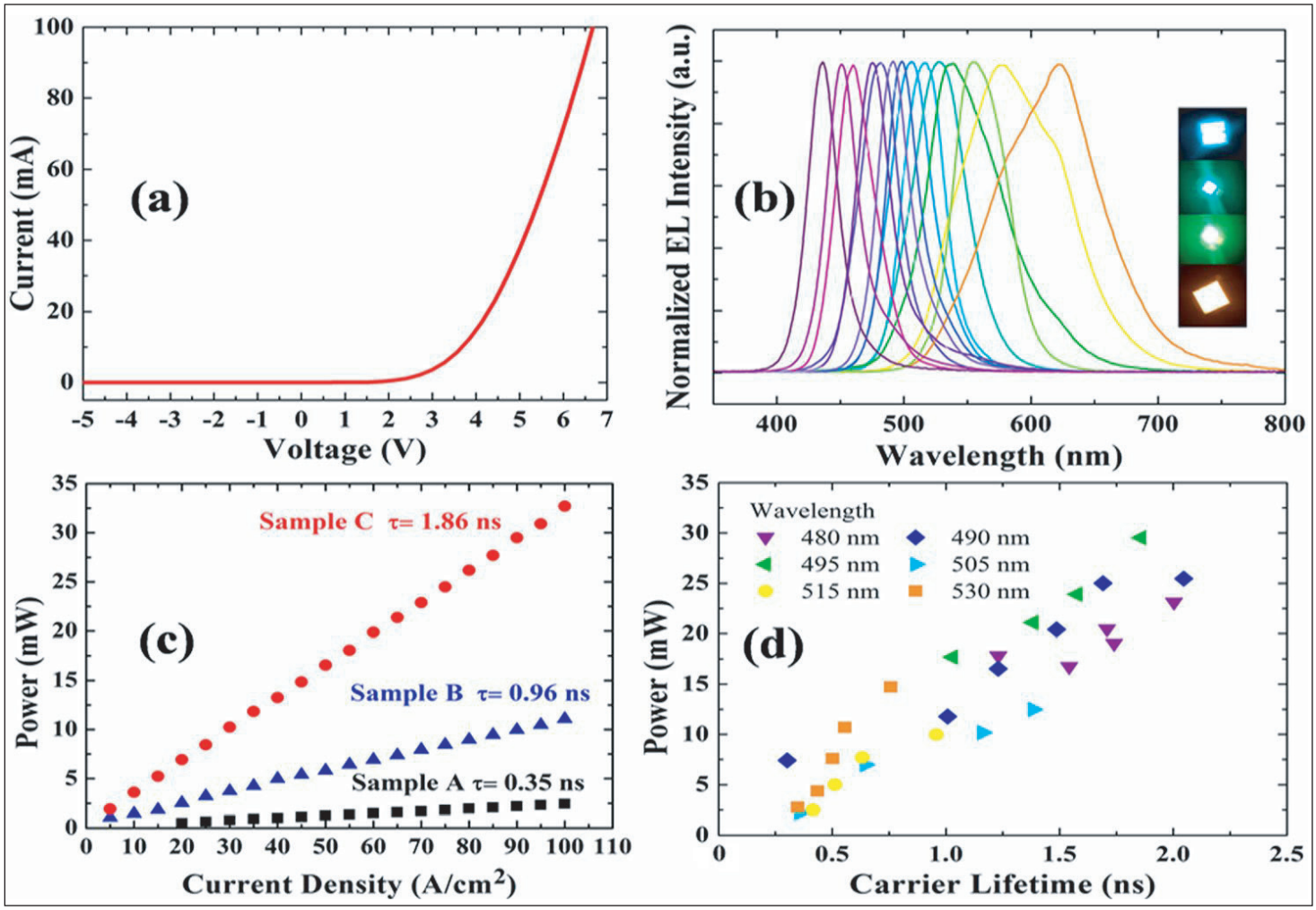


Figure 2. (a) Current–voltage characteristics of representative AlInGaN nanowire LED on Si. (b) Normalized electroluminescence spectra of AlInGaN core-shell nanowires LEDs grown under different conditions. Inset: electroluminescence images. (c) Light output power of 1mmx1mm AlInGaN LEDs versus injection current — τ = carrier lifetime. (d) Variations of output power under injection current of 90A/cm^2 versus carrier lifetime.

ding short lifetime. Sample B had a thicker shell, thanks to the higher Al flux (~13nm), and a longer lifetime.

The researchers add: "It is also worthwhile mentioning some additional advantages of the AlInGaN core–shell nanowire LEDs. The incorporation of Al in the active region can effectively reduce the strain and the associated defect formation. Moreover, the use of relatively thick active regions (70nm) can significantly reduce the carrier density under high-power operation, thereby minimizing non-radiative Auger recombination and hot-carrier effect under high-power operation."

The nanowire material was used to fabricate square LED chips with sides between 0.3mm and 1mm. Contacts were formed on the p-GaN and the back-side of the silicon substrate. The chips emitted at wavelengths between 430nm and 630nm in 1%-duty-cycle pulsed operation at 2°C (Figure 2). The output power was found to increase with carrier lifetime, since there was less non-radiative surface recombination sapping performance.

The researchers comment: "Under an injection current density of 100A/cm^2, an output power of >30mW was measured for Sample C, which is significantly higher than that of previously reported axial InGaN nanowire LEDs."

Unfortunately, aluminium concentrations have to be reduced for longer-wavelength devices, and the carrier lifetime suffers accordingly. In the green range of 530–570nm, the lifetimes were 0.6–0.8ns. For yellow-orange-red devices in the range 580–630nm the lifetimes were further reduced to 0.3–0.5ns. The blue-green devices had lifetimes up to ~2ns. ■

http://dx.doi.org/10.1063/1.4923246

Author: Mike Cooke

Table 1. Growth conditions and characterization results for representative AlInGaN segments.

Sample	BEP_{Al} (x10^{-9} Torr)	BEP_{In} (x10^{-7} Torr)	T_{sample} (°C)	Wavelength (nm)	τ (ns)
A	3.54	1.25	625	515	0.35
B	5.70	1.38	635	515	0.96
C	10.7	2.06	670	495	1.86

Electrochemical potentiostatic activation of p-gallium nitride

Technique can selectively break up magnesium-hydrogen complexes that block acceptor ionization.

Researchers in South Korea have used electrochemical potentiostatic activation (EPA) to alter the hydrogen content in p-type gallium nitride (GaN) layers with a view to improved performance of light-emitting diodes (LEDs) [June Key Lee et al, J. Appl. Phys., vol117, p185702, 2015].

Activation of p-GaN is difficult. Present thermal annealing methods generally release holes from about 10% of the magnesium acceptors used for the doping. Poor hole injection reduces the efficiency of GaN-based LEDs.

The presence of hydrogen is difficult to avoid, particularly in metal-organic chemical vapor deposition (MOCVD) where the organic component of precursor molecules such as trimethyl-gallium ($Ga(CH_3)_3$) contain hydrogen. Also, the nitrogen source is typically ammonia (NH_3).

The team from Chonnam National University, Korea Photonics Technology Institute (KOPTI) and Chonbuk National University believes there are two main forms of hydrogen incorporation in p-GaN layers (Figure 1): magnesium-hydrogen (Mg-H) complexes and hydrogen interacting in various ways with nitrogen defects (Ga-H).

The Mg-H complexes are believed to form during the cooling process after MOCVD. Removing hydrogen from the Mg-H complexes should release holes, giving improved p-type performance.

The Ga-H family involves nitrogen vacancies that act as electron sources, giving undoped GaN an n-type character. The binding of hydrogen passivates the vacancy, holding the electron in place. Such Ga-H passivation occurs during epitaxial growth.

The electron donor aspect of nitrogen vacancies increases with Mg-doping, compensating hole generation: undoped GaN has electron densities of ~10^{17}/cm^3, while Mg-doped GaN has compensating donor densities in the range 1x10^{18}/cm^3–4x10^{19}/cm^3.

The activation energy of the donors is less than 100meV, which compares with Mg acceptor activation energies of 170meV. So while many of the donors are activated, only around 10% of the Mg sites are ionized to give free holes.

The Chonnam/KOPTI/Chonbuk team studied simple two-layer and complex LED epitaxial structures. The simple structure consisted of 1μm undoped GaN and 1μm magnesium-doped p-GaN produced on sapphire using MOCVD. LED materials for 385nm ultraviolet and 455nm blue wavelength radiation were also used to create LEDs. These MOCVD materials came from the group's previous work and commercial sources.

EPA for 5 minutes using 1.0M hydrochloric acid electrolyte was found to be more effective in removing hydrogen, compared with a 10 minute anneal at 600°C in nitrogen (Figure 2). Varying the voltage up to 7V gave up to 59% reduction in hydrogen. With 10 minutes of EPA at 5V, the reduction was 63%.

Performing EPA for 10 minutes at 9V on the 450nm epitaxial wafer reduced the hydrogen content of the p-GaN layer by 70% more than with standard annealing (Figure 2c). The researchers point out that the p-GaN in this case was grown at a low temperature, less than 900°C. Such low-temperature processes are standard, since one does not want to damage the photon-emitting indium gallium nitride (InGaN) multiple quantum wells (MQWs). Standard 700°C annealing processes can remove between 50% and 90% of the hydrogen after 60 minutes.

LEDs with 385nm wavelength increased their output

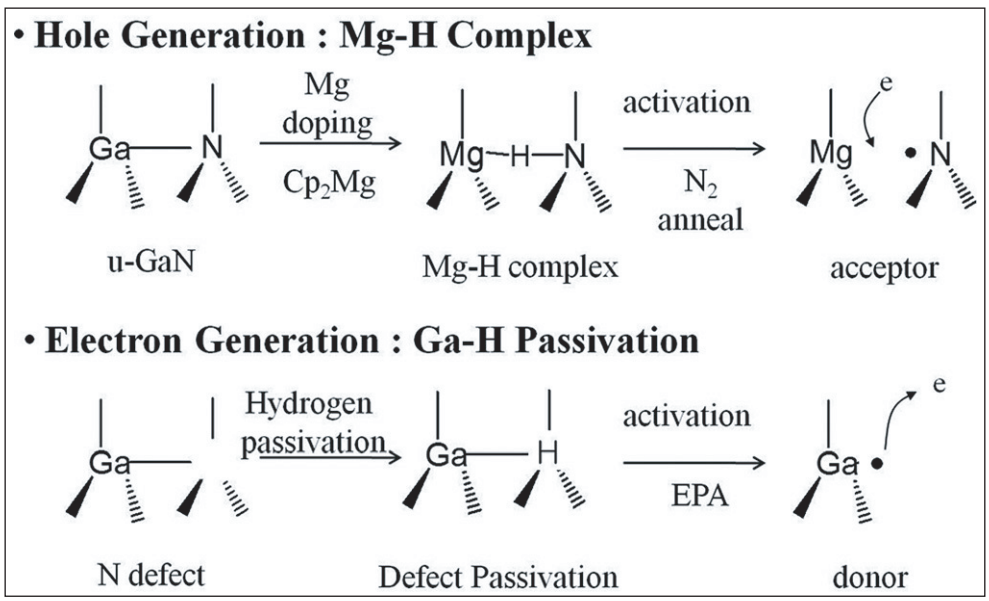


Figure 1. Two types of major hydrogen species inside Mg-doped GaN epilayer. Mg-H complex generates holes if activated, and Ga-H passivation generates electrons if detached.

power from 72mW to 86mW at 50mA after 3V EPA for 5 minutes. The reduction in hydrogen content of the p-GaN layer was estimated to be 32%. However, increasing the voltage to 5V reduced the enhancement, giving only 78mW at 50mA. And 7V EPA actually degraded the performance to 67mW, despite a 59% reduction in hydrogen content of the p-GaN layer.

The team estimates the internal quantum efficiencies (IQEs) at 67% for 3V EPA, 60% for 5V, and 51% for 7V. Thermally annealed material had an IQE of 55%.

The researchers estimate that the concentration of Ga-H sites in their samples are around $10^{18}/cm^3$, the same order of magnitude as the hole carrier density. The UV LED results are interpreted as showing that 3V EPA mainly breaks up the Mg-H complexes, while the 7V EPA largely removes the Ga-H passivation. Another research group has determined that 1.93eV is need to break up the Mg-H complex; the Chonnam/KOPTI/Chonbuk team infers from their results that more energy is needed to deactivate the Ga-H passivation.

The researchers comment: "Selective hydrogen elimination from Mg-H complexes is the key to achieving high-quality p-type GaN epi-layers."

EPA experiments on a commercial 450nm LED wafer with ~85% IQE showed no change in IQE, "which indirectly implies that a similar amount of hydrogen atoms was removed from the Mg-H complex and Ga-H passivation", according to the researchers.

The team hopes that further EPA process optimization could lead to lower levels of Mg-doping being needed for a given hole carrier density, which should improve crystal quality and performance of the p-GaN layer in LEDs.

The current-voltage behavior of LEDs with EPA or with annealing were similar above 2V forward voltage. However, in the 1–2V region the 7V EPA was an order of magnitude lower. Reverse-bias behavior was improved with EPA – breakdown was delayed by about 5V and the leakage at 10V was about an order of magnitude lower.

The improved electrical properties also gave increased robustness against external electric stress — the lifetime at 20mA injection was 1000 hours, slightly better than for conventional annealing; electrostatic discharge testing of conventional annealed devices degraded significantly after 3x 1-second 1000V pulses, while EPA LEDs retained their performance characteristics up to 3500V stressing. ■

http://dx.doi.org/10.1063/1.4920927

Author: Mike Cooke

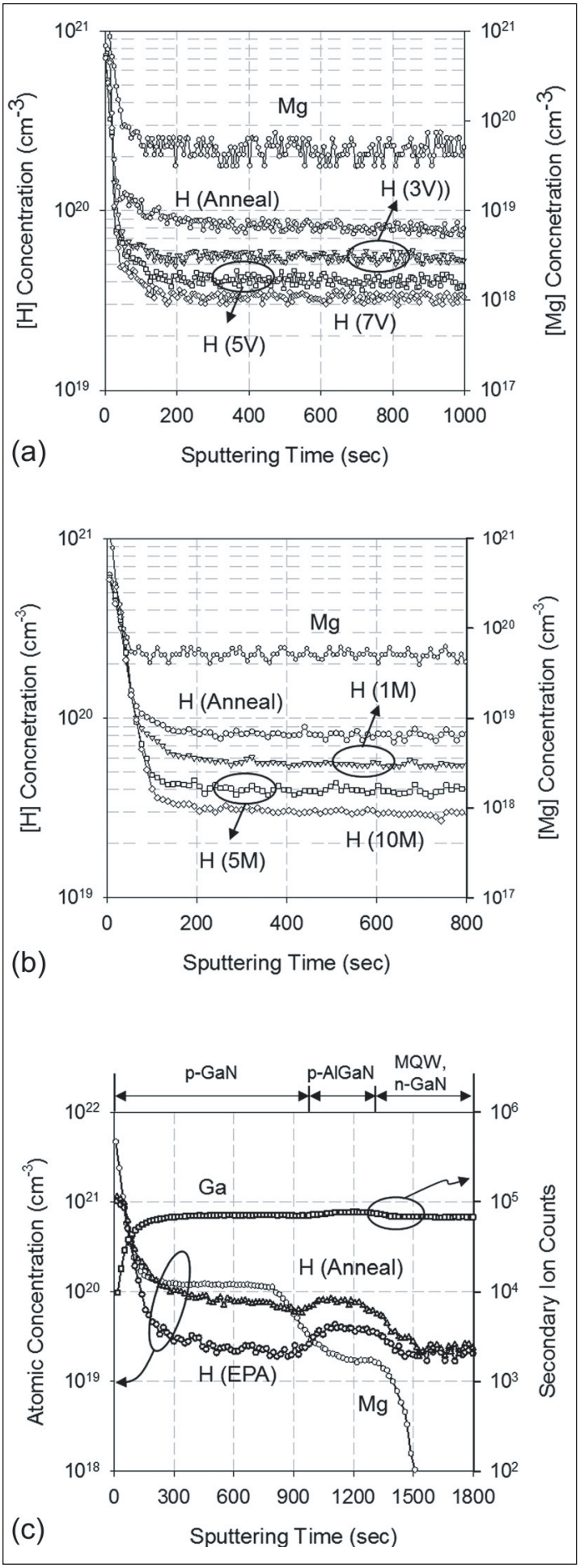


Figure 2. (a) Secondary-ion mass spectrometer (SIMS) depth profile of hydrogen concentration in p-GaN epilayer after 5 minute EPA, and (b) for conventional anneal and 1-, 5-, and 10-minute 5V EPA. (c) SIMS depth profile of hydrogen concentration in 450nm LED epiwafer for conventional anneal and 10-minute 9V EPA.

Neutral pH electrochemical etching of silicon-doped gallium nitride

Solutions of common salt and sodium nitrate enable etching of pores with and without crystallographic preference.

Yale University in the USA has developed an electrochemical process of porous structures in gallium nitride (GaN) involving neutral pH solutions of common salt (NaCl) or sodium nitrate ($NaNO_3$) [Mark J. Schwab et al, Appl. Phys. Lett., vol106, p241603, 2015]. The researchers comment: "These results open up the possibility of using safe and environmentally friendly etchants for processing GaN films, along with demonstrating crystallographic alignment of pores in anodically etched GaN."

Normally, wet etching of GaN involves acidic or basic solutions that are often extremely toxic. Porous etching could be used in chemical sensor applications.

The researchers developed their etching techniques using GaN templates grown on c-plane sapphire via metal-organic chemical vapor deposition (MOCVD).

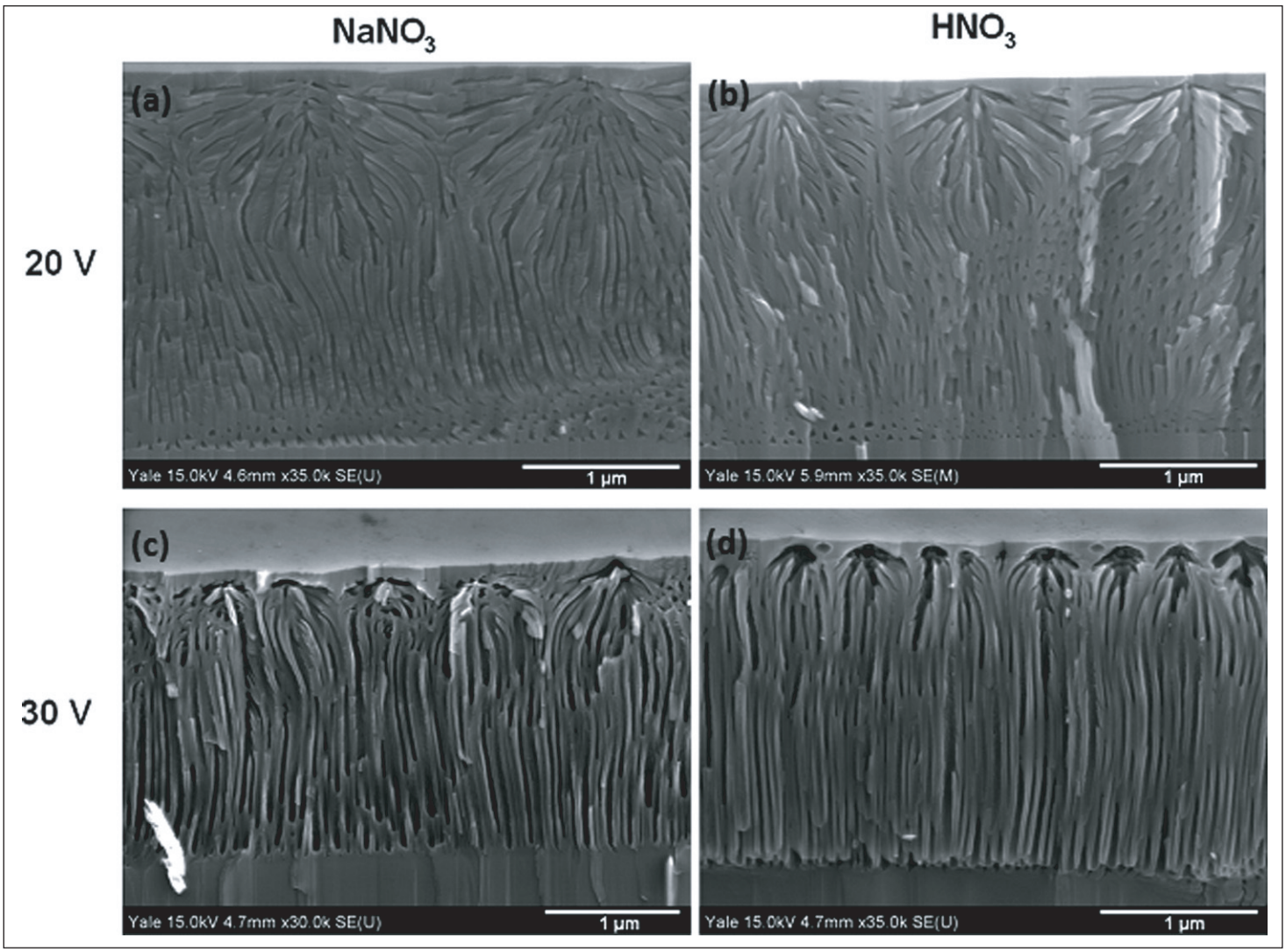


Figure 1. Angled cross-section views of films etched at (a) 20V in $NaNO_3$, (b) 20V in HNO_3, (c) 30V in $NaNO_3$, and (d) 30V in HNO_3. The films etched at 20V show highly branching pores, while films etched at 30V display vertically aligned pores beneath nucleation layer.

The GaN layers consisted of an unintentionally doped buffer and 2μm of silicon-doped n-type material. The wafers were diced into 1.5cmx0.5cm chips.

The electrochemical etching solutions were 0.3M $NaNO_3$ or 3M NaCl. A 0.3M nitric acid (HNO_3) solution was also used for comparison with $NaNO_3$ etching. The $NaNO_3$ and HNO_3 solutions were used to etch layers with $3x10^{18}/cm^3$ doping density. The NaCl was used on more heavily ($2x10^{19}/cm^3$) doped GaN.

The GaN was electrically connected through a metallic tape electrode. The counter-electrode was a platinum wire cathode. The bias was applied before the samples were lowered at 1cm/minute into the etching solution. The aim of the 45 second dipping stage was uniform etching of the sample. Including the dipping, the sample etch lasted for 2 minutes. An exception was an NaCl etch carried out for 30 minutes with low 6V bias. The etch time was sufficient to fully etch the doped layer, after which the current dropped to near zero.

The etched material consisted of a low-porosity top 'nucleation layer' near the top surface from which the pores branch out (Figure 1). The researchers comment: "This nucleation layer is left largely intact because etching accelerates in the vicinity of the initial etch pits due to the enhancement of the electric field from the radius of curvature."

The density of pore mouths for $NaNO_3$ was significantly lower than for HNO_3 etching (Table 1). However, the pore density deep within the GaN was about the same for these etchants. Other etching characteristics were also largely similar for $NaNO_3$ and HNO_3 etching.

Although previous reports of chemical etching suggested the gallium product was Ga_2O_3, this is not soluble in a neutral pH context. The researchers suggest a different reaction product — $Ga(NO_3)_3$, which is soluble.

The NaCl etch was preferential along certain crystallographic directions at the low bias of 6V, unlike the $NaNO_3$ etch, which proceeds in the direction of the current (Figure 2). The researchers explain: "The walls of these triangular pores are oriented at 58° to the (0001) plane, which indicates that the {10−1-1} family of planes is resistant to etching in NaCl. The {10−1-1} planes are polar and have previously been noted to act as etch-terminating planes in photo-chemical etching of GaN, photo-electro-chemical etching, and hot-wet chemical etching."

Table 1. Density of pore mouths at various etch conditions.

	$NaNO_3$	HNO_3
20V	$3.6x10^7cm^2$	$1.1x10^8cm^2$
30V	$4.2\ x10^8cm^2$	$5.5x10^8cm^2$

Even at higher biases, the NaCl etch has a crystallographic preference. The researchers suggest that the chlorine atoms passivate {10-1-1} facets, inhibiting further etch in that direction.

The neutral pH etch could be extended in various ways, such as employing the technique on layers with different doping levels or using a low ~3V bias in combination with ultraviolet illumination. The latter photo-electro-chemical etching could also be combined with photoresist masking for selective processes.

The researchers report: "It has also been shown that selective etching is possible by growing GaN films with different layered doping levels, and using conductivity-selective etching to etch away highly doped layers while leaving the low-doped layers intact, giving the ability to create devices such as cantilevers and distributed Bragg reflectors." ■

http://dx.doi.org/10.1063/1.4922702

Author: Mike Cooke

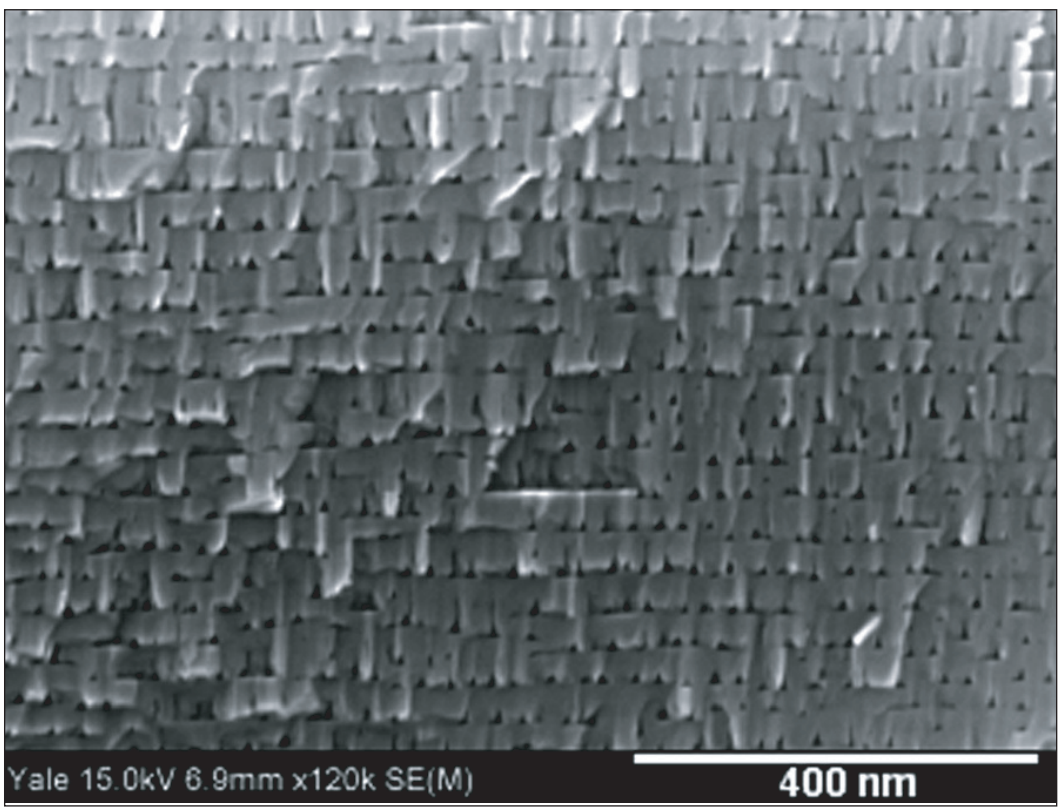


Figure 2. Film etched in NaCl at 3M concentration at 6V with $2x10^{19}/cm^3$ doping density. Triangular pores are bounded by {10-1-1} and (0001) planes.

High-temperature recess for normally-on gallium nitride transistors

Researchers claim the highest output power density and power-added efficiency reported to date for enhancement-mode devices.

Researchers in China and Hong Kong have claimed the highest output power density and power-added efficiency reported to date for gallium nitride (GaN)-based enhancement-mode metal-insulator-semiconductor high-electron-mobility transistors (MIS-HEMTs) at 4GHz and in pulsed-mode [Sen Huang et al, IEEE Electron Device Letters, published online 15 June 2015].

Enhancement-mode or 'normally-off' devices are desired for radio frequency (RF), microwave and power applications, giving fail-safe operation and simpler gate control. Unfortunately, without special processing, GaN HEMTs tend to be 'normally-on'/depletion-mode.

Gate recessing and the addition of a gate dielectric can produce enhancement-mode devices with high transconductance and low gate leakage. Gate recessing requires some form of etch, which can introduce lattice damage. Also, the etch process can leave residues. Both these factors can introduce electron trap states that negatively impact performance.

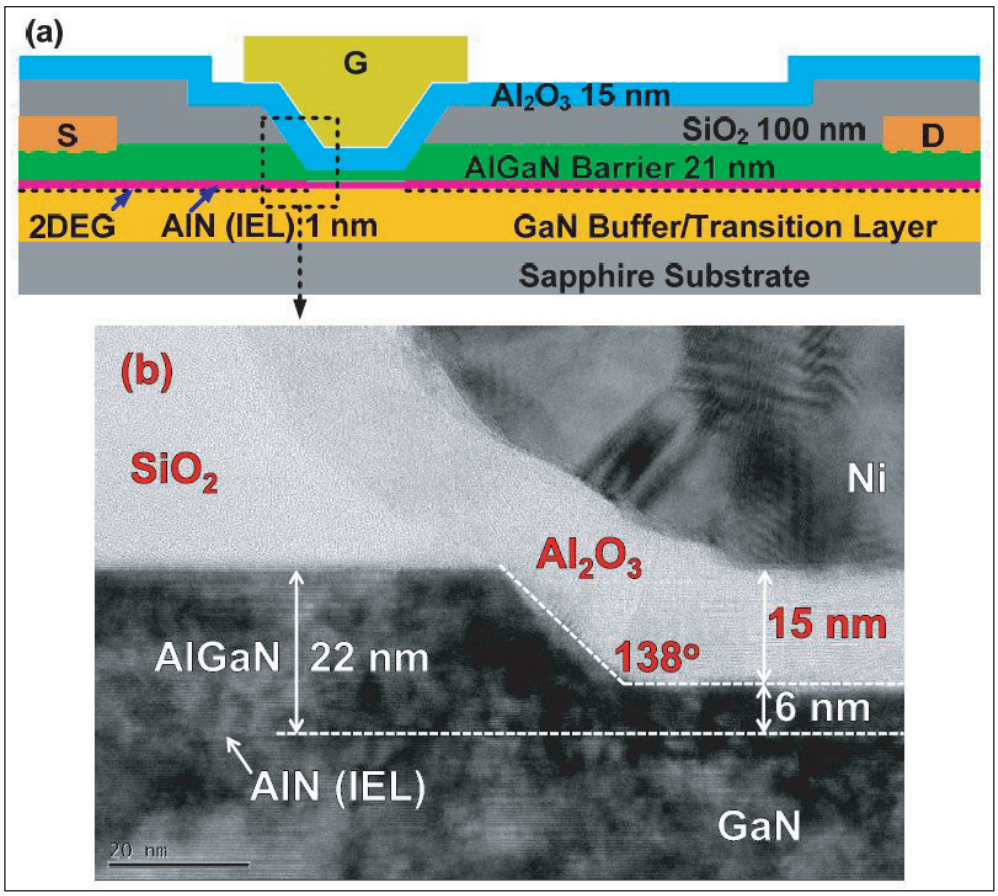


Figure 1. (a) Schematic device structure of E-mode $A_{l2}O_3$/AlGaN/GaN MISHEMTs. (b) TEM cross-sectional view of gate edge of E-mode MISHEMTs with gate recessed at 180°C.

The team from Chinese Academy of Sciences' Institute of Microelectronics, Xidian University, and Hong Kong University of Science and Technology (HKUST) have developed a high-temperature plasma etch that removes residues and recovers lattice damage.

The epitaxial material for the device (Figure 1) was grown by metal-organic chemical vapor deposition (MOCVD) on sapphire. The 21nm $Al_{0.25}Ga_{0.75}N$ barrier was grown on a 1nm AlN interface enhancement layer on GaN buffer. The sheet resistance of the AlGaN/GaN heterostructure was 310Ω/square (1980cm^2/V-s mobility).

The ohmic source-drain contacts were fabricated with titanium/aluminium/nickel/gold metallization, annealed at 870°C in nitrogen for 50 seconds. Passivation and etch masking was provided by 100nm silicon dioxide from plasma-enhanced chemical vapor deposition (PECVD).

Gate recessing was performed after mesa isolation. The low-RF-power mixed chlorine/boron trichloride inductively coupled plasma (ICP) etch for the gate recessing was performed at 180°C. "The high temperature enables effective desorption of chlorine-based etching residues, e.g. $AlCl_3$, $GaCl_3$, and NCl_3," the researchers explain. The recess depth was about 16nm

into the AlGaN barrier.

The recessed gate region was covered with 15nm aluminium oxide gate dielectric from a thermal-mode 300°C atomic layer deposition (ALD). The precursors were trimethylaluminium and water/ozone. The water precursor was used for the first 2nm and the ozone for the remaining 13nm. The use of the water precursor avoided oxidation of the AlGaN barrier. A post-deposition anneal was carried out at 500°C for 1 minute in nitrogen.

The gate electrode was nickel/gold with 1μm length, 100μm width, and 1μm overhangs toward the source and drain electrodes. The gate–drain and gate-source separations were 3μm and 2μm, respectively.

Devices produced with the high-temperature (HT) recess process have similar threshold voltages compared with MISHEMTs from room-temperature (RT) recessing. However, the HT-MISHEMTs have smaller hysteresis in double-mode characteristics, suggesting "significant suppression of deep interface/bulk traps". The OFF-state standby power for the HT-MISHEMT was 6x10-8W/mm for 0V gate and 30V drain.

In small-signal RF measurements on the HT-MISHEMT at 10V drain bias and 2.5V gate, the current-gain cut-off (f_T) was 7.6GHz and the unit power gain (f_{max}) came at 27GHz. The maximum values for the RT device were 5.4GHz and 14.9GHz.

Pulsed operation at 7V gate gave 1.13A/mm drive current for the HT device, while the RT-MISHEMT could only manage 0.42A/mm (Figure 2). The researchers comment: "The pulsed currents are much higher than the corresponding dc output current in both devices. There may be some trapping mechanisms other than self-heating effect that is responsible for the degradation of IDmax, and these trapping processes only appear in quasi-static dc measurement."

The current collapse effects are small at quiescent drain biases below 40V, but are large at 60V. The researchers comment: "It is probably caused by oxidation-induced deep interface states (at the PECVD-SiO_2/AlGaN and/or ALD-Al_2O_3/AlGaN interfaces)." They also believe that the interface properties could be improved with crystalline AlN passivation.

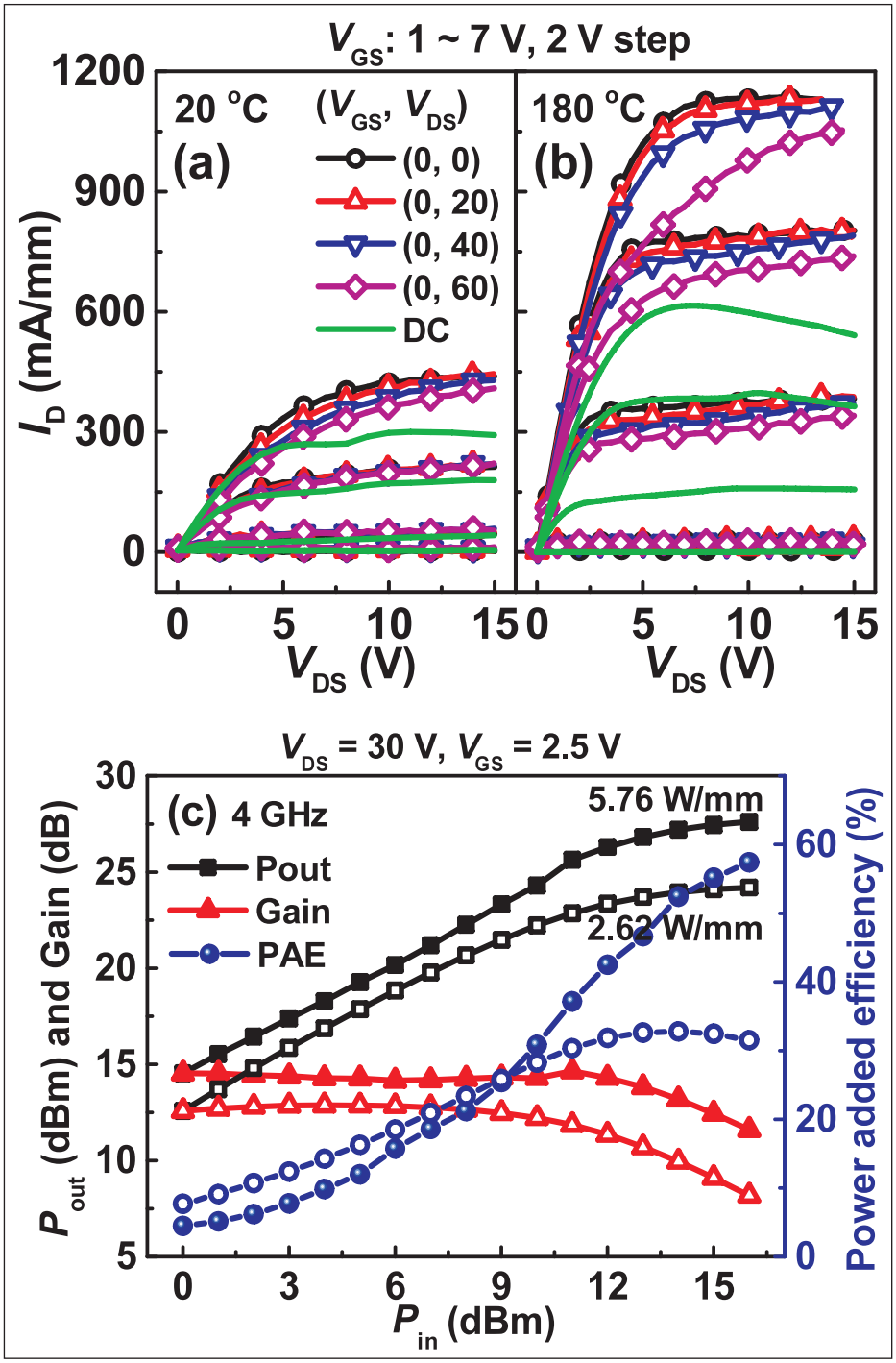


Figure 2. Pulsed ID-VDS characteristics of E-mode $A_{l2}O_3$/AlGaN/GaN MISHEMTs with gate recessed at 20°C (a) and 180°C (b). (c) ON-wafer large-signal RF characteristics (4GHz) of E-mode MIS-HEMTs with gate recessed at 180°C (solid symbols: pulse-mode; open symbols: continuous-wave).

Large-signal 4GHz RF power performance was measured with class AB biasing. Output power was 5.76W/mm at the 3dB compression point in pulsed mode. In continuous-wave operation, the output was 2.62W/mm, compared with 1.05W/mm for the RT-MISHEMT. The power-added efficiencies for the HT-MISHEMT were 33% for continuous wave and 57% in pulsed mode. ■

http://dx.doi.org/10.1109/LED.2015.2445353

Author: Mike Cooke

Substrates for III-nitride vertical power electronic devices

Researchers have in the past few years been exploring the potential advantages of vertical over lateral devices. Mike Cooke reports.

Gallium nitride's wide bandgap has enabled light-emitting diodes (LEDs) to achieve short-wavelength blue and near-ultraviolet radiation for more than 20 years. The material's wide bandgap of 3.4eV also implies a higher critical field, which raises the possibility of creating a range of high-voltage and power devices, and some gallium nitride (GaN) transistors and diodes have become available commercially.

These devices tend to use lateral structures to create high-electron-mobility transistors and Schottky diodes. Lateral structures suffer from a number of reliability and integration challenges

At the heart of such devices is current flow in a 'two-dimensional electron gas' (2DEG) that forms near an interface between GaN and an even wider-bandgap material such as aluminium gallium nitride (AlGaN) or aluminium indium nitride (AlInN) due to different charge polarization properties of the chemical bonds. Of course, the confined electron gas is not truly two-dimensional, but it is restricted to a very thin layer, constricting the amount of flow that can be achieved in small devices.

Vertical devices could be able to handle higher voltages and current with a smaller footprint. Also, vertical devices should benefit from a structure where the peak field is away from the surface of the diode, along with better thermal performance.

A possible drawback is current leakage and breakdown along threading dislocations and other defects. Hence, the performance of vertical devices tends to depend on the substrate used for growth of the GaN and other III-nitride layers. One expects bulk and free-standing GaN substrates to result in lower leakage compared with alternatives due to the lower defect generation in growth with zero lattice mismatch. (Free-standing GaN is grown in a thick layer on a non-GaN substrate that is removed.) The disadvantage of bulk and free-standing GaN is much higher cost than material grown on sapphire or, especially, silicon (Si).

A number of groups have started exploring the vertical option, and a number of reports have been made since the beginning of this year. These include both transistors [e.g. Semiconductor Today, p90, June/July 2015] and diodes. Here, we report on recent work on diodes on different growth substrates. We also report the first claim of Schottky barrier diode (SBD) fabrication on aluminium nitride (AlN) with a bandgap of 6.1eV, almost twice that of GaN at 3.4eV.

Bulk

Avogy Inc of San Jose, CA, USA has used bulk GaN substrates to create vertical p-n diodes with breakdown voltage of more than 4kV and area-differential specific on-resistance of less than 3mΩ-cm^2 [I.C. Kizilyalli et al, IEEE Electron Device Letters, published online 9 September 2015].

The company is developing GaN-on-GaN technology aiming to produce discrete semiconductor devices, modules and systems that increase efficiency and reliability of power conversion while reducing cost, size and weight.

Increasing breakdown to 4kV brings potential application for ship propulsion, rail, wind power, uninterruptable power supplies (UPS), geothermal instrumentation, high-voltage multipliers, military power supplies, and the power grid, according to the researchers.

Avogy has begun with p–n junction devices as a first step towards the realization of more complex vertical junction field-effect transistors (JFETs) and junction barrier Schottky (JBS) diodes, which have lower turn-on voltages (<1V) and lower conduction losses.

The epitaxial structures were grown by metal-organic chemical vapor deposition (MOCVD) on 2-inch bulk GaN substrate with very low threading dislocation density of 10^4/cm^2. "This is four orders of magnitude lower than for GaN films grown in the conventional manner on non-native substrates," according to the researchers.

The researchers designed the edge termination, n-type drift layer and thickness to achieve junction breakdown around 5kV. In particular, the edge termination spread the anode potential to a distance that exceeded the

drift layer thickness by a factor of about 4.5. The edge termination involved two implant steps.

The net doping density of the 40μm drift layer was 2–5x10^{15}/cm^3. "Controlling the doping of GaN to these levels by MOCVD is challenging since it is at or below the level of typical unintentional background impurities, particularly carbon," the researchers comment.

The p-region of the diode consisted of heavily magnesium-doped GaN deposited on the drift layer. The contacts were palladium/platinum.

The researchers have found that nominally c-plane oriented devices with a slight inclination towards the m-plane are optimal for reverse leakage performance and reliability. The inclination is achieved by mis-cutting by several tenths of a degree to encourage step-flow growth, avoiding the formation of screw dislocations.

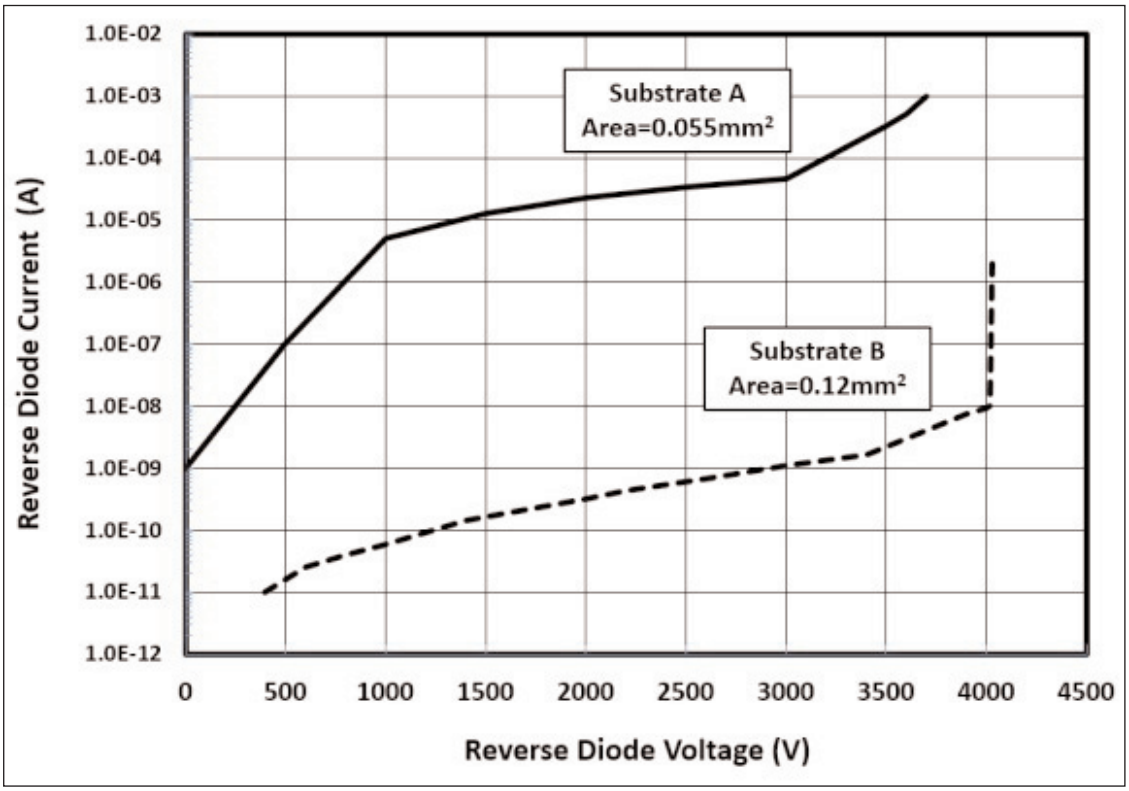


Figure 1. Reverse characteristics at 300K of GaN p-n diodes on optimized substrate B and comparison devices on unoptimized substrate A.

Spiral growth around screw dislocations leads to unwanted large hexagonal hillocks on the GaN surface in on-axis deposition. White-light interferometry gave a mean roughness of less than 20nm over a 1mmx1mm area for an optimized substrate (B), compared with more than 50nm for a sample with lower mis-cut angle (A).

The researchers report: "The implementation of the improved substrate specification results in a marked improvement in the reverse leakage and the first demonstration of a breakdown voltage exceeding 4kV in GaN vertical p–n diodes [see Figure 1]." Last year, Avogy researchers reported devices with breakdowns up to 3.5kV and leakage about 10μA through a 0.055mm^2 effective area.

The team believes that further improvement of the edge-termination should lead to 5kV breakdown. The researchers calculate the field in the drift region at 2.0–2.7MV/cm at breakdown, well short of GaN's critical field of ~5MV/cm. They conclude that the breakdown occurs in the edge termination.

The turn-on voltage is around 3.0V, consistent with GaN's bandgap of 3.4eV. The effective device area was 250μm x 500μm, as defined by the edge-termination implants. The device can handle up to 1A without substrate thinning or packaging.

In 30ms-pulsed quasi-DC operation, the area differential specific on-resistance was 2.3mΩ-cm^2 at room temperature. An increase in resistance with temperature was attributed to reduced electron mobility.

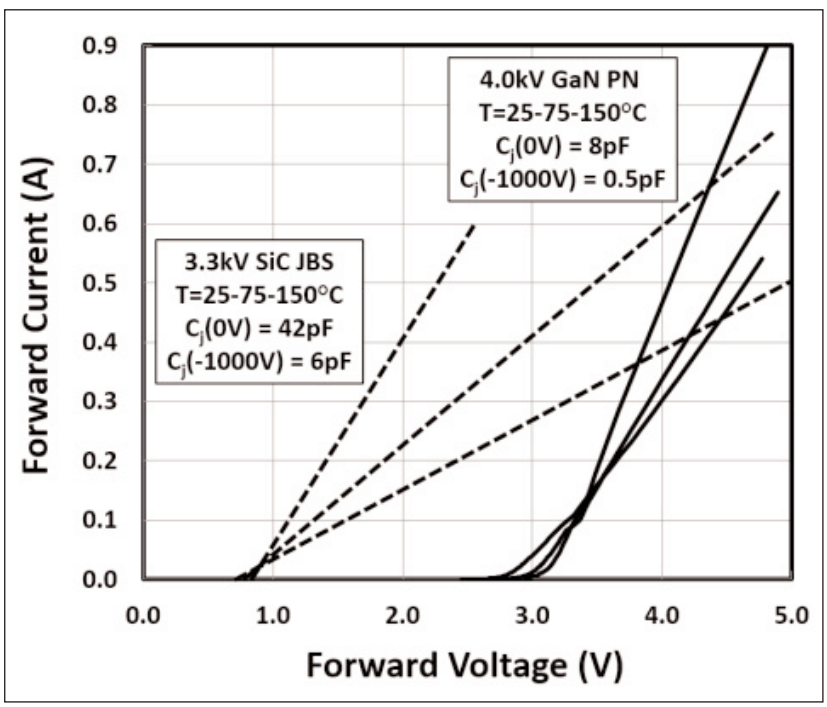


Figure 2. Forward current-voltage characteristics of 4kV GaN p-n diode and 3.3kV SiC JBS diode (dotted line) at 25–75–150°C.

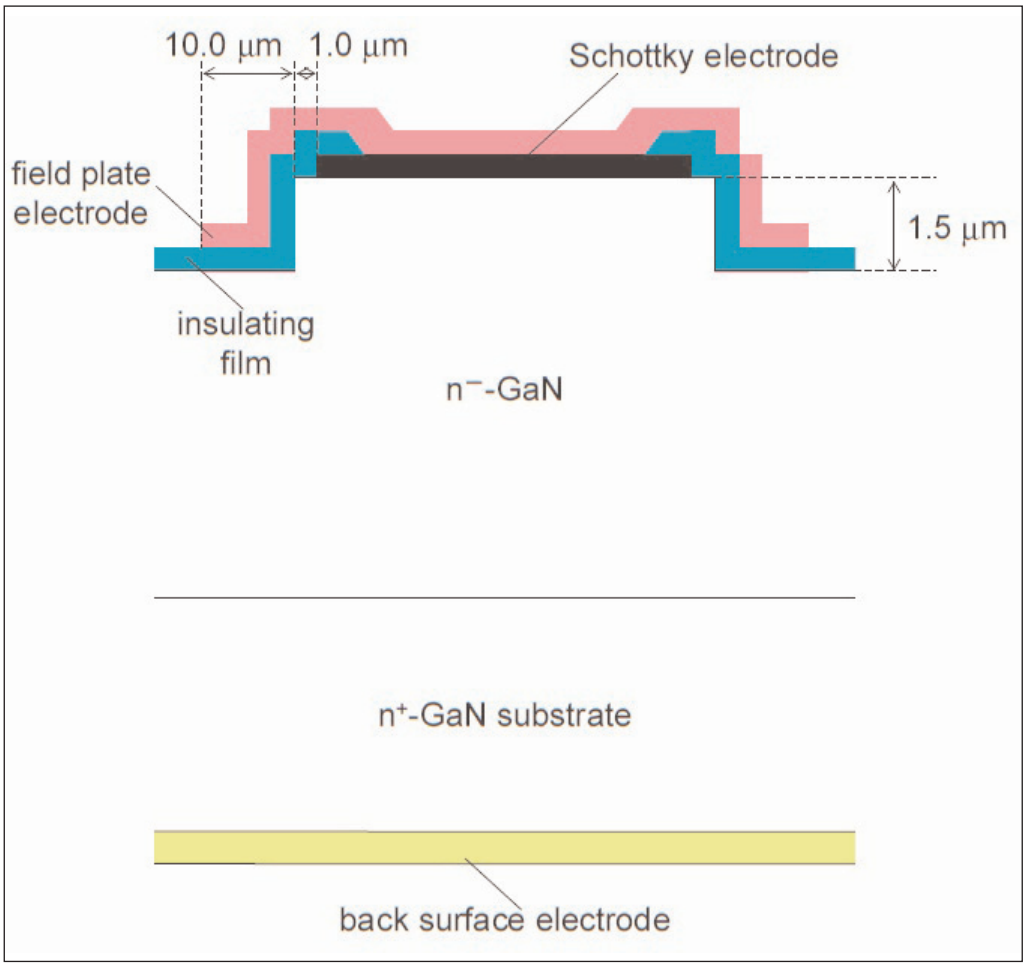


Figure 3. Vertical GaN SBD.

The researchers compared the performance with silicon carbide junction barrier Schottky (SiC JBS) diodes (Figure 2). The junction capacitance of the GaN device was much lower, suggesting lower switching losses.

Avogy has licensing and supply agreements with multiple GaN substrate vendors. The company's equipment base consists of sub-micron lithography, multiple MOCVD reactors, device fabrication, and a full suite of electrical testing and metrology tools. Cleanroom facilities cover 3500ft^2 in a 27,000ft^2 facility.

Free-standing

Japan's Toyoda Gosei Co Ltd has made a number of reports on vertical GaN devices in recent months. These have involved both transistors [Semiconductor Today, p88, June/July 2015; Semiconductor Today, p94, April/May 2015] and diodes. Most recently, the company research team has reported Schottky barrier diodes (SBDs) capable of handling 50A forward current with 790V reverse blocking [Nariaka Tanaka et al, Appl. Phys. Express, vol8, p071001, 2014].

"To our knowledge, the characteristics of operation with a simultaneous high forward current and high blocking voltage are reported for the first time for vertical GaN SBDs on free-standing GaN substrates," the researchers comment.

Toyoda Gosei sees potential applications of high-power GaN rectification and switching in power control units in hybrid cars and for solar power conversion. The company has developed GaN technology for light-emitting diodes since 1986 and began research into GaN power electronics in 2010. Toyoda Gosei's main business is supplying automotive parts, although it also has divisions for LEDs and general industry products (e.g. telecoms, air conditioning, home construction).

MOCVD was used to create a 10µm lightly doped n$^-$-GaN layer on commercially available free-standing heavily doped n$^+$-GaN substrate. The SBD (Figure 3) consisted of mesa isolation, nickel Schottky anode, insulating film, aluminium-based field-plate, and aluminium/titanium back-contact cathode. The insulating film was 500nm of silicon dioxide and 100nm of aluminium oxide. The field-plate was designed to relieve potential crowding at the edge of the Schottky electrode. Potential crowding increases leakage current and reduces blocking voltages.

A 3mmx3mm device managed a 50A forward current with a bias of 2.05–2.25V. The researchers expect that higher currents can be achieved, since their equipment was limited to 50A. The differential on-resistance above 20A was 25–29mΩ. Since this value was very close to estimates based on the resistivity of the GaN material, the researchers believe the contact resistance of the back-electrode was negligible.

The blocking voltage under reverse bias was 730–790V. Repeat measurements showed the breakdown to be non-catastrophic. The researchers believe the combination of high forward current and high reverse blocking to be a first for vertical SBDs on free-standing GaN.

The reverse blocking was about 200V short of a simple prediction based on thermionic field emission theory. The researchers comment that the difference could be due to potential crowding at the Schottky electrode edge, dislocations, or a combination of the two.

Experiments with different area Schottky diodes showed the forward current density behavior with respect to voltage up to 0.5V to be very similar down to 200µm dimensions. The Schottky barrier height was estimated to be 1.01–1.02eV and the ideality was 1.01, according to the thermionic emission model.

The reverse current density versus voltage was also similar across the different area SBDs. Since the higher-than-expected reverse leakage was thought to be due either to potential crowding or dislocations in the bulk material, the researchers tried to disentangle the effect by seeking the behavior of the leakage according to the perimeter (edge) or area (bulk) of the device. In particular, the leakage at 400V reverse bias was plotted against the perimeter-to-area ratio (Figure 4). Since the effect of the perimeter was small, the researchers concluded that perimeter current was small compared with the bulk current.

The researchers believe that improving the n^--GaN growth process will enable the achievement of higher reverse blocking voltage combined with the same high forward current.

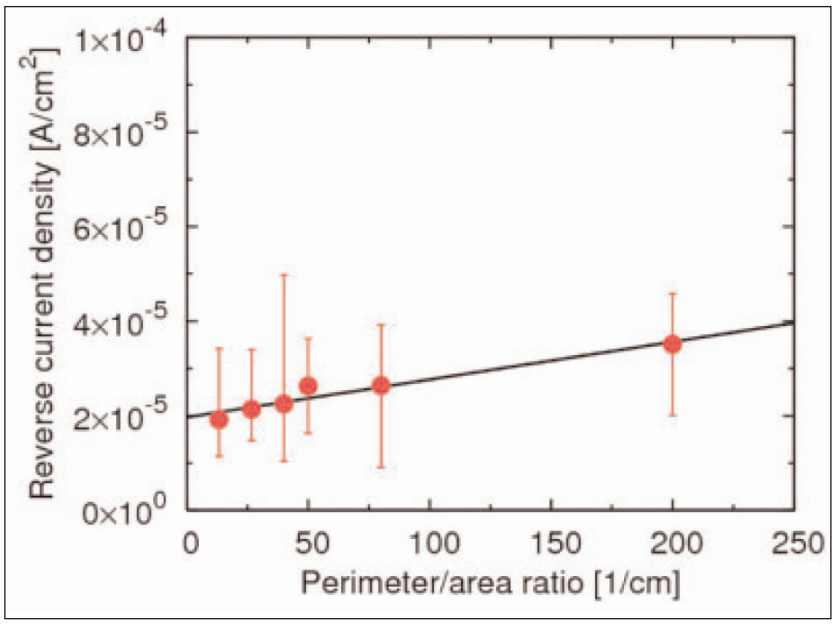


Figure 4. Reverse current density at 400V as a function of perimeter/area ratio.

Cutting leakage on silicon

Researchers in the USA have developed vertical Schottky and pn GaN diodes on silicon with performance comparable to devices grown on much more expensive substrates [Yuhao Zhang et al, IEEE Transactions On Electron Devices, vol.62, p2155, 2015].

The researchers from Massachusetts Institute of Technology, and from Synopsys Inc and Applied Materials–Varian, worked in particular to reduce reverse leakage currents from a number of sources.

The heterostructures for the Schottky and pn diodes (Figure 5) were grown on (111) Si using MOCVD. The devices were fabricated by etching 1.6μm cathode electrodes from the top GaN layers, and depositing cathode and anode ohmic contacts, 200nm silicon nitride passivation and field-plates. Titanium/aluminium were used for the cathode contact ring and field-plates. The circular anode contact consisted of nickel/gold.

The researchers investigated four possible routes of current leakage: "(1) through the transition layers and Si substrate; (2) through the drift layer; (3) along the etch sidewall; and (4) through the passivation layer."

Tests with trench structures suggested that leakage path 1 was negligible. Also, improvements in the silicon nitride passivation at MIT have reduced path 4 currents to a similarly negligible level. The improvement involves using sputtering rather than plasma-enhanced chemical vapor deposition (PECVD) [Semiconductor Today, p72, June/July 2015].

Inductively coupled plasma (ICP) etch damage (giving defects such as nitrogen vacancies) tends to lead to leakage through path 3. Such etches can change a p-GaN surface into a depleted or n^--GaN region, giving reverse bias leakage.

To overcome the etching problem, an edge-termination process was developed to repair dry etch damage that combined carbon tetrafluoride or nitrogen plasma

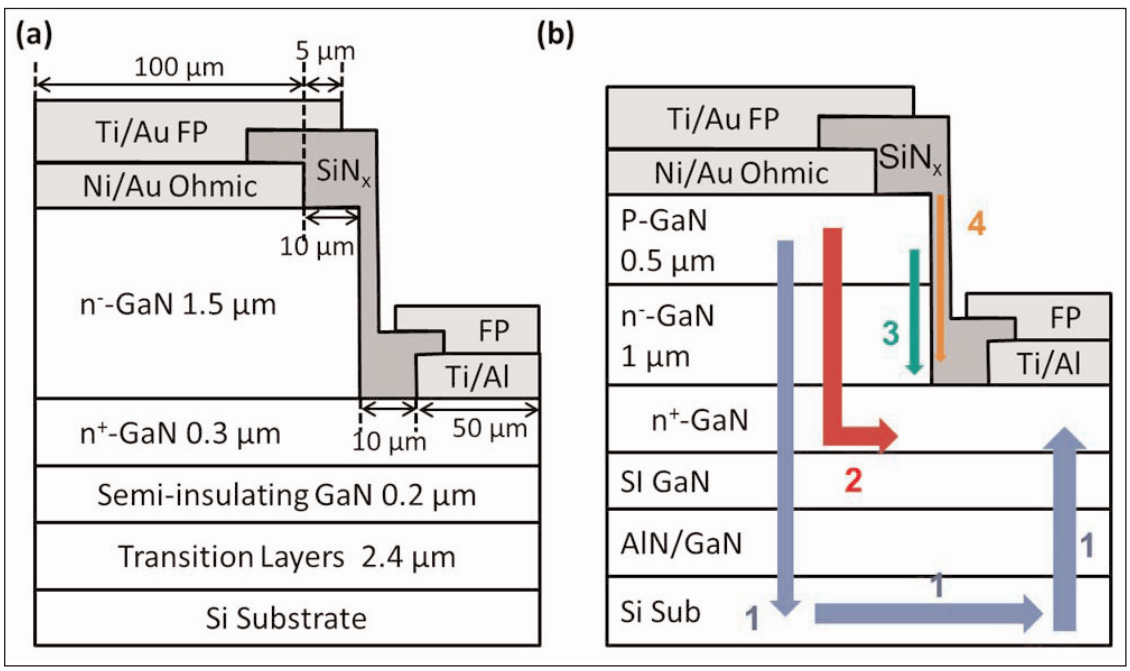


Figure 5. Schematic of GaN-on-Si vertical (a) Schottky and (b) p-n diodes. Four possible leakage paths in GaN-on-Si vertical diodes are shown in (b).

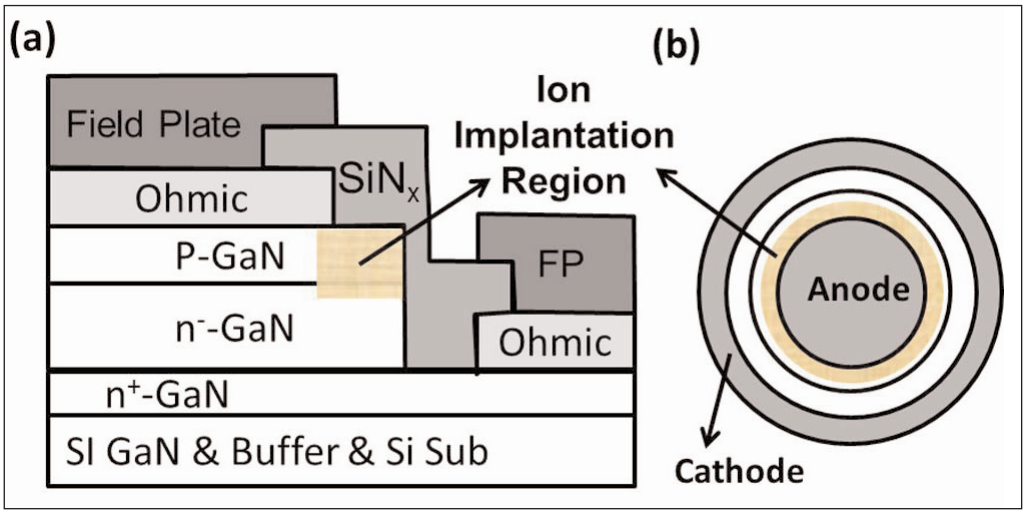


Figure 6. (a) Cross section and (b) top view of the GaN-on-Si vertical p-n diodes with ion implantation regions as edge termination.

treatment, tetramethylammonium hydroxide (TMAH) wet etching, and argon ion implantation. The ion implantation ring isolated the main vertical current from the etch sidewall (Figure 6).

By creating diodes of various diameters, the researchers concluded that the edge-termination process effectively suppressed leakage through path 3, leaving bulk leakage through path 2 as the main contributor.

The reverse leakage in the enhanced pn diodes was reduced by two orders of magnitude, while maintaining a soft breakdown voltage of more than 300V (peak field estimated at more than 2.9MV/cm). The 300V soft breakdown performance is close to the theoretical maximum for a 1.5μm-thick drift layer. Thicker GaN layers should increase the breakdown voltage.

Schottky and pn diodes of 600μm diameter demonstrated forward currents of more than 2A (500A/cm^2) in pulsed measurements with duty cycles up to 1%. The on-resistance for 600μm-diameter Schottky diodes was 6mΩ-cm^2 — for similar pn diodes the resistance was higher, at 10mΩ-cm^2.

The researchers comment: "The relatively high on-resistance of our GaN-on-Si vertical diodes is due to the relatively high contact resistance of ohmic on p-GaN, low mobility of p-GaN (~14cm^2/V-s), and the current crowding near the corner of the etching sidewall. An improvement of the p-GaN material quality is expected to further reduce the on-resistance of our GaN-on-Si vertical diodes."

The researchers compared their device performance with diodes produced on more expensive substrates (Table 1). They comment: "With over 1000x lower substrate cost than the GaN-on-GaN device, our GaN-on-Si vertical devices achieved an off-state leakage current lower than the GaN lateral devices and similar to the one in the state-of-the-art Si and SiC devices."

Aluminium nitride

Researchers based in Japan and USA report fabrication of vertical Schottky barrier diodes (SBDs) on AlN substrates for the first time [Toru Kinoshita et al, Appl. Phys. Express, vol8, p061003, 2015]. The team involved researchers from Tokuyama Corp, Fuji Electric Co Ltd and Tokyo University of Agriculture and Technology of Japan, along with HexaTech Inc and North Carolina State University in the USA.

In addition to its extremely wide 6.1eV bandgap, AlN also has a high thermal conductivity of 3.2W/cm-K, enabling higher power density. The wide bandgap is also attractive for deep-ultraviolet (~200nm) light emission.

One barrier to AlN power electronics is developing n-type conductivity in thick layers so that free-standing substrates can be developed. MOCVD is slow (~1μm/hour). Hydride vapor phase epitaxy (HVPE) is much faster and enables such a development.

The Si-doped AlN HVPE was carried out at 1450ºC on 15mm-diameter highly insulating 10TΩ-cm AlN substrates. The growth substrates were produced in a

Table 1. Leakage and cost benchmarking for the GaN vertical device on different substrates, GaN lateral device, Si and SiC device.

Diode	Leakage current (density) at –200V	I_{on}/I_{off} ratio	Available substrate	Substrate cost per cm^2
GaN-on-Si vertical (this work)	<1μA (10^{-4}–10^{-3}A/cm^2)	~10^6	200mm Si	~$0.08
GaN-on-sapphire vertical	10^{-3}A/cm^2	~10^5	100mm sapphire	~$2.2
GaN-on-GaN vertical	10^{-5}—10^{-6}A/cm^2	~10^9	50mm GaN	~$100
AlGaN/GaN lateral	10^{-2}A/cm^2	~10^5	200mm Si	~$0.08
Si (NTE 588)	5μA	~10^6	200mm Si	~$0.08
SiC (APT6SC60K)	<1μA	~10^6	75mm SiC	~$6
Si power MOSFET (IRHNJ597230)	>10μA (10μA at –160V)	~10^6	200mm Si	~$0.08

physical vapor transport (PVT) process at HexaTech. The Al-polar growth surface was prepared using chemical mechanical polishing (CMP). The average HVPE growth rate was 25μm/hour.

X-ray analysis showed that the crystal quality of the HVPE material was similar to that of the PVT substrate. Secondary-ion mass spectrometry (SIMS) gave uniform values for impurity concentrations of silicon, oxygen and carbon. The silicon concentration of the AlN:Si was $3x10^{17}/cm^3$.

Hall measurements on a 32μm AlN:Si layer resulted in $2.4x10^{14}/cm^3$ net electron concentration, $115cm^2/V\text{-}s$ mobility, and $2.3x10^2\Omega$-cm resistivity. The concentration was the same order as for AlN:Si grown using MOCVD. However, the HVPE mobility was lower than for MOCVD. At the same time, the HVPE dislocation density is estimated to be at least four orders of magnitude lower than for MOCVD. The researchers attribute the counter-intuitive mobility result as being due to a higher number of point defects in the HVPE material.

Temperature-dependent Hall analysis gave a donor density of $2.6x10^{17}/cm^3$, an acceptor density of $1.5x10^{17}/cm^3$, and a donor activation energy of 245meV. The activation energy was similar to values reported for MOCVD AlN. "These results revealed that HVPE can produce AlN:Si layers with n-type conductivity similar to those grown by MOCVD," the researchers write.

Schottky barrier diodes (Figure 7) were fabricated from a 250μm-thick AlN layer, which was subjected to chemical mechanical polishing on the AlN:Si side and mechanical polishing to remove the PVT AlN substrate. The resulting free-standing AlN:Si was 150μm thick.

Annealed titanium/aluminium/titanium/gold on the Al-polar surface was used as the ohmic contact. Several 270μm x270μm Schottky nickel/gold contact electrodes were applied to the N-polar side. The device was mounted ohmic side down on a ceramic AlN carrier with silver paste.

The turn-on voltage was 2.2V. The series resistance was $3.5x10^6\Omega$, much higher than the value expected from the Hall mobility. The researchers suggest that this could be due to high resistance damage from mechanical polishing of the surface on which the Schottky contacts are made. Increasing the temperature to 373K reduced the series resistance to $2.9x10^5\Omega$.

Reverse-bias leakage was less than $10^{-6}A/cm^2$ below 400V (Figure 8). Reverse breakdown voltages for $10^{-3}A/cm^2$ were between 550V and 770V for six devices. Since the thermionic field emission theory breakdown voltage for the device was 200V, the researchers believe that the ionized donor concentration is significantly lower than the silicon concentration. Toru Kinoshita of Tokuyama reports that a mid $10^{16}/cm^3$ value for the ionized donor concentration would fit the 550–770V breakdown behavior.

The researchers comment that the large discrepancy between experimental and theoretical breakdown values might be reduced by suppressing the effect of surface damage and by creating better defined Schottky contacts. ■

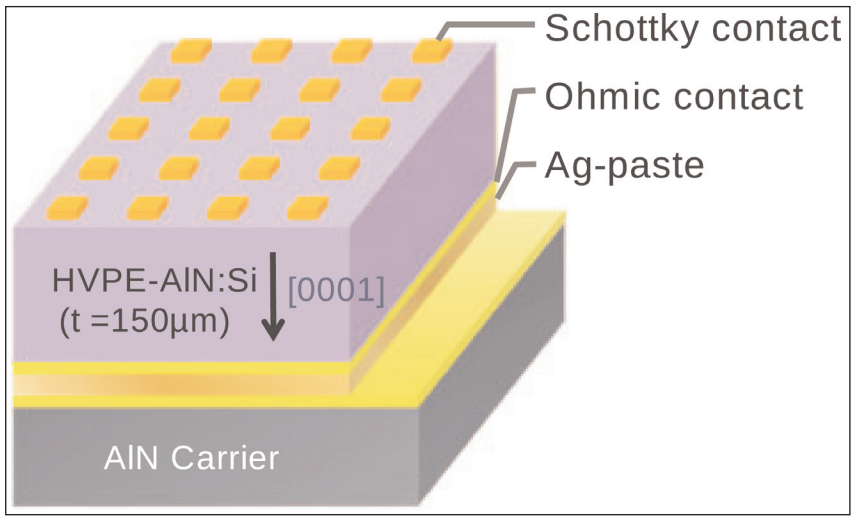


Figure 7. Schematic vertical Schottky barrier diode on HVPE-AlN:Si substrate.

The author Mike Cooke is a freelance technology journalist who has worked in the semiconductor and advanced technology sectors since 1997.

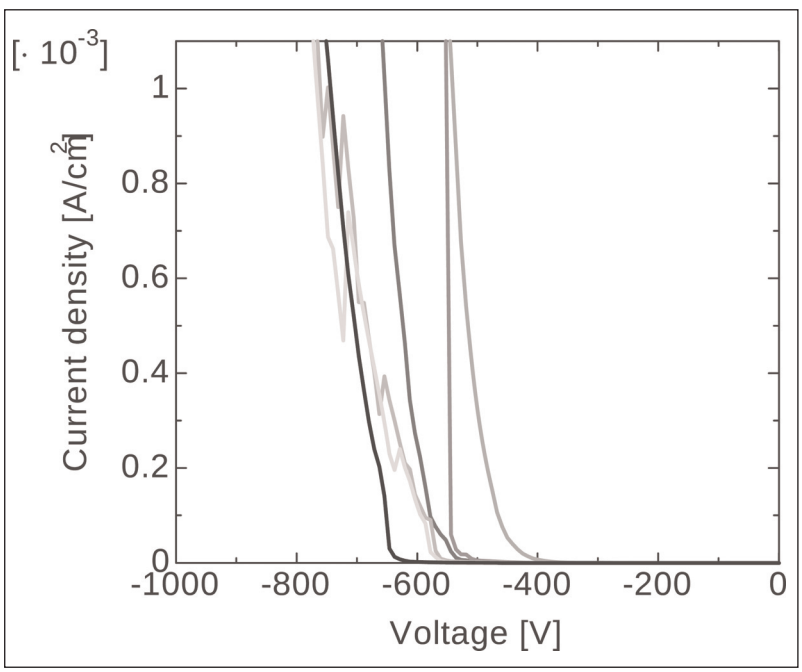


Figure 8. Reverse current–voltage characteristics of vertical Schottky barrier diodes on free-standing n-type HVPE-AlN substrate.

High-pressure anneal for indium gallium arsenide transistors

Process reduces interface and border traps in aluminium oxide/hafnium dioxide gate stacks, improving performance and reliability.

Researchers in the USA and Korea have developed a hydrogen high pressure annealing (HPA) process for aluminium oxide/hafnium dioxide (Al_2O_3/HfO_2) gate stacks on indium gallium arsenide (InGaAs) quantum wells [Tae-Woo Kim et al, IEEE Electron Device Letters, vol36, p672, 2015]. The aim of the team, from SEMATECH Inc in the USA, the Korea Advanced Nano Fab Center in South Korea, Poongsan Inc in the USA, and Kyungpook National University in South Korea, was to reduce interface and border traps that adversely affect transistor performance and threshold voltage reliability.

Although the work was carried out on planar metal-oxide-semiconductor capacitors (MOSCAPs) and field-effect transistors (MOSFETs), the researchers add: "We also believe that the HPA process developed in this work would be invaluable for non-planar InGaAs MOSFETs, such as tri-gate architecture, in the sense of recovering the sidewall gate-stack damage through the annealing step."

The researchers see indium-rich InGaAs n-channels as the most promising non-silicon option for continuous scaling down of supply voltages for low-power consumption and boosting transistor performance in future electronics. Although much progress has been made, performance and reliability degradation from interface and border traps continues to be a concern.

Consistent with findings in the InGaAs MOSCAPs, the improvement in the electrostatic integrity of the InGaAs MOSFETs arises mostly from the reduction of D_{it} during the HPA process step

The epitaxial material was grown by molecular beam epitaxy (MBE) on indium phosphide (InP). The quantum well channel consisted of 10nm $In_{0.7}Ga_{0.3}As$ on an indium aluminium arsenide ($In_{0.52}Al_{0.48}As$) barrier layer with inverted silicon δ-doping.

Electrical isolation of the devices was achieved with a wet etch using a solution based on phosphoric acid (H_3PO_4). Ohmic metals for the source–drain contacts were molybdenum/titanium/gold. The gate region was patterned and Al_2O_3/HfO_2 gate insulators and the titanium nitride gate electrode were applied using atomic layer deposition (ALD).

The last stage was the hydrogen HPA, carried out at 300°C under 20 atmospheres pressure for 30 minutes. The tool used was a Poongsan GENI-SYS system (www.poongsan.co.kr/eng/products/high-pressure-annealing-process-system).

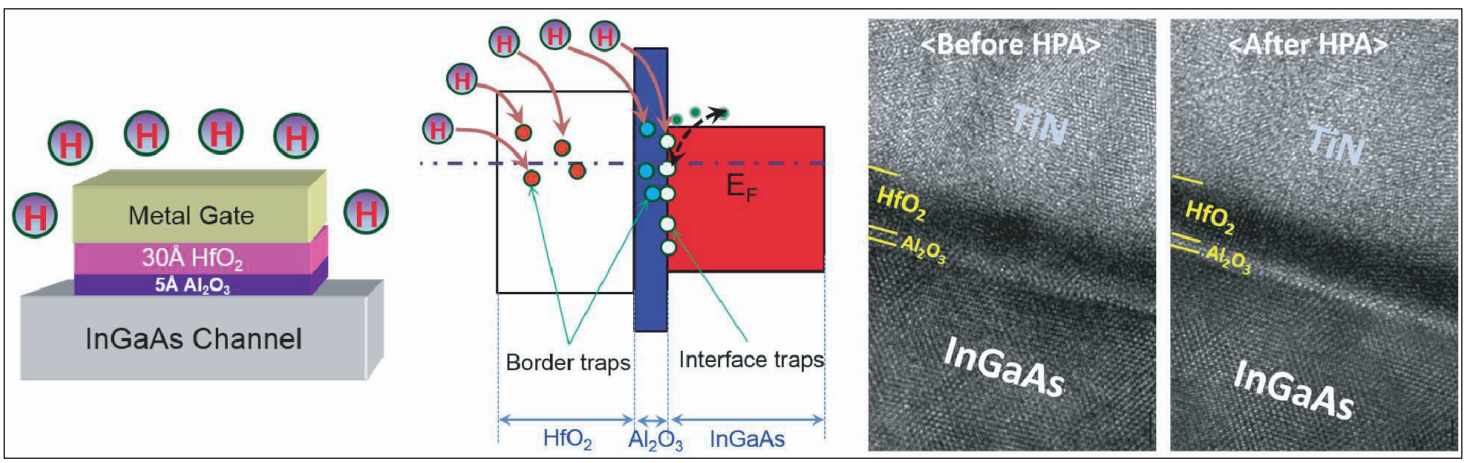


Figure 1. (a) Schematic cross-section for InGaAs MOSCAPs and MOSFETs with HPA, (b) energy-band diagram with interfacial and border traps, and (c) cross-sectional TEM images for Al_2O_3/HfO_2 gate stack before and after HPA.

Table 1. Comparison between InGaAs MOSCAPs and MOSFETs before and after HPA.

	Interface trap density	Capacitance equivalent thickness	Sub-threshold swing	Drain-induced barrier lowering	On-resistance
Before HPA	2.0×10^{12}/eV-cm^2	1.9nm	130mV/decade	68mV/V	540Ω-μm
After HPA	1.1×10^{12}/eV-cm^2	1.8nm	105mV/decade	20mV/V	520Ω-μm

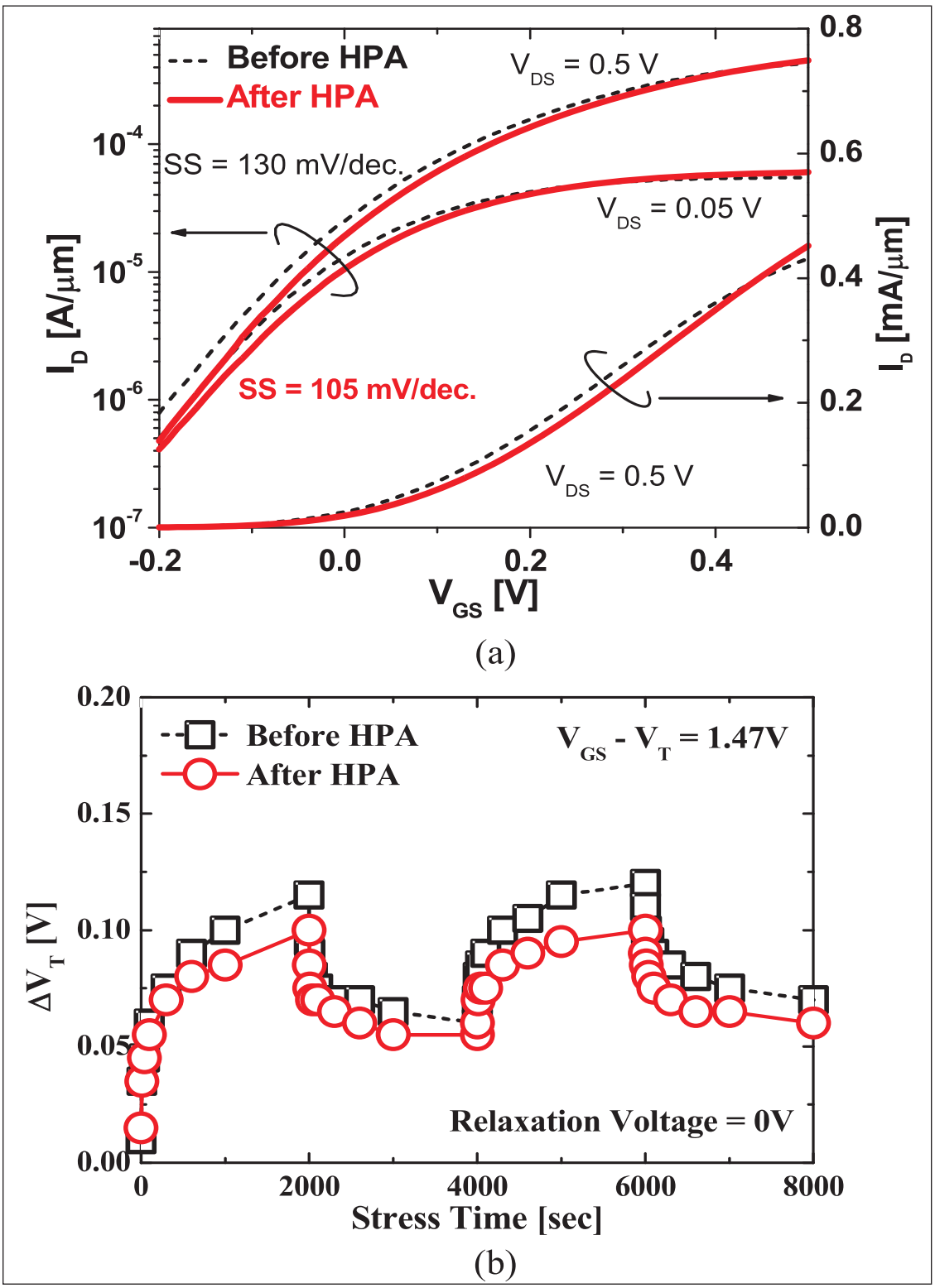


Figure 2. (a) Subthreshold (left) and transfer (right) characteristics of MOSFETs, and (b) ΔV_T profile as a function of iteration of constant voltage stress before (dashed line) and after (solid line) HPA.

The researchers say, on the basis of the capacitance–voltage measurements, that the anneal was effective in reducing border traps. Also, the interface trap density (D_{it}) was reduced by more than 30%, indicating effective passivation (Table 1).

The performance of MOSFETs with 50nm gate length showed reduced subthreshold swing and drain-induced barrier lowering from the anneal process that the researchers describe as "remarkable" (Figure 2a). The researchers comment: "Consistent with findings in the InGaAs MOSCAPs, the improvement in the electrostatic integrity of the InGaAs MOSFETs arises mostly from the reduction of D_{it} during the HPA process step in this work."

Constant voltage stress (3.47MV/cm field) reliability tests showed reduced threshold voltage shift (ΔV_T) from annealed devices (Figure 2b). This was attributed to the reduction in border traps. ■

http://ieeexplore.ieee.org/xpl/articleDetails.jsp?arnumber=7114237

Author: Mike Cooke

Tellurium doping for n-type indium gallium arsenide

Researchers claim record active doping concentration of $8x10^{19}/cm^3$ for MOCVD process on 300mm silicon wafers.

Researchers in the USA claim a record active doping concentration of $8x10^{19}/cm^3$ for n-type indium gallium arsenide ($In_{0.53}Ga_{0.47}As$) grown on 300mm silicon (Si) wafers by metal-organic chemical vapor deposition (MOCVD) using diethyl-telluride (DETe) as the dopant source [Tommaso Orzali et al, Journal of Crystal Growth, vol426, p243, 2015]. The work involved SEMATECH, Aixtron Inc, and State University of New York (SUNY) Polytechnic Institute.

The team sees potential application in re-grown source–drain (S/D) structures for future InGaAs high-mobility-channel transistor very-large-scale integration (VLSI) electronics. Silicon is the most common dopant for n-InGaAs. Unfortunately, as a group IV element it is amphoteric, so it can act as a donor or acceptor. Silicon begins to auto-compensate at $5x10^{18}/cm^3$ electron concentration, limiting free carriers to around $10^{19}/cm^3$.

The researchers used an Aixtron CRIUS-R 300mm system to perform MOCVD of $In_{0.53}Ga_{0.47}As$ on 3-inch indium phosphide (InP) and 300mm Si (100) substrates. The precursors were trimethyl-gallium, trimethyl-indium, arsine, and diethyl-telluride in palladium-purified hydrogen carrier. The attractive properties of diethyl-telluride for MOCVD include being a liquid up to 136°C, low reactivity with air or water, and a vapor pressure of 12Torr at 30°C.

On InP, active electron densities higher than $1x10^{19}/cm^3$ were easily achieved at a growth temperature of 660°C and a V/III ratio of 44 (Table 1). This level was produced by diethyl-telluride flows as low as 0.024µmol/min, giving a dopant concentration of $5.8x10^{19}/cm^3$ and an active electron density of $3.5x10^{19}/cm^3$ (efficiency 60.3%). Increasing the flow by 50x only increased the dopant level to $10x10^{19}/cm^3$, but since the activation efficiency was then only 23%, the active electron density was reduced to $2.3x10^{19}/cm^3$.

The volatile nature of tellurium leads to a surfactant behavior and segregation at step edges of the growing InGaAs crystal structure. At higher growth temperature the tellurium tends to evaporate rather than be incorporated into the crystal.

Reducing the V/III ratio to 22 to ease the substitution of tellurium for arsenic in the InGaAs structure with 0.13µmol/min diethyl-telluride flow increased the activation efficiency from 19.6% to 59.6%. The respective dopant concentrations were $6.6x10^{19}/cm^3$ and $5.7x10^{19}/cm^3$. The active electron densities were $1.3x10^{19}/cm^3$ and $3.4x10^{19}/cm^3$, respectively.

The active electron density therefore seems to saturate around $3.5x10^{19}/cm^3$ for growth at 660°C.

For growth on 300mm silicon, the process was used on an InP/GaAs buffer that bridged the 8% $In_{0.53}Ga_{0.47}As$/Si lattice mismatch. A highly resistive 300nm indium aluminium arsenide barrier was inserted between the buffer and InGaAs to ensure electrical isolation from the buffer. The InGaAs/InAlAs/InP were lattice matched. The bandgap of the InAlAs was 1.47eV, confining the electrons to the InGaAs layer (~0.75eV).

Table 1. Hall & SIMS data for Te-doped $In_{0.53}Ga_{0.47}As$ on 3" InP wafers grown at 660°C.

DETe (µmol/min)	V/III ratio	Sheet resistance (Ω/square)	Mobility (cm^2/V-s)	Active electron density ($10^{19}/cm^3$)	Tellurium concentration ($10^{19}/cm^3$)	Activation efficiency (%)
0.024	44	13.6	1310	3.5	5.8	60.3
0.13	44	43.5	1100	1.3	6.6	19.6
0.13	22	13.8	1320	3.4	5.7	59.6
1.2	44	24.4	1110	2.3	10	23

Table 2. Hall & SIMS data for Te-doped $In_{0.53}Ga_{0.47}As$ as function of growth temperature.

Temp (°C)	Substrate	Sheet resistance (Ω/square)	Mobility (cm^2/V-s)	Active electron density ($10^{19}/cm^3$)	Activation efficiency (%)
500	Si	12.1	841	8.0	14.5
600	Si	44.2	970	4.4	62.8
660	InP	13.8	1320	3.4	59.6

Attempting to improve tellurium incorporation, the researchers varied the growth temperature down to 500°C for the InGaAs growth with 22 V/III ratio and 0.13µmol/min diethyl-telluride flow (Table 2). At 500°C, the active electron density was $8x10^{19}/cm^3$, with 14.5% activation efficiency on

a 5.5x10^{20}/cm^3 tellurium concentration.

The researchers comment: "a carrier concentration of 8x10^{19}/cm^3 is, to the best of our knowledge, amongst the highest values reported for MOCVD grown $In_{0.53}Ga_{0.47}As$ [see Figure 1]."

The sheet resistance of a 100nm tellurium-doped InGaAs layer grown at 500°C was 9.53Ω/square with 0.8% coefficient of variation (standard deviation/mean). "This is an excellent value considering that the layer is grown at 500°C, in the MOCVD kinetic controlled regime, where a slight temperature non-uniformity can severely affect the alloy composition and the dopant concentration," the researchers write.

The surfactant properties of tellurium on InGaAs growth at 600°C reduced root-mean-square surface roughness from 3.6nm for undoped material to 0.4nm for heavily Te-doped InGaAs in 5μmx5μm atomic force microscopy (AFM) scans. At 500°C, the surface roughness of Te-doped InGaAs was 2.3nm.

A drawback of the surfactant property of Te was the slow turn-off of doping when the researchers tried to create a 110nm undoped InGaAs cap on a 300nm Te-doped InGaAs layer, as revealed by secondary-ion mass spectroscopy (SIMS) — see Figure 2. The 'memory effect' is attributed to accumulation of Te on the growth surface retarding incorporation in the bulk material. At the surface of the cap layer, the Te concentration was ~10^{18}/cm^3.

The researchers comment: "Although the slow Te turn-off may not be important for the targeted VLSI S/D re-growth application, the slow turn-on will prevent the formation of an abrupt junction in the source/drain region, which is crucial for short-channel devices."

Possible ways to combat the memory effect include pulsing the dopant precursor before growth for sharp turn-on or inserting a post-growth bake after the doped layer to sublimate tellurium precursor products from the wafer surface.

The tellurium content also affected the indium composition of the InGaAs — the presence of higher concentrations of tellurium improves indium incorporation (and vice versa). Further, the tellurium atom is larger than arsenic, introducing compressive strain into the doped InGaAs. Care must be taken to avoid introducing dislocations from strain relaxation. ■

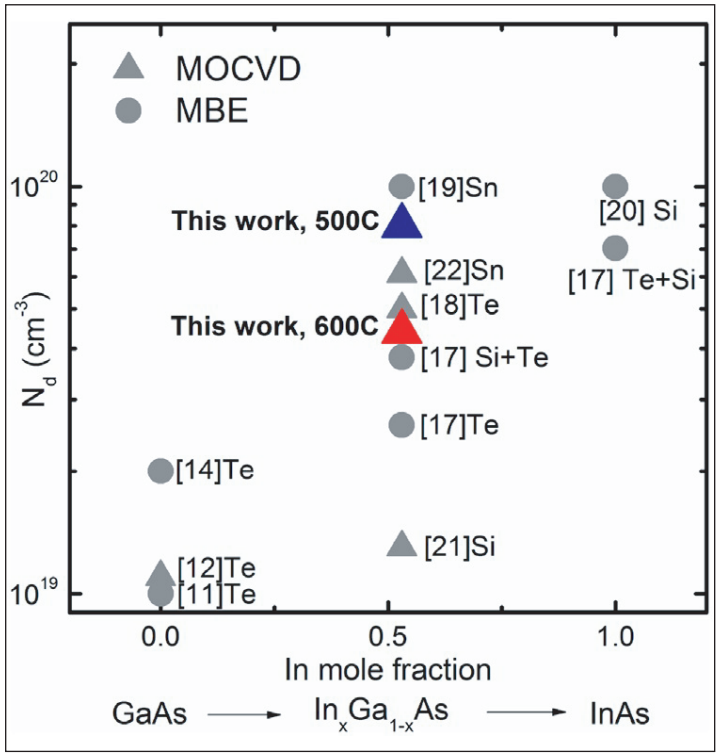


Figure 1. $In_xGa_{1-x}As$ active carrier concentration benchmarking.

www.sciencedirect.com/science/article/pii/S0022024815003541

Author: Mike Cooke

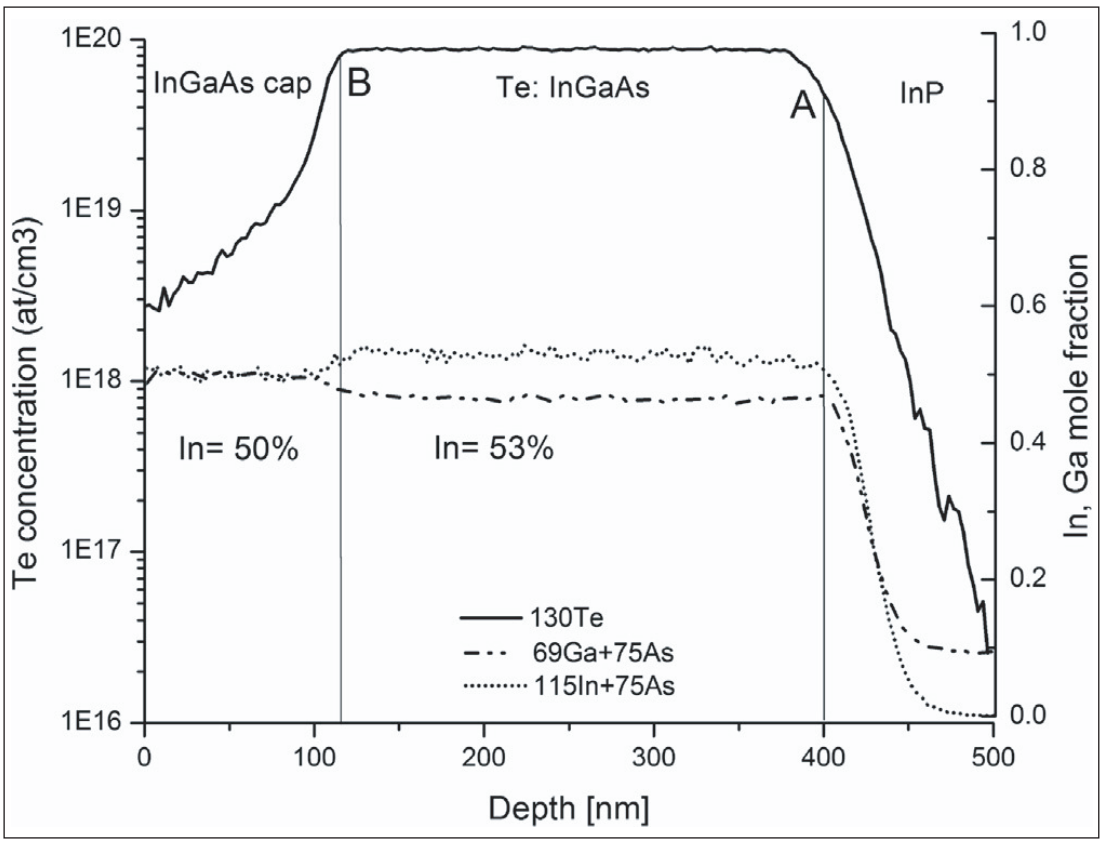


Figure 2. SIMS profile of 300nmTe-doped InGaAs grown on InP/GaAs buffer heterostructure on Si capped with 110nm undoped InGaAs.

suppliers' directory

Index

To have your company listed in this directory, e-mail details (including categories) to mark@semiconductor-today.com
Note: advertisers receive a free listing. For all other companies, a charge is applicable.

1 Bulk crystal source materials

Mining & Chemical Products Ltd (part of 5N Plus, Inc)
1-4, Nielson Road,
Finedon Road Industrial Estate,
Wellingborough,
Northants NN8 4PE,
UK
Tel: +44 1933 220626
Fax: +44 1933 227814
www.MCP-group.com

Umicore Indium Products
50 Simms Avenue,
Providence, RI 02902,
USA
Tel: +1 401 456 0800
Fax: +1 401 421 2419
www.thinfilmproducts.umicore.com

United Mineral & Chemical Corp
1100 Valley Brook Avenue,
Lyndhurst, NJ 07071,
USA
Tel: +1 201 507 3300
Fax: +1 201 507 1506
www.umccorp.com

2 Bulk crystal growth equipment

MR Semicon Inc
PO Box 91687,
Albuquerque,
NM 87199-1687,
USA
Tel: +1 505 899 8183
Fax: +1 505 899 8172
www.mrsemicon.com

3 Substrates

AXT Inc
4281 Technology Drive,
Fremont,
CA 94538,
USA
Tel: +1 510 438 4700
Fax: +1 510 683 5901
www.axt.com
Supplies GaAs, InP, and Ge wafers using VGF technology with manufacturing facilities in Beijing and five joint ventures in China producing raw materials, including Ga, As, Ge, pBN, B_2O_3.

CrystAl-N GmbH
Dr.-Mack-Straße 77,
D-90762
Fürth,
Germany
Tel: +49 (0)911 650 78 650 90
Fax: +49 (0)911 650 78 650 93
E-mail: info@crystal-n.com
www.crystal-n.com

Crystal IS Inc
70 Cohoes Avenue
Green Island, NY 12183, USA
Tel: +1 518 271 7375
Fax: +1 518 271 7394
www.crystal-is.com

Freiberger Compound Materials
Am Junger Loewe Schacht 5,
Freiberg, 09599, Germany
Tel: +49 3731 280 0
Fax: +49 3731 280 106
www.fcm-germany.com

Kyma Technologies Inc
8829 Midway West Road,
Raleigh, NC, USA
Tel: +1 919 789 8880
Fax: +1 919 789 8881
www.kymatech.com

MARUWA CO LTD
3-83, Minamihonjigahara-cho,
Owariasahi, Aichi 488-0044,
Japan
Tel: +81 572 52 2317
www.maruwa-g.com/e/products/ceramic

MARUWA is a global supplier of ceramic substrates and wafers made of aluminium nitride (AlN), alumina (Al_2O_3), ZTA and silicon nitride (Si_3N_4). Products meet required properties such as high thermal conductivity and bending strength for power devices, especially wafers are suitable as a bonding wafer (GaN, SOI) for epi wafers.

sp3 Diamond Technologies
2220 Martin Avenue,
Santa Clara, CA 95050, USA
Tel: +1 877 773 9940
Fax: +1 408 492 0633
www.sp3inc.com

Sumitomo Electric Semiconductor Materials Inc
7230 NW Evergreen Parkway,
Hillsboro, OR 97124,
USA
Tel: +1 503 693 3100 x207
Fax: +1 503 693 8275
www.sesmi.com

III/V-Reclaim
Wald 10,
84568 Pleiskirchen, Germany
Tel: +49 8728 911 093
Fax: +49 8728 911 156
www.35reclaim.de
III/V-Reclaim offers reclaim (recycling) of GaAs and InP wafers, removing all kinds of layers and structures from customers' wafers. All formats and sizes can be handled. The firm offers single-side and double-side-polishing and ready-to-use surface treatment.

Umicore Electro-Optic Materials
Watertorenstraat 33,
B-2250 Olen, Belgium
Tel: +32-14 24 53 67
Fax: +32-14 24 58 00
www.substrates.umicore.com

Wafer World Inc
1100 Technology Place, Suite 104,
West Palm Beach, FL 33407,
USA
Tel: +1-561-842-4441
Fax: +1-561-842-2677
E-mail: sales@waferworld.com
www.waferworld.com

4 Epiwafer foundry

Spire Semiconductor LLC
25 Sagamore Park Drive,
Hudson, NH 03051,
USA
Tel: +1 603 595 8900
Fax: +1 603 595 0975
www.spirecorp.com

Albemarle Cambridge Chemical Ltd
Unit 5 Chesterton Mills,
French's Road, Cambridge CB4 3NP,
UK
Tel: +44 (0)1223 352244
Fax: +44 (0)1223 352444
www.camchem.co.uk

Intelligent Epitaxy Technology Inc
1250 E Collins Blvd,
Richardson,
TX 75081-2401,
USA
Tel: +1 972 234 0068
Fax: +1 972 234 0069
www.intelliepi.com

IQE
Cypress Drive,
St Mellons, Cardiff
CF3 0EG,
UK
Tel: +44 29 2083 9400
Fax: +44 29 2083 9401
www.iqep.com
IQE is a leading global supplier of advanced epiwafers, with products covering a diverse range of applications within the wireless, optoelectronic, photovoltaic and electronic markets.

OMMIC
2, Chemin du Moulin B.P. 11,
Limeil-Brevannes, 94453,
France
Tel: +33 1 45 10 67 31
Fax: +33 1 45 10 69 53
www.ommic.fr

Soitec
Place Marcel Rebuffat, Parc de Villejust, 91971 Courtabouef, France
Tel: +33 (0)1 69 31 61 30
Fax: +33 (0)1 69 31 61 79
www.picogiga.com

5 Deposition materials

Akzo Nobel High Purity Metalorganics
www.akzonobel.com/hpmo
Asia Pacific:
Akzo Nobel (Asia) Co Ltd,
Shanghai,
China
Tel. +86 21 2216 3600
Fax: +86 21 3360 7739
metalorganicsAP@akzonobel.com
Americas:
AkzoNobel Functional Chemicals,
Chicago,
USA
Tel. +31 800 828 7929 (US only)
Tel: +1 312 544 7000
Fax: +1 312 544 7188
metalorganicsNA@akzonobel.com
Europe, Middle East and Africa:
AkzoNobel Functional Chemicals,
Amersfoort, The Netherlands
Tel. +31 33 467 6656
Fax: +31 33 467 6101
metalorganicsEU@akzonobel.com

Cambridge Chemical Company Ltd
Unit 5 Chesterton Mills,
French's Road,
Cambridge CB4 3NP,
UK
Tel: +44 (0)1223 352244
Fax: +44 (0)1223 352444
www.camchem.co.uk

Dow Electronic Materials
60 Willow Street,
North Andover, MA 01845,
USA
Tel: +1 978 557 1700
Fax: +1 978 557 1701
www.metalorganics.com

Matheson Tri-Gas
6775 Central Avenue,
Newark, CA 94560,
USA

Tel: +1 510 793 2559
Fax: +1 510 790 6241
www.mathesontrigas.com

Mining & Chemical Products Ltd
(see section 1 for full contact details)

Praxair Electronics
542 Route 303, Orangeburg,
NY 10962,
USA
Tel: +1 845 398 8242
Fax: +1 845 398 8304
www.praxair.com/electronics

SAFC Hitech
Power Road, Bromborough,
Wirral, Merseyside CH62 3QF,
UK
Tel: +44 151 334 2774
Fax: +44 151 334 6422
www.safchitech.com

Materion Advanced Materials Group
2978 Main Street,
Buffalo, NY 14214,
USA
Tel: +1 716 837 1000
Fax: +1 716 833 2926
www.williams-adv.com

6 Deposition equipment

AIXTRON SE
Dornkaulstr. 2,
52134 Herzogenrath,
Germany
Tel: +49 2407 9030 0
Fax: +49 2407 9030 40
www.aixtron.com

AIXTRON is a leading provider of deposition equipment to the semiconductor industry. The company's technology solutions are used by a diverse range of customers worldwide to build advanced components for electronic and optoelectronic applications (photonic) based on compound, silicon, or organic semiconductor materials and, more recently, carbon nanotubes (CNT), graphene and other nanomaterials.

Evatec AG
Hauptstrasse 1a,
CH-9477 Trübbach, Switzerland
Tel: +41 81 403 8000
Fax: +41 81 403 8001
www.evatecnet.com

Ferrotec-Temescal
4569-C Las Positas Rd,
Livermore,
CA 94551,
USA
Tel: +1 925 245 5817
Fax: +1 925 449-4096
www.temescal.net

Temescal, the expert in metallization systems for the processing of compound semiconductor-based substrates, provides the finest evaporation systems available. Multi-layer coatings of materials such as Ti, Pt, Au, Pd, Ag, NiCr, Al, Cr, Cu, Mo, Nb, SiO_2, with high uniformity are guaranteed. Today the world's most sophisticated handsets, optical, wireless and telecom systems rely on millions of devices that are made using Temescal deposition systems and components.

Oxford Instruments Plasma Technology
North End, Yatton,
Bristol, Avon BS49 4AP, UK
Tel: +44 1934 837 000
Fax: +44 1934 837 001
www.oxford-instruments.co.uk

We provide flexible tools and processes for precise materials deposition, etching and controlled nanostructure growth. Core technologies include plasma and ion-beam deposition and etch and ALD.

Plasma-Therm LLC
10050 16th Street North,
St. Petersburg, FL 33716, USA
Tel: +1 727 577 4999
Fax: +1 727 577 7035
www.plasmatherm.com

Plasma-Therm, LLC is an established leading provider of advanced plasma processing equipment for the semiconductor industry and related specialty markets.

Riber
31 rue Casimir Périer, BP 70083,
95873 Bezons Cedex, France
Tel: +33 (0) 1 39 96 65 00
Fax: +33 (0) 1 39 47 45 62
www.riber.com

SVT Associates Inc
7620 Executive Drive,
Eden Prairie, MN 55344, USA
Tel: +1 952 934 2100
Fax: +1 952 934 2737
www.svta.com

Veeco Instruments Inc
100 Sunnyside Blvd.,
Woodbury, NY 11797,
USA
Tel: +1 516 677 0200
Fax: +1 516 714 1231
www.veeco.com

Veeco is a world-leading supplier of compound semiconductor equipment, and the only company offering both MOCVD and MBE solutions. With complementary AFM technology and the industry's most advanced Process Integration Center, Veeco tools help grow and measure nanoscale devices in worldwide LED/wireless, data storage, semiconductor and scientific research markets—offering important choices, delivering ideal solutions.

7 Wafer processing materials

Air Products and Chemicals Inc
7201 Hamilton Blvd.,
Allentown, PA 18195, USA
Tel: +1 610 481 4911
www.airproducts.com/compound

MicroChem Corp
1254 Chestnut St. Newton,
MA 02464, USA
Tel: +1 617 965 5511
Fax: +1 617 965 5818
www.microchem.com

Praxair Electronics
(see section 5 for full contact details)

8 Wafer processing equipment

EV Group
DI Erich Thallner Strasse 1,
St. Florian/Inn, 4782,
Austria
Tel: +43 7712 5311 0
Fax: +43 7712 5311 4600
www.EVGroup.com
Technology and market leader for wafer processing equipment.
Worldwide industry standards for aligned wafer bonding, resist processing for the MEMS, nano and semiconductor industry.

Logitech Ltd
Erskine Ferry Road,
Old Kilpatrick,
near Glasgow G60 5EU,
Scotland, UK
Tel: +44 (0) 1389 875 444
Fax: +44 (0) 1389 879 042
www.logitech.uk.com

Oxford Instruments Plasma Technology
(see section 6 for full contact details)

Plasma-Therm LLC
(see section 6 for full contact details)

SAMCO International Inc
532 Weddell Drive,
Sunnyvale,
CA,
USA
Tel: +1 408 734 0459
Fax: +1 408 734 0961
www.samcointl.com

SPTS Technology Ltd
Ringland Way,
Newport NP18 2TA,
UK
Tel: +44 (0)1633 414000
Fax: +44 (0)1633 414141
www.spts.com

SUSS MicroTec AG
Schleißheimer Strasse 90,
85748 Garching,
Germany
Tel: +49 89 32007 0
Fax: +49 89 32007 162
www.suss.com

Veeco Instruments Inc
(see section 6 for full contact details)

9 Materials & metals

Goodfellow Cambridge Ltd
Ermine Business Park,
Huntingdon,
Cambridgeshire
PE29 6WR,
UK
Tel: +44 (0) 1480 424800
Fax: +44 (0) 1480 424900
www.goodfellow.com
Goodfellow supplies small quantities of metals and materials for research, development, prototyping and specialised manufacturing operations.

10 Gas and liquid handling equipment

Air Products and Chemicals Inc
(see section 7 for full contact details)

Cambridge Fluid Systems
12 Trafalgar Way, Bar Hill,
Cambridge CB3 8SQ,
UK
Tel: +44 (0)1954 786800
Fax: +44 (0)1954 786818
www.cambridge-fluid.com

CS CLEAN SYSTEMS AG
Fraunhoferstrasse 4,
Ismaning, 85737,
Germany
Tel: +49 89 96 24 00 0
Fax: +49 89 96 24 00 122
www.cscleansystems.com

SAES Pure Gas Inc
4175 Santa Fe Road,
San Luis Obispo,
CA 93401,
USA
Tel: +1 805 541 9299
Fax: +1 805 541 9399
www.saesgetters.com

11 Process monitoring and control

k-Space Associates Inc
2182 Bishop Circle
East, Dexter,
MI 48130,
USA
Tel: +1 734 426 7977
Fax: +1 734 426 7955
www.k-space.com
k-Space Associates Inc specializes in in-situ, real-time thin-film process monitoring tools for MBE, MOCVD, PVD, and thermal evaporation. Applications and materials include the research and production line monitoring of compound semiconductor-based electronic, optoelectronic, and photovoltaic devices.

KLA-Tencor
One Technology Dr,
1-2221I, Milpitas, CA 95035, USA
Tel: +1 408 875 3000
Fax: +1 408 875 4144
www.kla-tencor.com

LayTec AG
Seesener Str. 10–13,
10709 Berlin,
Germany
Tel: +49 30 89 00 55 0
Fax: +49 30 89 00 180
www.laytec.de
LayTec develops and manufactures optical in-situ and in-line metrology systems for thin-film processes with particular focus on compound semiconductor and photovoltaic applications. Its know-how is based on optical techniques: reflectometry, emissivity corrected pyrometry, curvature measurements and reflectance anisotropy spectroscopy.

WEP (Ingenieurbüro Wolff für Elektronik- und Programmentwicklungen)
Bregstrasse 90, D-78120
Furtwangen im Schwarzwald,
Germany
Tel: +49 7723 9197 0
Fax: +49 7723 9197 22
www.wepcontrol.com

12 Inspection equipment

Bruker AXS GmbH
Oestliche Rheinbrueckenstrasse 49,
Karlsruhe, 76187,
Germany
Tel: +49 (0)721 595 2888
Fax: +49 (0)721 595 4587
www.bruker-axs.de

13 Characterization equipment

J.A. Woollam Co. Inc.
645 M Street Suite 102,
Lincoln, NE 68508, USA
Tel: +1 402 477 7501
Fax: +1 402 477 8214
www.jawoollam.com

Lake Shore Cryotronics Inc
575 McCorkle Boulevard,
Westerville, OH 43082,
USA
Tel: +1 614 891 2244
Fax: +1 614 818 1600
www.lakeshore.com

14 Chip test equipment

Keithley Instruments Inc
28775 Aurora Road,
Cleveland, OH 44139,
USA
Tel: +1 440.248.0400
Fax: +1 440.248.6168
www.keithley.com

15 Assembly/packaging materials

ePAK International Inc
4926 Spicewood Springs Road,
Austin, TX 78759,
USA
Tel: +1 512 231 8083
Fax: +1 512 231 8183
www.epak.com

Gel-Pak
31398 Huntwood Avenue,
Hayward, CA 94544, USA
Tel: +1 510 576 2220
Fax: +1 510 576 2282
www.gelpak.com

Wafer World Inc
(see section 3 for full contact details)

Materion Advanced Materials Group
2978 Main Street,
Buffalo, NY 14214,
USA
Tel: +1 716 837 1000
Fax: +1 716 833 2926
www.williams-adv.com

16 Assembly/packaging equipment

Ismeca Europe Semiconductor SA
Helvetie 283, La Chaux-de-Fonds,
2301, Switzerland
Tel: +41 329257111
Fax: +41 329257115
www.ismeca.com

Kulicke & Soffa Industries
1005 Virginia Drive,
Fort Washington,
PA 19034,
USA
Tel: +1 215 784 6000
Fax: +1 215 784 6001
www.kns.com

Palomar Technologies Inc
2728 Loker Avenue West,
Carlsbad, CA 92010,
USA
Tel: +1 760 931 3600
Fax: +1 760 931 5191
www.PalomarTechnologies.com

TECDIA Inc
2700 Augustine Drive, Suite 110,
Santa Clara, CA 95054,
USA
Tel: +1 408 748 0100
Fax: +1 408 748 0111
www.tecdia.com

17 Assembly/packaging foundry

Quik-Pak
10987 Via Frontera,
San Diego, CA 92127, USA
Tel: +1 858 674 4676
Fax: +1 8586 74 4681
www.quikicpak.com

18 Chip foundry

Compound Semiconductor Technologies Ltd
Block 7, Kelvin Campus,
West of Scotland, Glasgow,
Scotland G20 0TH,
UK
Tel: +44 141 579 3000
Fax: +44 141 579 3040
www.compoundsemi.co.uk

United Monolithic Semiconductors
Route departementale 128,
BP46, Orsay, 91401,
France
Tel: +33 1 69 33 04 72
Fax: +33 169 33 02 92
www.ums-gaas.com

19 Facility equipment

MEI, LLC
3474 18th Avenue SE,
Albany, OR 97322-7014,
USA
Tel: +1 541 917 3626
Fax: +1 541 917 3623
www.marlerenterprises.net

20 Facility consumables

W.L. Gore & Associates
401 Airport Rd, Elkton,
MD 21921-4236,
USA
Tel: +1 410 392 4440
Fax: +1 410 506 8749
www.gore.com

21 Computer hardware & software

Ansoft Corp
4 Station Square, Suite 200,
Pittsburgh, PA 15219, USA
Tel: +1 412 261 3200
Fax: +1 412 471 9427
www.ansoft.com

Crosslight Software Inc
121-3989 Henning Dr.,
Burnaby, BC, V5C 6P8, Canada
Tel: +1 604 320 1704
Fax: +1 604 320 1734
www.crosslight.com

Semiconductor Technology Research Inc
10404 Patterson Ave., Suite 108,
Richmond, VA 23238,
USA
Tel: +1 804 740 8314
Fax: +1 804 740 3814
www.semitech.us

22 Used equipment

Class One Equipment Inc
5302 Snapfinger Woods Drive,
Decatur, GA 30035, USA
Tel: +1 770 808 8708
Fax: +1 770 808 8308
www.ClassOneEquipment.com

23 Services

Henry Butcher International
Brownlow House, 50–51
High Holborn, London WC1V 6EG,
UK
Tel: +44 (0)20 7405 8411
Fax: +44 (0)20 7405 9772
www.henrybutcher.com

M+W Zander Holding AG
Lotterbergstrasse 30,
Stuttgart,
Germany
Tel: +49 711 8804 1141
Fax: +49 711 8804 1950
www.mw-zander.com

24 Consulting

Fishbone Consulting SARL
8 Rue de la Grange aux Moines,
78460 Choisel,
France
Tel: + 33 (0)1 30 47 29 03
E-mail: jean-luc.ledys@neuf.fr

25 Resources

Al Shultz Advertising Marketing for Advanced Technology Companies
1346 The Alameda,
7140 San Jose, CA 95126, USA
Tel: +1 408 289 9555
www.alshuktz.com

SEMI Global Headquarters
3081 Zanker Road,
San Jose, CA 95134, USA
Tel: +1 408 943 6900
Fax: +1 408 428 9600
www.semi.org

Yole Développement
45 rue Sainte Geneviève,
69006 Lyon, France
Tel: +33 472 83 01 86
www.yole.fr

event calendar

If you would like your event listed in *Semiconductor Today*'s Event Calendar, then please e-mail all details to the Editor at mark@semiconductor-today.com

4–8 October 2015
IPC 2015: 28th IEEE Photonics Conference
Reston, VI, USA
E-mail: c.c.scott@ieee.org
www.ipc-ieee.org

4–9 October 2015
16th International Conference on Silicon Carbide and Related Materials (ICSCRM 2015)
Congress Center Atahotel Naxos Beach, Giardini Naxos, Sicily, Italy
E-mail: webmaster@icscrm2015.org
http://icscrm2015.imm.cnr.it

6–8 October 2015
SEMICON Europa 2015
Dresden, Germany
E-mail: semiconeuropa@semi.org
www.semiconeuropa.org

12–14 October 2015
International Semiconductor Conference (CAS 2015)
Sinaia, Romania
E-mail: cas@imt.ro
www.imt.ro/cas

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

13–16 October 2015
SCTE Cable-Tec Expo 2015
New Orleans Ernest N. Morial Convention Center, Louisiana, USA
E-mail: expo@scte.org
http://expo.scte.org

14–15 October 2015
High Power Diode Lasers & Systems (HPDLS 2015), co-located at PHOTONEX 2015
Ricoh Arena, Coventry, UK
E-mail: brenda@xmarkmedia.com
www.hpdls.org

26–29 October 2015
IMAPS 2015: 48th International Symposium on Microelectronics
Orlando, FL, USA
E-mail: blamm@imaps.org
www.imaps.org

26–29 October 2015
2015 IEEE International Topical Meeting on Microwave Photonics
Paphos, Cyprus
E-mail: info@cyprusconferences.org
www.mwp2015.org

advertisers' index

28–29 October 2015
UV LED 2015
Troy, NY, USA
E-mail: mickey@radtech.org
www.uvled2015.com

2–4 November 2015
ChinaSSL 2015 (12th China International Forum on Solid-State Lighting)
Shenzhen Exhibition Center, China
E-mail: liuh@china-led.net
www.sslchina.org

3–5 November 2015
Global Summit on Electronics and Electrical Engineering
Valencia, Spain
E-mail: electricalengineering@conferenceseries.net
http://electricalengineering.global-summit.com

4–6 November 2015
Successful Semiconductor Fabless 2015: Technology & supply chain challenges for fabless semiconductor companies
Paris, France
E-mail: veyrier@yole.fr
www.i-micronews.com/trade-shows-conferences.html

8–13 November 2015
ISGN-6 (6th International Symposium on Growth of III-Nitrides)
Act City Hamamatsu, Hamamatsu, Japan
E-mail: secretary@isgn6.jp
www.isgn6.jp

10–12 November 2015
12th Avionics Fiber-Optics & Photonics Conference (AVFOP)
Santa Barbara, CA, USA
E-mail: m.figueroa@ieee.org
www.avfop-ieee.org

17–19 November 2015
6th annual Strategies in Light (SIL) Europe 2015 (co-located with LuxLive 2015)
ExCeL London Exhibition and Convention Center, UK
E-mail: registration@pennwell.com
www.sileurope.com

7–9 December 2015
2015 IEEE International Electron Devices Meeting (IEDM)
Washington Hilton, Washington DC, USA
E-mail: iedm@his.com
www.ieee-iedm.org

13–18 February 2016
SPIE Photonics West 2016
Moscone Center San Francisco, CA, USA
E-mail: customerservice@spie.org
http://spie.org/SPIE-PHOTONICS-WEST-conference

1–3 March 2016
Strategies in Light (SIL 2016), co-located with The LED Show
Santa Clara Convention Center, CA, USA
E-mail: registration@pennwell.com
www.strategiesinlight.com

19–24 March 2016
2016 IEEE Applied Power Electronics Conference and Exposition (APEC)
Long Beach Convention Center, CA, USA
E-mail: apec@apec-conf.org
www.apec-conf.org

4–7 April 2016
SPIE Photonics Europe 2016
SQUARE Brussels Meeting Centre, Brussels, Belgium
Abstract deadline: 19 October 2015
E-mail: info@spieeurope.org
http://spie.org/SPIE-PHOTONICS-EUROPE-conference

13–16 April 2016
LED Taiwan 2016 and Taiwan International Lighting Show
Taiwan World Trade Center, Taipei, Taiwan
E-mail: sluo@semi.org
www.ledtaiwan.org

17–21 April 2016
SPIE Defense + Commercial Sensing 2016 (DCS), incorporating:
SPIE Defense + Security (Conference on Sensors, Imaging, and Optics)
SPIE Commercial + Scientific Sensing and Imaging (Conference on Advanced Technologies and Applications)
Baltimore Convention Center, Baltimore, MD, USA
Abstract deadline: 5 October 2015
E-mail: customerservice@spie.org
http://spie.org/SPIE-DCS-conference
http://spie.org/SPIE-DCS-Defense+Security
http://spie.org/SPIE-DCS-Commercial-Sensing

25–27 April 2016
12th International Conference on Concentrator Photovoltaics (CPV-12)
Beijing, China
E-mail: info@cpv-12.org
www.cpv-12.org

semiconductorTODAY

COMPOUNDS & ADVANCED SILICON

Choose *Semiconductor Today* for . . .

MAGAZINE

Accurate and timely coverage of the compound semiconductor and advanced silicon industries

Targeted 41,000+ international circulation

Published 10 times a year and delivered by e-mail and RSS feeds

WEB SITE

Average of over 19,700 unique visitors to the site each month

Daily news updates and regular feature articles

Google-listed news source

E-BRIEF

Weekly round-up of key business and technical news

E-mail delivery to entire circulation

Banner and text marketing opportunities available

www.semiconductor-today.com

Join our LinkedIn group: Semiconductor Today

Follow us on Twitter: Semiconductor_T